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 [21] Appl. No. **760,408**
 [22] Filed **Sept. 18, 1968**
 [45] Patented **June 1, 1971**
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[54] CONDITIONER FOR GASEOUS SAMPLE

9 Claims, 3 Drawing Figs.

[52] U.S. Cl. **55/126,**
 55/128, 55/135, 55/150, 55/154, 55/269, 55/270,
 55/315, 55/410, 55/418, 55/439, 55/447, 73/23,
 73/421.5
 [51] Int. Cl. **B03c 3/01**
 [50] Field of Search. 55/126,
 128, 134, 135, 150, 154, 269, 270, 315, 410, 418,
 439, 447, 73/23, 28, 421, 421.5

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ABSTRACT: A conditioner for removing particulate and liquid impurities from a gaseous sample comprising a number of stages in sequence; there is an initial stage, optional with the designer, which consists of a means for cooling the gaseous sample before it passes to the conditioner; the first stage of the conditioner is a cyclone, which is an enclosed chamber against the interior wall of which the sample makes first contact; the particulate impurities spiral down the chamber wall and eventually settle in a liquid filled trap at the lower end of the cyclone; a manometer is formed by the liquid in the trap and the open lower end of the cyclone, where the liquid is drawn into the lower end of the cyclone by the reduced pressure within the cyclone due to sample being drawn out of the cyclone; as its next stage, the conditioner has an electrostatic precipitator through which the treated gaseous sample passes; the high electric potential ionizes the remaining particulate impurities and causes same to cling to an electrode of the precipitator, and also vaporizes the liquid impurities; the precipitator has a novel high potential central electrode comprising a hollow, closed shell into which incoming sample is delivered and out of which the sample moves only through narrow slots; the next stage is a pump for pumping the gaseous sample through the conditioner; the next stage is a flow dividing chamber which enables only part of the conditioned sample to flow to an apparatus requiring it.

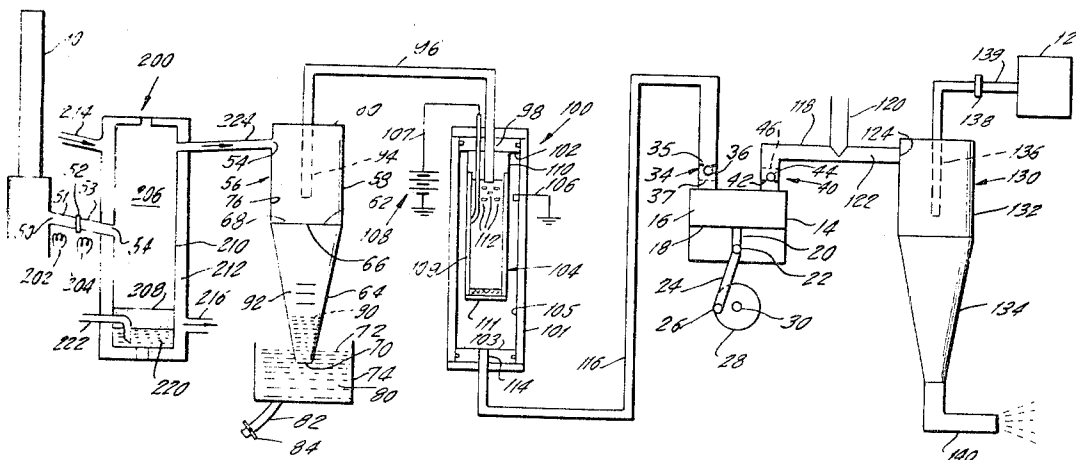
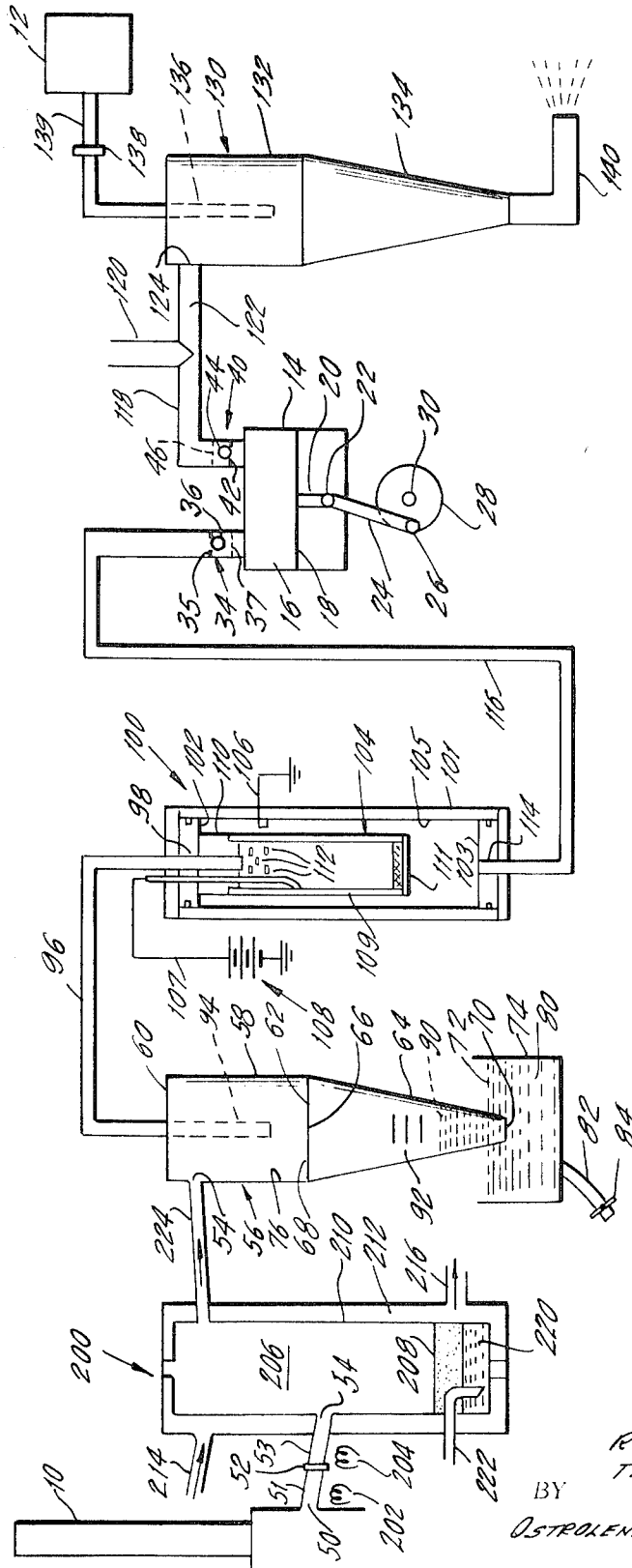


