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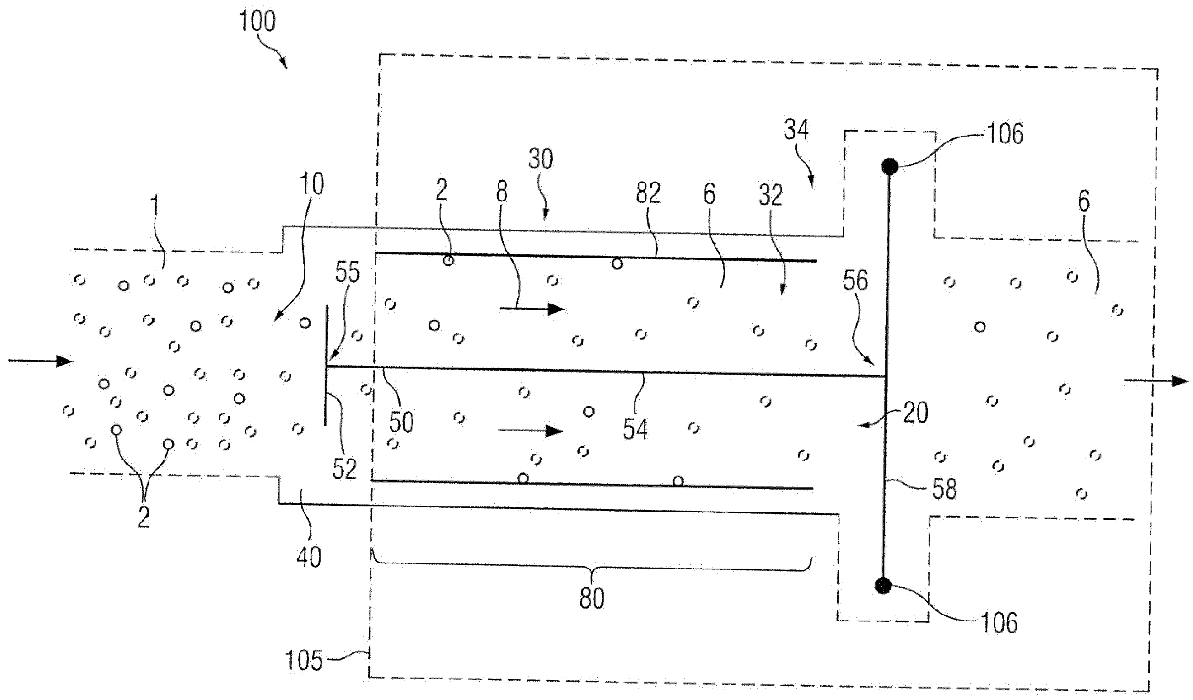
(54) **An improved wet electrostatic precipitator for cleaning fuel gas**

(57) The present technique is a wet electrostatic precipitator (ESP; 100) for removing particulates (2) from a gas (1) to produce a clean gas (6) on a clean gas side (105) of the wet ESP (100). The gas (1) flows through a duct (30) of the wet ESP (100) in a flow direction (8) substantially horizontally from an inlet (10) to an outlet (20) of the wet ESP (100). The duct (30) comprises an ionization zone (40) for receiving the gas (1) from the inlet (10), at least one discharge electrode assembly (50) extending into the ionization zone (40), and a precipitation zone (80) downstream of the ionization zone (40) and fluidly connected to the ionization zone (40). The precipitation zone (80) includes at least one precipitation electrode assembly (82). The discharge electrode assembly (50) is suspended from the clean gas side (105) towards the ionization zone (40) such that a discharge electrode (52) of the discharge electrode assembly (50) for generating a corona discharge inside the duct (30)is positioned inside the duct (30).

FIG 1



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Description

[0001] The present technique relates generally to fuel gas cleaning systems and more particularly to a wet electrostatic precipitator for cleaning fuel gas.

[0002] Fuel gases are widely used for deriving power. The fuel gases such as producer gas, syngas, and so forth, are produced by various techniques e.g. biomass gasification which is a well established technology for decentralized power generation application. Fuel gases when generated contain various contaminants such as particulate matter (ash and carbon particles), moisture and Tar. These contaminants, generally referred to as particulates including particulate matter, tar, and so forth, limit direct use of the gas in internal combustion engines or other end applications. Thus, the gases need to be at least partially cleaned of the particulates before being used. Additionally, there is a need to at least partially remove the particulates to meet various environmental norms identified by different regulatory authorities.

[0003] Presently, in order to clean the gas, it is conditioned in an elaborate gas cooling and clean- up system. The prevalently known and widely used techniques for gas cleaning contain one or combination of the following elements: cyclone, water based scrubbers, chilled water or solvent based scrubber, filtration system and so forth. However, the techniques used in the art have several drawbacks.

[0004] Firstly, the internal power consumption in the presently known cleaning systems is high and thus resulting in reduced overall efficiency of the system. Secondly, the known gas cleaning systems are voluminous and use a lot of space causing a major constraint, particularly for mobile based renewable energy solution. Thirdly, the present systems generate large amount of waste water posing serious issues of disposal. Finally, periodic maintenance of the presently known gas cleaning systems and their components such as filter is cumbersome resulting in frequent plant shut down and loss of revenue to the end user.

[0005] The above mentioned problems may be solved by using a wet electrostatic precipitator technique. The electrostatic precipitator, as known generally in the art, is a device that uses electrical forces to move particles out of a gas stream and onto collector plates. The particles in the gas to be cleaned are charged by making them pass through a corona discharge region in the electrostatic precipitator and thus electrically forced towards the collector plates that are either grounded or have an opposite polarity with respect to the charge on the particles. The particles so deposited on the collector plates are then removed from the collector plates without reentering them into the gas stream. In wet electrostatic precipitators the particles are removed from the surface of the collector plates by a continuous or intermittent flow of water to wash the surface of the collector plates.

[0006] The above mentioned electrostatic precipitator technique is widely used in large scale thermal power plants to filter fly ash down to sub-micrometer size efficiently out of the flue gas. However, the usage of the known wet electrostatic precipitator for cleaning fuel gases is highly unsafe because of the high voltage of operation of the electrostatic precipitator, the associated risk of sparking in the electrostatic precipitator and high flammability of the fuel gas. Additionally, the usage of water in the wet electrostatic precipitator further increases the risks of electrical accidents and raises operational issues.

[0007] Moreover, in contrast to the flue gas, particulates contained in fuel gas may have high electrical conductivity. Thus deposition of the particulates on insulator surfaces will lead to current leakage, parasitic corona discharges, and frequent sparking. Thus evidently the presently known wet electrostatic precipitator designs are unfit for the cleaning of fuel gas such as producer gas, syngas, etc. in an electrically safe way.

[0008] Thus, object of the present invention is to provide an electrically safe wet electrostatic precipitator suitable for cleaning gases like producer gas, syngas, and so forth.

[0009] The object is achieved by the invention disclosed in a wet electrostatic precipitator of claim 1. Advantageous developments emerge from the dependent claims.