FIG. 1-



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FIG. 3.

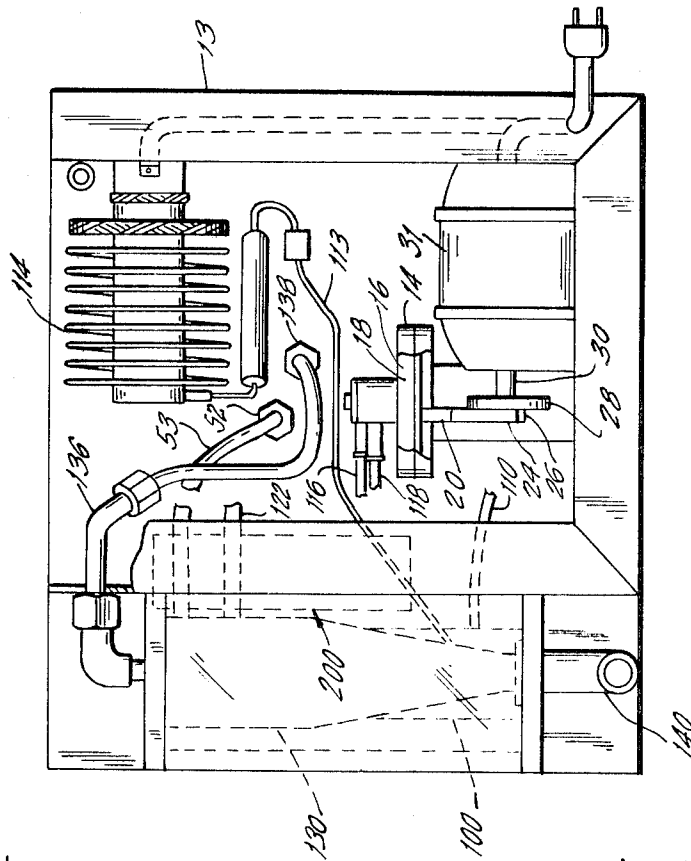
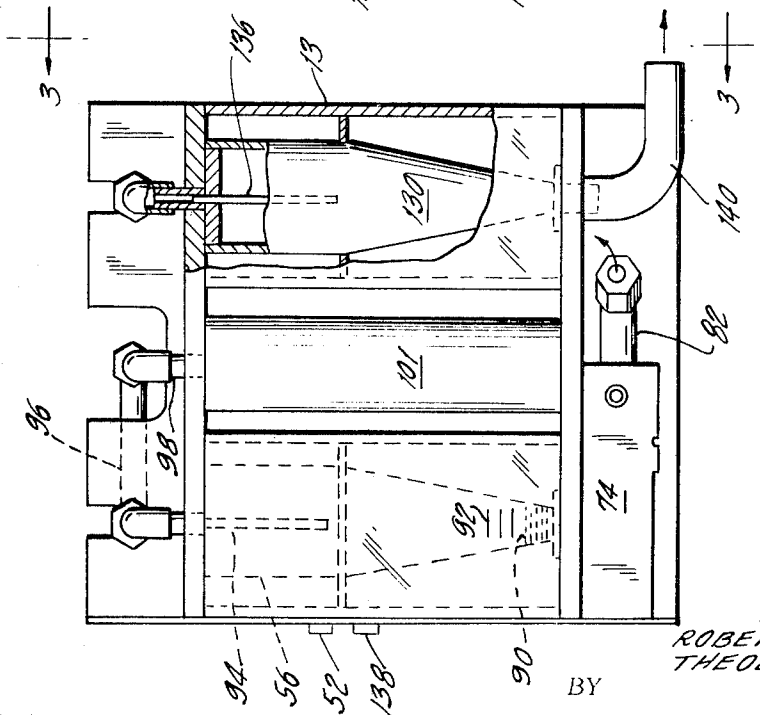