[0010] The present technique is a wet electrostatic precipitator (hereinafter referred to as ESP). The wet ESP removes particulates from a gas to produce a clean gas. The clean gas is produced on a clean gas side of the wet ESP. The wet ESP contains an inlet for receiving the gas, an outlet for releasing the clean gas, and a duct. The duct fluidly connects the inlet and the outlet. The gas flows through the duct in a flow direction substantially horizontally from the inlet to the outlet, i.e. the duct itself is oriented substantially horizontally.

[0011] The duct comprises an ionization zone for receiving the gas from the inlet, at least one discharge electrode assembly extending into the ionization zone, and a precipitation zone downstream of the ionization zone and fluidly connected to the ionization zone. The precipitation zone includes at least one precipitation electrode assembly. The discharge electrode assembly is suspended from the clean gas side towards the ionization zone such that a discharge electrode of the discharge electrode assembly for generating a corona discharge inside the duct is positioned inside the duct.

[0012] This design of the wet ESP is advantageous in the sense that the points from which the discharge electrode assembly is suspended are exposed only to the clean gas and thereby the particulate deposition around the points is avoided.

[0013] In one embodiment of the wet ESP, the discharge electrode assembly is mounted from outside the duct. As the gas flows in the wet ESP being confined within the duct, outside the duct means outside the gas flow. Thus the position of mounting is outside the gas flow and the chance of deposition of the particulates in and around the mounting region is reduced. This ensures that there is no electrical leakage at the position of mounting of the discharge electrode assembly.

[0014] In another embodiment of the wet ESP, the discharge electrode assembly is suspended from the clean gas side towards the ionization zone in a cantilever type of suspension anchored at the clean gas side. Due to this arrangement, exact leveling of the wet ESP for reliable operation is not required because the discharge electrode assembly is kept in proper position by a rigid construction.

[0015] In another embodiment of the wet ESP, the discharge electrode assembly comprises a cross-rod extending across a cross-section of the duct, a horizontal rod extending from the cross-rod towards the ionization zone and the discharge electrode. The horizontal rod contains a first end and a second end. The first end of the horizontal rod is attached to the cross-rod, and the discharge electrode is attached to the second end of the horizontal rod. The cross-rod, the horizontal rod and the discharge electrode are in electrical connection. With the help of the cross-rod and the horizontal rod, the discharge electrode is held in place in the ionization zone. Moreover, by varying a length of the horizontal rod the position of the discharge electrode may be adjusted as required.

[0016] In another embodiment of the wet ESP, at least a part of a surface of the cross-rod is covered by an electrically insulating material. As a result the risk of unwanted sparking or electrical conduction between the cross-rod and any conducting surface present in proximity of the cross-rod is at least partially obviated.

[0017] In another embodiment of the wet ESP, the discharge electrode assembly further comprises a HV plate. The HV plate is a high voltage plate positioned along the horizontal rod in the precipitation zone and is in series between the discharge electrode and the cross-rod. The HV plate, being at the same polarity as the charged particulates resulting from their passage through the corona discharge, electrically repels the particulates towards the precipitation electrode assembly in the precipitation zone. The HV plate has rounded edges and thus even when a high voltage is provided across the HV plate, no unwanted corona discharge or sparking occurs in the precipitation zone.

[0018] In another embodiment, the wet ESP contains an insulator. The insulator electrically insulates the discharge electrode assembly from a body of the duct. Thus the discharge electrode assembly and the body of the duct which may be electrically conducting are electrically disconnected and results in electrical safety by at least partially obviating the possibility of application of the high voltage to the body of the duct. Moreover, the insulator is on the clean gas side thereby avoiding the chances of particulate deposition over it.

[0019] In another embodiment of the wet ESP, the insulator has a zigzag shape. Thus even if the particulates or other unwanted electrically conducting contaminants get deposited on the surface of the insulator, formation of a continuous electrically conducting path is avoided.

[0020] In another embodiment of the wet ESP, the insulator is situated in an insulator housing. The insulator housing is present outside the duct and contains an opening through which the cross-rod extends inside the duct. The insulator housing ensures that any electrically conducting impurities from the surroundings of the wet ESP are stopped from getting deposited on the surface of the insulator.

[0021] In another embodiment of the wet ESP, the opening of the insulator housing is at least partially enclosed by an aperture. The aperture may be detached from the cross-rod. This ensures that the deposition of the particulates from the gas on the insulator surface inside the insulator housing is reduced. Furthermore since the aperture is detached from the cross-rod, even if some particulates get deposited on the aperture, the chances of formation of an electrical connection between the cross-rod and the body of the duct are reduced.

[0022] In another embodiment, the wet ESP further comprises a high voltage feed. The high voltage feed passes through the insulator and is in electrical connection to the discharge electrode assembly. Thus if an active high voltage source is electrically connected to the high voltage feed, a high voltage is applied to the discharge electrode assembly and the corona discharge is generated at the discharge electrode in the ionization zone facilitating cleaning of the gas.

[0023] In another embodiment, the wet ESP comprises a heating arrangement for heating at least a part of the insulator. The heating ensures that if any moisture gets deposited on the surface of the insulator, the same is removed as a result of the heating, thereby maintaining electrical safety in the wet ESP.

[0024] In another embodiment, the wet ESP further comprises a fluid dispenser for dispensing a fluid on the precipitation electrode assembly. A direction of the fluid so dispensed is non-parallel to the flow direction of the gas. This provides the advantage that the fluid does not flow towards any part of the discharge electrode assembly such as the cross-rod which is at high voltage during operation of the wet ESP.

[0025] In another embodiment, the wet ESP comprises an oxygen monitoring system to monitor a concentration of the oxygen inside the duct. The concentration of oxygen inside the duct is monitored for controlling an operation of the wet ESP based on the concentration of the oxygen. Thus, if the concentration of the oxygen inside the duct rises above a pre-determined value, operation of the wet ESP is stopped, i.e. the wet ESP is turned off. The pre-determined value is decided based on the flammability of the gas to be cleaned. As a result, in case if a flammable mixture of the gas and oxygen is formed inside the wet ESP, removing the high voltage from the wet ESP by turning off the wet ESP ensures safe operation of the wet ESP.

[0026] In another embodiment, the wet ESP comprises a cleaning nozzle for at least partially removing the particulates from an unclean surface inside the duct by sprinkling a cleaning fluid on the unclean surface. This provides the advantage of removal of depositions of particulates from unwanted surfaces inside the duct and thus ensuring that unwanted sparking inside the duct is minimized.

[0027] In another embodiment of the wet ESP, the discharge electrode assembly and/or the precipitation electrode assembly of the wet ESP may be constructed of light weight materials thus lowering the mechanical requirements of construction.

[0028] The disclosed wet ESP provides several other advantages. The wet ESP of the present technique requires low maintenance and is easy to use. Compared to conventional fuel gas cleaning systems, the wet ESP of the present technique requires less electrical energy and less water. The wet ESP may be constructed as a mobile unit.