FIG. 2.



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CONDITIONER FOR GASEOUS SAMPLE

This invention relates to a conditioner for a gaseous sample and, more particularly, to a conditioner for removing particulate and liquid impurities from a gaseous sample.

Gaseous samples are often analyzed or otherwise operated upon. Frequently, these gaseous samples contain particulate and/or liquid impurities which should be removed before the gaseous sample is operated upon. For example, if smoke, and particularly smoke from a chimney, is being analyzed for the presence of a particular component, e.g., sulfur dioxide, waste and impurities, e.g. ash particles and water vapor, should be removed from the gaseous sample before it is analyzed, because the impurities may affect the result of the analysis, and will coat both the conduits leading to the analyzing apparatus and the interior of the analyzing apparatus causing deterioration in the effectiveness of the analyzing apparatus. In addition, the impurities may contaminate the reagent used in the analyzing apparatus which would both prevent it from properly performing its function during analysis and affect the results of the analysis. To prevent interference with the analysis process, the gaseous sample should be conditioned to remove particulate and/or liquid impurities. The present invention provides a self-contained gaseous sample conditioner.

In addition, where the analyzing apparatus is intended to be portable, it is desirable to also have the sample conditioner portable to be readily moved to where it is needed, e.g., adjacent a chimney, the smoke emanating from which is being tested. The present invention provides a compact, readily portable gaseous sample conditioner.

The novel conditioner includes a pump means for moving gaseous sample through the conditioner from its inlet to its outlet so that the sample might be treated. The pump means may be of any type, but is preferably of a type which is designed to protect the sample being pumped from contacting the internal mechanism of the pump means which might contaminate the sample with lubricant or other materials in the pump mechanism. The pump means may be located anywhere along the flow path through the conditioner. The reasons for its placement at particular locations will be discussed below.

The conditioner has an inlet which leads into the initial stage of the conditioner. This initial stage, at the option of the designer of the conditioner, may comprise a sample preconditioner, e.g. a sample cooling and dehumidifying chamber. As the particular application may require, the preconditioner might be used to heat, rather than cool, the sample or to add or remove a component, for example. One contemplated use for the present invention is in analysis of smoke and other emanations from a chimney. These materials will be heated when they exit from the chimney. It may be desirable to keep the sample heated until it first enters the conditioner because a change in temperature in the sample while it is traveling through the inlet conduits into the conditioner might change its chemical composition undesirably or the cooling of the sample as it travels toward the conditioner may cause some of the impurities to precipitate out of the sample and coat the walls of the inlet conduits, undesirably occluding these conduits which are not so readily cleaned out as the conditioning apparatus itself. If the heated transmission line from the sample source to the sample conditioner is used, the preconditioner is required to reduce the temperature of the sample before it enters the conditioner. If, on the other hand, the sample from sample source 10 is not heated either by the sample source or by heating means, and if the sample has cooled before it enters the conditioner, or if the temperature of the sample is not critical, then there is no need for the preconditioner.