[0029] The present technique is further described hereinafter with reference to illustrated embodiments shown in the accompanying drawings, in which:

FIG 1 is a schematic drawing of top view of a wet electrostatic precipitator (ESP) representing a scheme of arrangement of its constituents;

FIG 2a is a schematic drawing of an exemplary embodiment of the wet ESP showing a cross-section of a duct of the wet ESP and arrangement of a cross-rod across the cross-section of the duct;

FIG 2b is a schematic drawing of another exemplary embodiment of the wet ESP showing a cross-section of the duct of the wet ESP and arrangement of the cross-rod across the cross-section of the duct;

FIG 3 schematically represents a cross-rod covered with an electrically insulating material;

FIG 4 schematically represents an exemplary discharge electrode assembly of the wet ESP;

FIG 5 schematically represents an exemplary embodiment of an insulator in the wet ESP;

FIG 6 schematically represents another exemplary embodiment of the insulator in the wet ESP;

FIG 7 schematically represents a high voltage feed of the wet ESP;

FIG 8 schematically represents a heating arrangement of the wet ESP;

FIG 9 schematically represents a cross-flow design of the wet ESP;

FIG 10 schematically represents an arrangement of the discharge electrode assembly and the precipitation electrode assembly in an exemplary embodiment of the wet ESP; and

FIG 11 schematically represents an exemplary embodiment of the wet ESP with an oxygen monitoring system and a cleaning nozzle.

[0030] Hereinafter, the best mode for carrying out the present technique is described in details. Various embodiments are described with reference to the drawings, wherein like reference numerals are used to refer to like elements throughout. In the following description, for purpose of explanation, numerous specific details are set forth in order to provide a thorough understanding of one or more embodiments. It may be evident that such embodiments may be practiced without these specific details.

[0031] Referring to the figures, FIG 1 is a schematic drawing of top view of a wet electrostatic precipitator 100, hereinafter referred to as wet ESP 100, representing a scheme of arrangement of its constituents.

[0032] The wet ESP 100 of the present technique at least partially removes particulates 2 from a gas 1 to produce a clean gas 6. The clean gas 6 is produced at a clean gas side 105 of the wet ESP 100.

[0033] The wet ESP 100 includes an inlet 10 for receiving the gas 1 to be cleaned, an outlet 20 for releasing the clean gas 6, and a duct 30. The duct 30 fluidly connects the inlet 10 and the outlet 20.

[0034] In the wet ESP 100, the gas 1 flows in a space 32 inside the duct 30 in a flow direction 8. The flow direction 8 as used herein means a direction of net flow of the gas 1. In the wet ESP 100 according to the present technique, the flow direction 8 is from the inlet 10 to the outlet 20 and the gas 1 flows substantially horizontally from the inlet 10 to the outlet 20 in the flow direction 8.

[0035] The duct 30 contains an ionization zone 40, at least one discharge electrode assembly 50 extending into the ionization zone 40, and a precipitation zone 80 downstream of the ionization zone 40 towards the flow direction 8. The precipitation zone 80 is fluidly connected to the ionization zone 40. The precipitation zone 80 includes at least one precipitation electrode assembly 82.

[0036] The gas 1 containing the particulates 2 is received from the inlet 10 by the ionization zone 40. A discharge electrode 52 of the discharge electrode assembly 50 generates a corona discharge in the ionization zone 40 when electrically supplied with a high voltage. In the ionization zone 40 the particulates 2 are electrically charged as a result of the corona discharge. The particulates 2 so charged move towards and get deposited on the precipitation electrode assembly 82 in the precipitation zone 80. The precipitation electrode assembly 82 is either grounded or is having a polarity opposite to the charge on the particulates 2 acquired in the ionization zone 40. The precipitation electrode assembly 82 may have plate like structures.

[0037] The clean gas 6 as used herein means the gas 1 that is fed into the wet ESP 100 and from which at least one particulate 2 has been removed by operation of the wet ESP 100, i.e. by getting deposited on the precipitation electrode assembly 82. Depending on the dimensions of the wet ESP 100, especially the length in gas flow direction 8, and of the precipitation electrode assembly 82, respectively, and on the high voltages used for generating the corona discharge, the ratio of particulates 2 removed from the gas 1 will vary. The term "clean gas" does not necessarily mean that all particulates 2 have been removed from the gas 1.

[0038] The clean gas side 105 of the wet ESP 100 as used herein may be understood as indicated in FIG 1. The clean gas side 105 includes the precipitation zone 80 inside the duct 30 and any point (not shown) present radially outside the precipitation zone 80 in a space 34 outside the duct 30. However, the clean gas side 105 does not include the ionization zone 40 or any point (not shown) present radially outside the ionization zone 40 in a space 34 outside the duct 30.

[0039] The discharge electrode assembly 50 is suspended from the clean gas side 105 towards the ionization zone 40. In a preferred embodiment of the wet ESP 100, the discharge electrode assembly 50 is suspended from points 106 on the clean gas side 105 and extending towards the ionization zone 40, thus the discharge electrode assembly 50 is mounted from outside the duct 30. The suspension is such that the discharge electrode 52 is positioned inside the ionization zone 40.

[0040] In one embodiment of the wet ESP 100, the discharge electrode assembly 50 is suspended from the clean gas side 105 in a cantilever type of suspension anchored at the clean gas side 105.

[0041] The cantilever type of suspension as used herein is a type of suspension in which a substantially rigid structure having at least two ends. The structure is anchored to another rigid support at one end and left overhanging on the other end. Thus the discharge electrode assembly 50 in the wet ESP 100 is a rigid structure with one end having the discharge electrode 52 forming the overhang and another end away from the discharge electrode 52 anchored at the clean gas side 105 at the points 106.

[0042] The discharge electrode 52 positioned in the ionization zone 40 may be a structure containing sharp edges for effective generation of corona discharges. The shape of the discharge electrode 52 may be simple knife-edge structure, pin-brush-like structure, tooth-like structure, or a combination thereof.

[0043] Referring now to FIGs 1, 2a, and 2b, the discharge electrode assembly 50 contains a cross-rod 58 extending across a cross-section 31 of the duct 30, a horizontal rod 54 extending from the cross-rod 58 towards the ionization zone 40 and the discharge electrode 52. The cross-rod 58, the horizontal rod 54 and the discharge electrode 52 are in electrical connection.

[0044] In an exemplary embodiment of the wet ESP 100, the cross-rod 58, the horizontal rod 54 and the discharge electrode 52 have metallic surfaces and are attached to one another such that an electric current can flow through the discharge electrode assembly 50.

[0045] In another exemplary embodiment of the wet ESP 100, there is a separate electrical conductor (not shown) attached to the discharge electrode 52. The cross-rod 58 and the horizontal rod 54 may have a hollow structure e.g. a tubular structure and the electrical conductor may pass through the hollow structures of the cross-rod 58 and the horizontal rod 54 to reach the discharge electrode 52. The electrical conductor may be, but not limited to, an electrically conducting wire.

[0046] Generally speaking, it has only to be made sure that the discharge electrode 52 at the end of the discharge electrode assembly 50 has a high voltage.

[0047] The horizontal rod 54 contains a first end 56 and a second end 55. The first end 56 of the horizontal rod 54 is attached to the cross-rod 58, and the discharge electrode 52 is attached to the second end 55 of the horizontal rod 54. The cantilever type of suspension is realized by the attachment of the first end 56 of the horizontal rod 54 to the cross-rod 58.

[0048] The cross-section 31 of the duct 30 has been schematically represented in exemplary embodiments shown in FIGs 2a and 2b which show different cross-sections 31 of the duct 30 of the wet ESP 100 and arrangement of the cross-rod 58 across the cross-sections 31 of the duct. As is clear from the FIGs 2a and 2b, the cross-rod 31 extends across the cross-section 31 of the duct 30 dividing the cross-section 31 symmetrically and/or non-symmetrically.

[0049] FIG 3 schematically represents the cross-rod 58 covered with an electrically insulating material 62. The cross-rod 58 has a surface 60, in which at least a part 59 of the surface 60 is covered by the electrically insulating material 62. The electrically insulating material 62 ensures that unwanted sparking is not developed from the cross-rod 58 when the cross-rod 58 is supplied with the high voltage.

[0050] The covering may be in form of a tube or a coating. The electrically insulating material 62 may be, but not limited to, polymeric material, fluorocarbon solid such as PTFE (polytetrafluoroethylene) , and so forth. The part 59 may be at the ends of the cross- rod 58 such as the surface 60 of the cross- rod 58 is around the point 106 (shown in FIG 1) ; or at positions where the cross- rod 58 is in vicinity to the precipitation electrode assembly 82.

[0051] In an exemplary embodiment of the wet ESP 100, the surface 60 of the cross-rod 58 may be entirely covered with the electrically insulating material 62.

[0052] FIG 4 schematically represents the discharge electrode assembly 50 containing a HV plate 64. The HV plate 64 is positioned along the horizontal rod 54 in the precipitation zone 80 and in series between the discharge electrode 52 and the cross-rod 58. As shown in the figure, in an exemplary embodiment, the wet ESP 100 may contain a plurality of the cross-rods 58, a plurality of the horizontal rods 54 and a plurality of the discharge electrodes 52. In the embodiment shown in FIG 4, one HV plate 64 is shown to be positioned on two of the horizontal rods 54. The HV plate 64 may have smooth edges. When the discharge electrode assembly 50 is supplied with the high voltage, the discharge electrodes 52 and the HV plate 64 have substantially the same voltage. The HV plate 64 has the same polarity as the charge on the particulates 2 and thus in the precipitation zone 80, the particulates 2 are electrically repelled on to the precipitation electrode assembly 82. Thus the HV plate 64 facilitates efficient cleaning of the gas 1.

[0053] FIG 5 schematically represents an exemplary embodiment of an insulator 66 in the wet ESP 100. The insulator 66 electrically insulates the discharge electrode assembly 50 from a body 36 of the duct 30. At the insulator 66 the cross-rod 58 is mounted and from the insulator 66 the cross-rod 58 extends into the duct 30. The insulator 66 may be made of glass, ceramic material, polymer such as Teflon, fluorocarbon solid, or a composite material e.g. composite of a polymer into which glass fibres or ceramic powder are embedded.

[0054] FIG 6 schematically represents another exemplary embodiment of the insulator 66 in the wet ESP 100. The insulator 66 is situated in an insulator housing 72. The insulator housing 72 is present outside the duct 30 and comprises an opening 74 through which the cross-rod 58 extends into the duct 30.

[0055] In an exemplary embodiment of the wet ESP 100, the insulator housing 72 may be a tubular structure (not shown) open at one end to form the opening 74. The tubular insulator housing 72 is fixed in a gas-tight manner to the body 36 of the duct 30. The cross-rod 58 is suspended along a longitudinal axis (not shown) of the tubular insulator housing 72. A diameter of the tubular insulator housing 72 is selected such that a distance 'D1' between the cross-rod 58 and a side wall of the tubular insulator housing 72 exceeds a distance 'D2' between the discharge electrode 52 and the precipitation electrode assembly 82.

[0056] In another exemplary embodiment of the wet ESP 100, a radial distance 'D3' between an insulator surface 68 and an inner wall of the insulator housing 72 exceeds the gap width 'D4' at which homogeneous electric field breakdown would occur when an operation voltage of the wet ESP 100 is applied. In another preferable embodiment 'D3' is at least twice of 'D4'.

[0057] In another exemplary embodiment of the wet ESP 100, a distance 'D5' between a region (not shown) of the surface 68 of the insulator 66 facing the inside of the duct 30 and the body 36 of the duct 30 is substantially similar to 'D1'.

[0058] In an exemplary embodiment of the wet ESP 100, the opening 74 may be at least partially enclosed by an aperture 76. In a preferable embodiment, as shown in the figure, the aperture 76 is detached from the cross-rod 58.

[0059] The insulator housing 72 is attached in a gas-tight manner to the body 36 of the duct 30. Various techniques such as using a gasket for gas-tight attachment of two structures are known in the art and the same has not been discussed herein for the sake of brevity. The insulator 66 inside the insulator housing 72 may be firmly mounted to a wall of the insulator housing 72. The insulator 66 has a surface 68. The firm mounting (not shown) may be at one or more positions of the surface 68 of the insulator 66.

[0060] The insulator 66 may be of various shapes and sizes. In a preferable embodiment, the insulator 66 has a zigzag shape. In the FIG 6, the zigzag shape of the insulator 66 has been represented. A region 69 on the surface 68 of the insulator along with a region 70 on the surface 68 forms the zigzag shape.

[0061] FIG 7 schematically represents a high voltage feed 78 of the wet ESP 100. The high voltage feed 78 passes through the insulator 66 and is in electrical connection to the discharge electrode assembly 50. As shown in the figure, the electrical connection is through the cross-rod 58. When an active high voltage source 79 is electrically connected to the high voltage feed 78 the corona discharge is generated at the discharge electrode 52 in the ionization zone 40.

[0062] FIG 8 schematically represents a heating arrangement 90 in the wet ESP 100. The function of the heating arrangement 90 is to heat at least a part 67 of the insulator 66. The heating arrangement may be, but not limited to, an electrical heating coil (not shown). The heating arrangement 90 may provide indirect heating of the part 67 or direct heating of the part 67.

[0063] For indirect heating, the heating arrangement 90 may be adapted to heat the insulator housing 72 wherefrom the part 67 of the insulator 66 is heated due to convective heat transfer between insulator housing 72 and the part 67 of the insulator 66.

[0064] For direct heating, the heating arrangement 90 may be adapted to heat the part 67 directly for example by introducing an electric heating coils on or inside the insulator 66 such that the part 67 of the insulator 66 may be heated due to heat conduction from the heating arrangement 90 to the part 67 of the insulator directly.