Assume there is a need for a preconditioner. It is comprised of a cooling chamber, which is merely a large hollow chamber through which the sample travels. The hollow chamber is surrounded by a jacket filled with cooling material, e.g. flowing water, which reduces the temperature of the contents of the hollow chamber. At the base of the hollow chamber is a water trap, e.g. a pool of oil. As the gaseous sample is cooled, the water in the sample condenses and is trapped by the water trap in the cooling chamber.

The next stage in the conditioner, if the sample preconditioner is used, or the first stage in the conditioner if, at the option of the designer, the sample cooling stage is not used, is a first chamber that includes means which cause separation of the particulate impurities from the gaseous sample. The inlet to the first chamber is aimed first, to direct the gaseous sample to move around the interior wall of the first chamber and second, to move the sample downward, so that impurities and the gaseous sample move in a descending spiral. The lower section of the first chamber may be inwardly downwardly, i.e. conically, tapered so that the particles passing through this section are greatly accelerated.

A trap may be provided which communicates with the lower end of the first chamber to trap the particulate and liquid impurities which contact it. The trap may be filled with a liquid bath, e.g., an oil bath, which serves to trap the particles as described.

When the water or other liquid impurities contact and are trapped by the oil bath, these heavier and denser liquid impurities settle through the oil bath and form a pool beneath it, whereby the oil bath trap does not deteriorate because of water and other dense liquid impurities mixing into it.

The liquid-filled trap cooperates with the first chamber to act as a manometer. The pump means, described above, may be downstream of the first chamber. If the pump is so positioned, it draws the gaseous sample into, through and out of the first chamber, thereby causing a slight pressure reduction in the chamber, as compared with atmospheric pressure. The reduced chamber pressure permits the pressure on the surface of the liquid in the trap to force some of the liquid up into the lower end of the first chamber. The greater the pressure reduction, the higher the liquid from the trap will rise. The liquid level is calibratable in terms of the chamber pressure, whereby a manometer is formed.

The conduits leading from the sample source, into the conditioner initial stage, if one is used, and into the first chamber of the first stage carry untreated gaseous sample which has a relatively large quantity of particulate and liquid impurities suspended in it. Consequently, these conduits are most likely to be the ones obstructed or blocked by a buildup of impurities in them. As the obstruction becomes progressively greater, the pump means will be able to draw gaseous sample only at a lesser flow volume rate. Accordingly, the pressure in the first chamber will be progressively reduced and this will cause the liquid from the trap to move further up into the first chamber.

The first chamber may have a gauge or meter on it to indicate the height of the liquid from the trap in the first chamber. When the height of the liquid exceeds a predetermined level, the obstruction to the inflow of gaseous sample into the first chamber has become so great that there cannot be a sufficient volume gaseous sample output from the conditioner. At this time, by checking the gauge, an operator would know that the conduits leading into the first chamber must be cleared of obstructions.

The outlet from the first chamber draws gaseous sample out of the center of the first chamber because the heavier impurities are traveling around the periphery of the chamber. This may readily be accomplished by having an outlet conduit extending into the center of the first chamber. A conduit leads from the first chamber into the inlet of the second chamber which holds an electrostatic precipitator. An electrostatic precipitator has two spaced-apart electrodes with a high electric potential drop across them. As the gaseous sample passes through the electrostatic precipitator, the particulate impurities become charged by one of the electrodes and are attracted to and cling to the other of the electrodes, whereby they are removed from the gaseous sample.

Any liquid impurities still remaining in the sample are electrical resistors in the high potential electric field and are vaporized and dispersed within the precipitator.