[0065] Alternatively, in an exemplary embodiment of the wet ESP 100, the heating arrangement 90 for heating the part 67 of the insulator 66 may be heating coils (not shown) operated using hot fluids such as hot water, hot oil, and so forth. Heating of the fluid may be obtained by utilizing waste heat from a gasifier (not shown) by which the gas 1 is produced or from a gas engine (not shown) that uses the clean gas 6. Fluids so heated may be stored in a thermally insulated container (not shown) and may be made available for heating the part 67 of the insulator 66 when required.

[0066] FIG 9 schematically represents a cross-flow design of the wet ESP 100 in a side view of the wet ESP 100. In an exemplary embodiment, the wet ESP 100 contains a fluid dispenser 92 for dispensing a fluid 93 on the precipitation electrode assembly 82. A direction 94 of the fluid 93 when dispensed is non-parallel to the flow direction 8 of the gas 1. The fluid 93 so dispensed removes the particulates 2 deposited on the precipitator electrode assembly 82 during the course of cleaning of the gas 1.

[0067] The fluid dispenser 92 may be or may comprise a dispensing nozzle (not shown) for releasing the fluid 93. The fluid 93 may be, but not limited to, water. Additionally the fluid dispenser 92 may comprise a fluid container (not shown) for storing the fluid 93 before the fluid 93 is dispensed. The fluid container may be, but not limited to, a tank, a barrel, and so forth.

[0068] In an exemplary embodiment of the wet ESP 100, the fluid dispenser 92 may comprise a flat, water filled tank on top of the wet ESP 100, a water inlet to provide water to the water tank, small bore holes to dispense water on to the precipitation electrode assembly 82. The small bore holes may be inclined such that water jets having equal flow rates impinge on the precipitation electrode assembly 82 causing thin films of water spreading out over the precipitation electrode assembly 82.

[0069] Surface wetting of any surface of the precipitation electrode assembly 82 may be improved by coating the surface of the precipitation electrode assembly 82 with thin layers of ceramic materials such as titanium dioxide using sol-gel spray coating method. This improves quality of the water film, proper spreading of the water film on the surface of the precipitator electrode assembly 82, reduces flow rate of the water, and reduces the power required for pumping the water.

[0070] FIG 10 schematically represents an arrangement of the discharge electrode assembly 50 and the precipitation electrode assembly 82 in an exemplary embodiment of the wet ESP 100. The discharge electrode assembly 50 is parallel to the precipitation electrode assemblies 82. The precipitation electrode assemblies 82 are parallel to the flow direction 8. The HV plate 64, a part of the horizontal rod 54 on which the HV plate 64 is positioned in and the precipitation electrode assemblies 82 are within the precipitation zone 80 of the wet ESP 100.

[0071] FIG 11 schematically represents an exemplary embodiment of the wet ESP 100 with an oxygen monitoring system 96 and a cleaning nozzle 98.

[0072] In an exemplary embodiment, the wet ESP 100 contains the oxygen monitoring system 96 to monitor a concentration of the oxygen inside the duct 30. The oxygen monitoring system 96 determines the concentration of the oxygen inside the duct 30. Based on the concentration of the oxygen so determined, operation of the wet ESP 100 may be controlled. Thus if the concentration of oxygen inside the duct 30 increases above a pre-determined level the wet ESP 100 may be turned off by removing the high voltage across the discharge electrode assembly 50. Subsequently if the concentration of oxygen inside the duct 30 falls below the pre-determined level the wet ESP 100 may be turned on by providing the high voltage across the discharge electrode assembly 50.

[0073] Alternatively, the oxygen monitoring system 96 may be present outside the duct 30 and monitor the concentration of the oxygen inside the duct 30. The oxygen monitoring system 96 may receive a stream of the gas 1 and/or the clean gas 6 from inside the duct 30 for monitoring the concentration of the oxygen in the gas 1 and/or the clean gas 6 so received.

[0074] Before starting operation of the wet ESP 100, the gas 1 may be allowed to be bypassed till the oxygen concentration in the gas 1 comes down to the pre-determined level. The bypassing of the gas 1 may be done by a flare line (not shown). The oxygen concentration in the flare line may also be monitored and only when the concentration of oxygen is at or below the pre-determined level, the gas 1 may be diverted through the wet ESP 100.

[0075] Referring again to FIG 11, an exemplary embodiment of the wet ESP 100 may contain a cleaning nozzle 98 for at least partially removing the particulates 2 from an unclean surface 38 inside the duct 30. The cleaning nozzle 98 removes the particulates 2 by sprinkling a cleaning fluid 99 on the unclean surface 38. The cleaning nozzle 98 may be present at different positions inside the duct 30. There may be a plurality of the cleaning nozzles 98 present at different positions inside the duct 30. The cleaning fluid 99 may be, but not limited to, water. The cleaning nozzle 98 may sprinkle the cleaning fluid 99 either continuously or intermittently.

[0076] In the wet ESP 100, to avoid collection of the particulates 2 in the ionization zone 40, a velocity of the gas 1 has to be kept high to provide lower residence time in the ionization zone 40. Thus the particulates 2 may not get sufficient time to separate from the gas 1. Even if it the particulates 2 get deposited inside the ionization zone 40, the cleaning fluid 99 when sprinkled from the cleaning nozzles 98 would remove the particulates 2 so deposited.

[0077] In an exemplary embodiment of the wet ESP 100, as shown in FIG 11, the cleaning nozzle 98 may be positioned such that the cleaning fluid 99 is sprinkled on the discharge electrode 52 and thus may remove the particulate 2, if any, from the unclean surface 38.

[0078] In another embodiment, the wet ESP 100 of the present technique may also contain a gas flow homogenizer (not shown) for providing homogeneous distribution of the gas 1. The techniques for providing homogenous distribution of a gas stream are well known in the art and thus the same has not been described herein for the sake of brevity. Examples of the gas flow homogenizer may be, but not limited to, static mixers placed at the inlet 10 of the wet ESP 100, arrangements of perforated plates placed at the inlet 10 and/or the outlet 20 of the wet ESP 100, and so forth.

[0079] While this invention has been described in detail with reference to certain embodiments, it should be appreciated that the present technique is not limited to those precise embodiments. Rather, in view of the present disclosure which describes the current best mode for practicing the invention, many modifications and variations would present themselves, to those of skilled in the art without departing from the scope and spirit of this invention. The scope of the invention is, therefore, indicated by the following claims rather than by the foregoing description. All changes, modifications, and variations coming within the meaning and range of equivalency of the claims are to be considered within their scope.

Claims

1. A wet electrostatic precipitator (100) for removal of particulates (2) from a gas (1) to produce a clean gas (6) on a clean gas side (105) of the wet electrostatic precipitator (100), the wet electrostatic precipitator (100) comprising:

- an inlet (10) for receiving the gas (1),
- an outlet (20) for releasing the clean gas (6), and
- a duct (30) for fluidly connecting the inlet (10) and the outlet (20) through which the gas (1) flows in a flow direction (8) substantially horizontally from the inlet (10) to the outlet (20), the duct (30) comprising:
- an ionization zone (40) for receiving the gas (1) from the inlet (10),
- at least one discharge electrode assembly (50) extending into the ionization zone (40), and
- a precipitation zone (80) downstream of the ionization zone (40) and fluidly connected to the ionization zone (40), wherein the precipitation zone (80) includes at least one precipitation electrode assembly (82),

wherein the discharge electrode assembly (50) is suspended from the clean gas side (105) towards the ionization zone (40) such that a discharge electrode (52) of the discharge electrode assembly (50) for generating a corona discharge inside the duct (30) is positioned inside the duct (30).

2. The wet electrostatic precipitator (100) according to claim 1, wherein the discharge electrode assembly (50) is mounted from outside the duct (30).

3. The wet electrostatic precipitator (100) according to claims 1 or 2, wherein the discharge electrode assembly (50) is suspended from the clean gas side (105) towards the ionization zone (40) in a cantilever type of suspension anchored at the clean gas side (105).

4. The wet electrostatic precipitator (100) according to any of claims 1 to 3, wherein the discharge electrode assembly (50) comprises:

- a cross-rod (58) extending across a cross-section (31) of the duct (30),
- a horizontal rod (54) extending from the cross-rod (58) towards the ionization zone (40) and comprising a first end (56) and a second end (55), wherein the first end (56) of the horizontal rod (54) is attached to the cross-rod (58), and the discharge electrode (52) is attached to the second end (55) of the horizontal rod (54).

5. The wet electrostatic precipitator (100) according to claim 4, wherein at least a part (59) of a surface (60) of the cross-rod (58) is covered by an electrically insulating material (62).

6. The wet electrostatic precipitator (100) according to claims 4 or 5, wherein the discharge electrode assembly (50) further comprises a HV plate (64) positioned along the horizontal rod (54) in the precipitation zone (80) and in series between the discharge electrode (52) and the cross-rod (58).

7. The wet electrostatic precipitator (100) according to any of claims 1 to 6, comprising an insulator (66), wherein the insulator (66) electrically insulates the discharge electrode assembly (50) from a body (36) of the duct (30).

8. The wet electrostatic precipitator (100) according to claim 7, wherein the insulator (66) has a zigzag shape.

9. The wet electrostatic precipitator (100) according to claims 7 or 8, wherein the insulator (66) is situated in an insulator housing (72) present outside the duct (30), wherein the insulator housing (72) comprises an opening (74) through which the cross-rod (58) extends inside the duct (30).

10. The wet electrostatic precipitator (100) according to claim 9, wherein the opening (74) is at least partially enclosed by an aperture (76) such that the aperture (76) is detached from the cross-rod (58).

11. The wet electrostatic precipitator (100) according to any of claims 7 to 10, further comprising a high voltage feed (78) passing through the insulator (66) and in electrical connection to the discharge electrode assembly (50) such that when an active high voltage source (79) is electrically connected to the high voltage feed (78) the corona discharge is generated at the discharge electrode (52).

12. The wet electrostatic precipitator (100) according to any of claims 7 to 11, comprising a heating arrangement (90) for heating at least a part (67) of the insulator (66).

13. The wet electrostatic precipitator (100) according to any of claims 1 to 12, further comprising a fluid dispenser (92) for dispensing a fluid (93) on the precipitation electrode assembly (82) such that a direction (94) of the fluid (93) when dispensed is non-parallel to the flow direction (8) of the gas (1).

14. The wet electrostatic precipitator (100) according to any of claims 1 to 13, comprising an oxygen monitoring system (96) to monitor a concentration of the oxygen inside the duct (30) for controlling an operation of the wet electrostatic precipitator (100) based on the concentration of the oxygen inside the duct (30).

15. The wet electrostatic precipitator (100) according to any of claims 1 to 14, comprising a cleaning nozzle (98) for at least partially removing the particulates (2) from an unclean surface (38) inside the duct (30) by sprinkling a cleaning fluid (99) on the unclean surface (38).