Desirably, the electrostatic precipitator consists of a hollow chamber surrounded by a wall comprised of a conductive

material, which wall serves as one electrode. Within the chamber, e.g., at the center thereof, is the other electrode. It is the electrode at the higher potential and particulate impurities are either contacted or influenced by the field surrounding this electrode and are charged thereby. In a preferred form, the high potential electrode itself is a shell defining a smaller chamber within the hollow chamber of the electrostatic precipitator. The inlet to the precipitator opens into the small chamber defined by the central electrode. The shell has a plurality of thin slots passing through it around its periphery near its upper end. The charged particles can exit from the chamber within the shell of the electrode to travel toward the outer electrode, only by passing through the slots. The lower end of the small chamber is closed. The gaseous sample enters the precipitator near the top of the small interior chamber. The heavier particulate impurities settle to the bottom of the interior chamber. The smaller particulate impurities are ionized by the high potential of the central electrode and fly away from the central electrode toward the low potential electrode with a high velocity, due to the small exit area presented by the slots through the shell of the central electrode. More of the smaller particles, than with known precipitators, adhere to the low potential outer wall of the precipitator because they are flung against that wall and because of the attraction of the wall for the charged particles.

The outlet conduit from the electrostatic precipitator has its entry port near the higher potential electrode, which is the electrode that the charged impurities move away from, and is located where the gaseous sample is least contaminated.

The pump means described above, may be either upstream or downstream of the electrostatic precipitator. In a preferred embodiment, the pump means is downstream of the precipitator and is connected with its outlet. By being downstream of both the first and second chambers, the pump is not contacted by gaseous sample until the sample has been decontaminated. The pump, therefore, is freed from having to have deposits of impurities cleaned out of it. The pump usually would not include means for conditioning or cleaning the gaseous sample, and there is no reason to position it where it will be unnecessarily contaminated without helping to clean the sample.

A gaseous sample flow dividing means may be provided downstream of the pump. A first outlet from the flow dividing means would be connected with the inlet to the apparatus which analyzes or otherwise operates upon the conditioned gaseous sample. This apparatus requires that gaseous sample pass to it at a predetermined flow rate. Presumably, this apparatus will draw gaseous sample into it at the predetermined rate so long as the conditioner can provide sample at that rate.

The flow divider also has a second outlet, which may be connected to the outside or to a waste receptacle. Unneeded conditioned gaseous sample passes out the second outlet.

It is expected and unavoidable that the conduits leading into and through the conditioner will become coated and partially obstructed with particulate impurities as the conditioner continues to operate. Therefore, the conditioner is designed to pass through itself and condition a greater volume of sample than would be required by the apparatus receiving conditioned sample from the conditioner. As the conditioner continues to operate and its flow rate decreases, there is still enough gaseous sample produced for the apparatus requiring it. Eventually, of course, the conditioner will cease to produce the required minimum of sample. But, with excessive sample being produced, the conditioner may be left unattended for a longer period of time than would be the case if it were designed to produce only the minimum sample flow rate, in which case the conduits of the conditioner would have to be frequently cleaned.

Accordingly, it is a primary object of the present invention to provide a conditioner for removing impurities from a gaseous sample.

It is another object of the present invention to provide such a conditioner which is compact, lightweight, and portable.

It is another object of the present invention to provide such a conditioner which may be left unattended for an extended period of time.

It is another object of the present invention to provide such a conditioner having a minimum of stages and components.

It is another object of the present invention to provide such a conditioner which can properly operate for prolonged period as the conduits leading into and through the conditioner become progressively coated with and obstructed by the impurities in the gaseous sample being conditioned.

It is another object of the present invention to provide such a conditioner which includes a gauge which indicates whether the conduits leading into the conditioner have become so obstructed as to preclude the conditioner from producing an adequate flow of conditioned gaseous sample.

It is another object of the invention to provide a novel electrostatic precipitator for removing impurities from a gaseous sample.

These and other objects of the present invention will become apparent when the following description is read in conjunction with the accompanying drawing in which:

FIG. 1 schematically illustrates one embodiment of the present invention;

FIG. 2 is a front elevation of a conditioner designed in accordance with the invention; and

FIG. 3 is a side elevation of the conditioner of FIG. 2 in the direction of arrows 3.

Identical elements in each of the Figures are identically numbered. As shown in FIGS. 2 and 3, the conditioner schematically illustrated in FIG. 1 can be placed in a compact and readily portable housing.

Referring to the Figures, the gaseous sample conditioner of the present invention is used for removing particulate and liquid impurities from a gaseous sample. A source of sample to be conditioned is chimney 10 out of which flows smoke containing the gaseous sample and various solid and liquid impurities, including ash and water. Another source of gaseous sample may be used. The sample passes to the conditioner which removes the solid and liquid impurities and thereafter, the sample passes to an apparatus 12 which operates upon the sample.