FIG 1

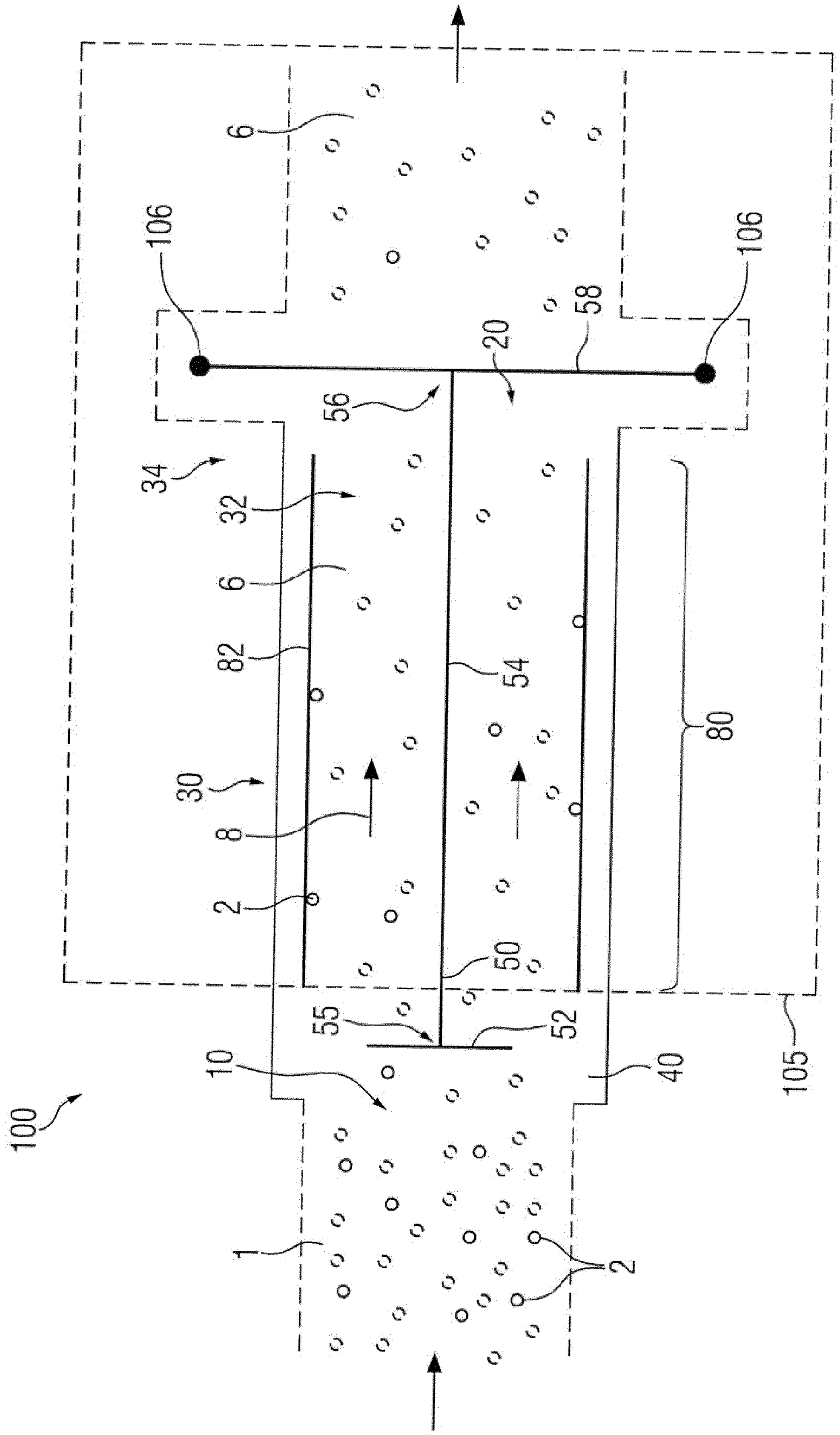

FIG 2a

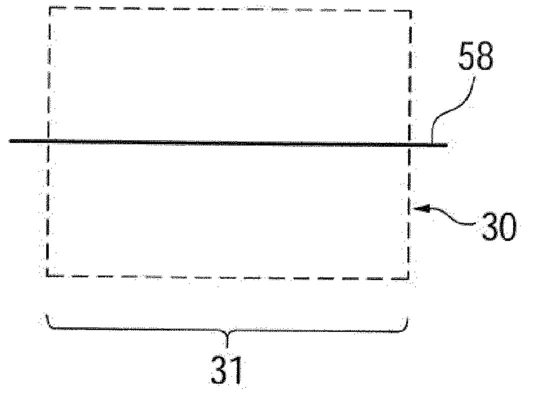

FIG 2b

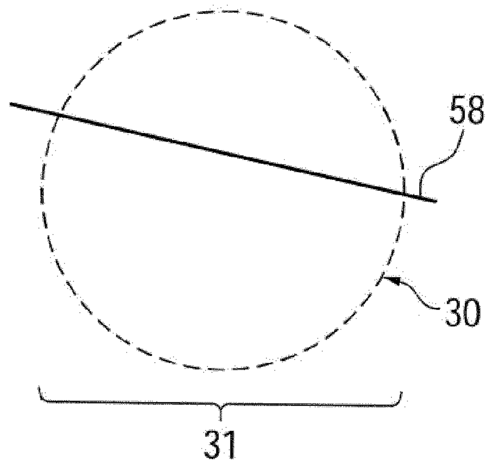

FIG 3

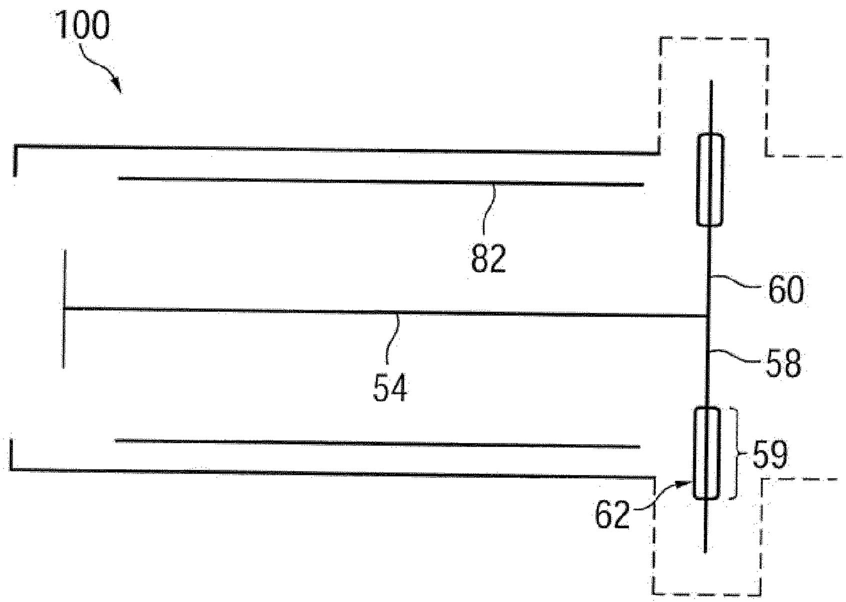

FIG 4

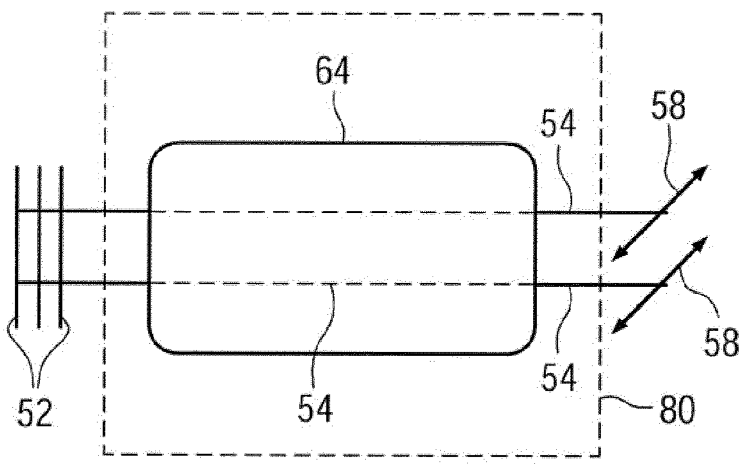

FIG 5

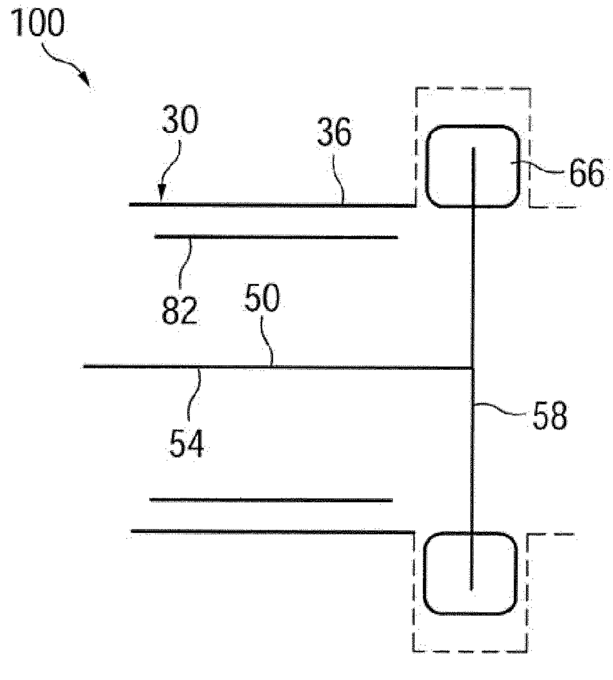

FIG 6

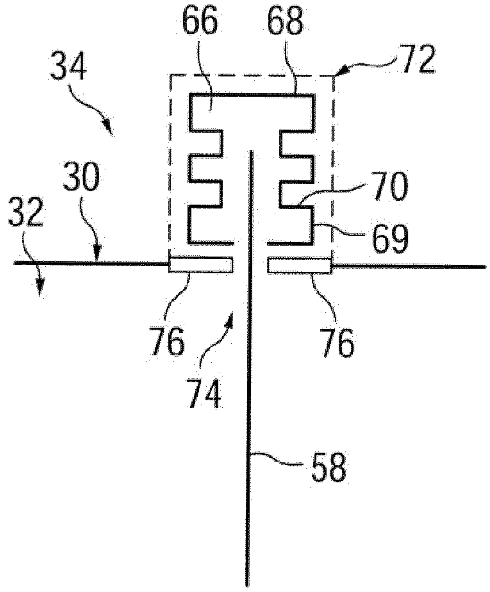
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FIG 7

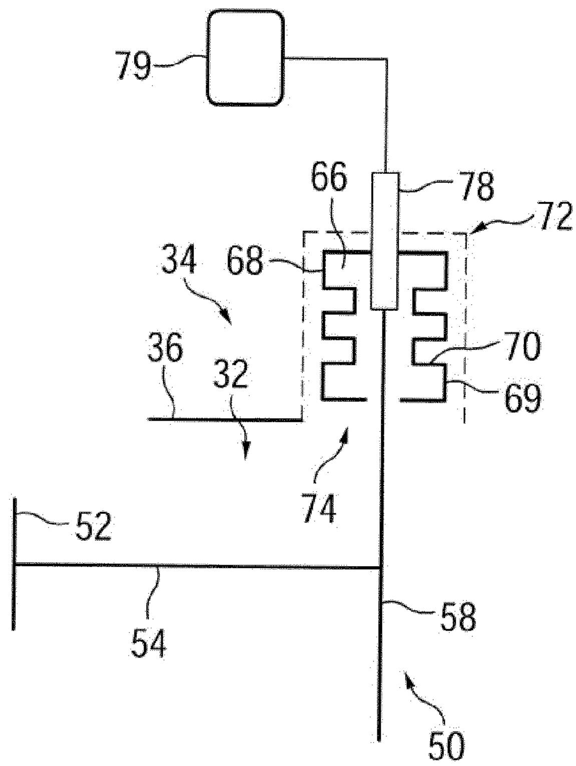
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FIG 8

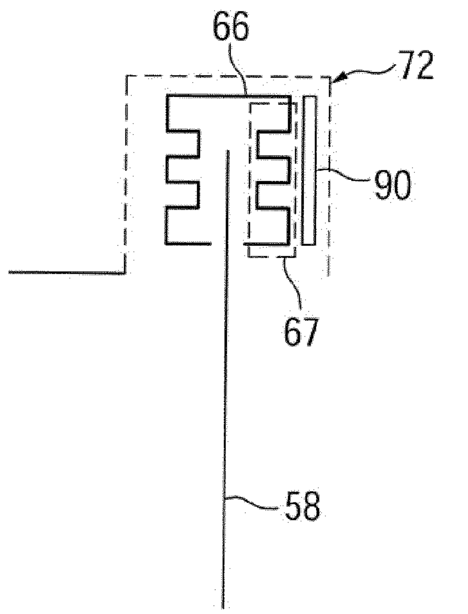


FIG 9

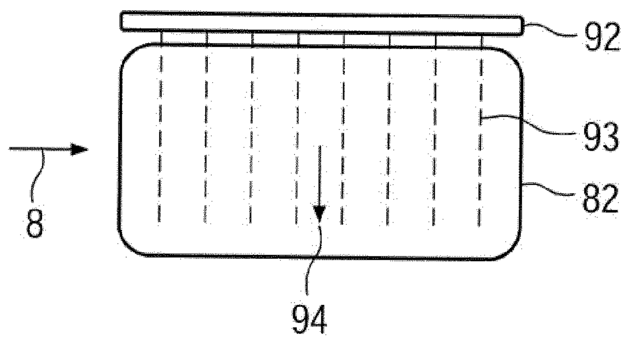


FIG 10

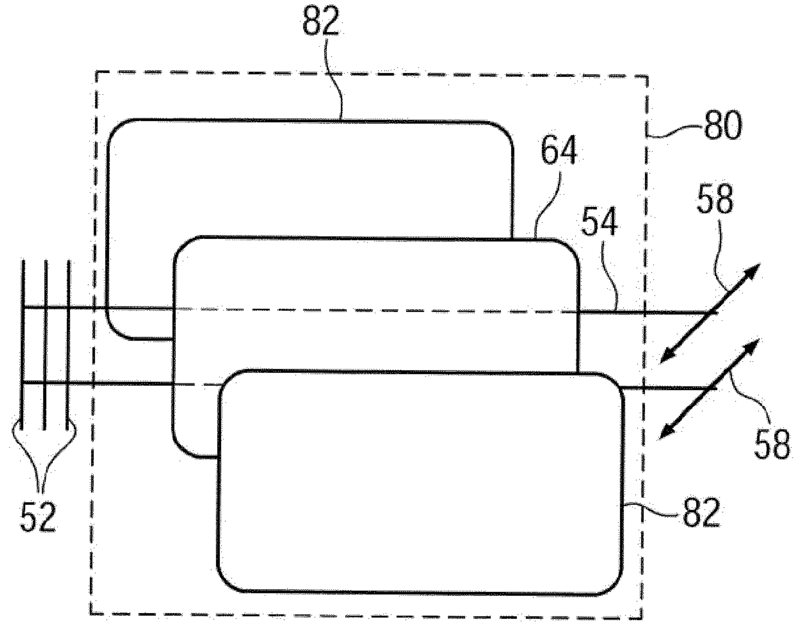
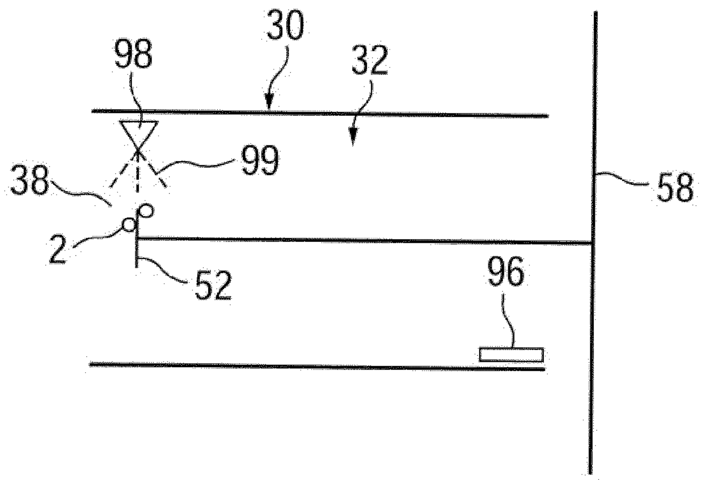


FIG 11



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EUROPEAN SEARCH REPORT

Application Number
EP 12 16 0246

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1

Place of search	Date of completion of the search	Examiner
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L : document cited for other reasons

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