For example, it may be desired to determine the sulfur dioxide content of the emission from chimney 10. The apparatus 12 would comprise an analyzer for analyzing the gaseous sample for the presence of sulfur dioxide. Such analyzer is shown in copending application Ser. No. 728,306, filed May 10, 1968, now U.S. Pat. No. 3,493,857 in the name of John Silverman, entitled "Analyzer Using an Operational Amplifier," and assigned to the assignee hereof. The analyzer should not be contaminated with particulate or liquid impurities which may coat the surfaces of containers and conduits within the analyzer and prevent their properly functioning and which may mix with the gaseous sample and with the analyzing reagent, thereby adversely affecting the reaction.

The conditioner of the present invention includes a housing 13 in which all of the conditioner components are mounted and in which are located all of the component connecting conduits.

The conditioner has a pump 14 which draws gaseous sample into the conditioner and toward and through the pump, and then pumps the gaseous sample out of the conditioner. Pump 14 may be at any location in the flow path through the conditioner between the first stage 56, to be described, of the conditioner and the flow dividing means 130, to be described. The further downstream in the flow path that the pump is located, the less it will be exposed to and contaminated with the impurities carried by the gaseous sample. Since the pump is not designed to remove impurities, it should be downstream where it cannot be contaminated. The pump sucks or draws gaseous sample through those components of the conditioner which are upstream of it and pumps gaseous sample through those components which are downstream of it.

Pump 14 may be any conventional pump for pumping a gaseous sample. Preferably, it is of a type designed to protect the gaseous sample moving through it from contacting the operating mechanism of the pump, which may contaminate the gaseous sample with impurities like lubricant or scrapings from the pump components. Pump 14 is shown as a diaphragm pump which includes an airtight sealed chamber 16 having one wall which is comprised of a flexible impermeable diaphragm 18. The diaphragm includes a mounting post 20 outside chamber 16 to which is pivotally connected at 22 a connecting rod 24 which is, in turn, pivotally connected at 26 eccentrically to a disc 28 which rotates around drive shaft 30. Motor means 31 rotates shaft 30 and disc 28, which causes rod 24 to move pivot 22, and hence, diaphragm 18 up and down, as viewed in FIG. 1, thereby reciprocatingly increasing and decreasing the volume of chamber 16.

Pump inlet and outlet ball check valves 34 and 40, respectively, ensure that the flow through pump 14 is only in the downstream direction. Valve 34 has a valve seat 35 with an opening therethrough which permits gaseous sample to travel into chamber 16. The ball 36 is pressed by elevated pressure within chamber 16, due to a decrease in the chamber volume, against its valve seat 35, whereby no gaseous sample within the chamber 16 can return upstream. A screen 37 permeable by gaseous sample keeps ball 36 near its valve seat 35 when chamber 16 is increasing in volume and sample is being drawn into the pump.

Valve 40 includes a valve seat 42 facing in the opposite direction to seat 35 and includes a ball 44 which sits on seat 42. When diaphragm 18 is moving downward and chamber 16 is increasing in size, ball 44 is drawn to seat 42 and prevents any sample downstream of the pump from being drawn upstream. Screen 46, which is permeable by sample, holds ball 44 in position near seat 42.

Moving now to the upstream end of the conditioner, the conditioner has an inlet 50 which is connected with the chimney 10 to draw some of the chimney emission into the conditioner. As pump 14 operates, the emission passes through the conditioner inlet 50, through conduit 51, through fitting 52 on the wall of housing 13, through conduit 53 in housing 13 and out exit 54 of conduit 53 into the preconditioner 200. As was noted above, the preconditioner may be used at the option of the operator to cool the emission from the sample source. The gaseous sample in conduits 51, 53 is at an elevated temperature due to the heat generated within the chimney. As a further option for the designer, if the preconditioner 200 is to be used, the conduits 51 and/or 53 may be heated by heating means 202 and/or 204 which would heat up or keep heated the sample exiting from sample source 10. The heated sample passes through conduit 53 and exits therefrom through its outlet 54 into the vacant chamber 206 of the preconditioner 200. At the bottom of the vacant chamber 206 is a pool 208 of oil or other water and impurity entrapping material, for reasons to be described. Chamber 206 is enclosed by wall 210 which is surrounded by an enclosed jacket 212 which holds a cooling medium, such as water. The contents of jacket 212 are always kept segregated from the contents of chamber 206 so that there will be no contamination. If water is the cooling medium, an inlet 214 from a conventional cool water supply empties into jacket 212. The jacket becomes filled with cool water. Spent cooling water exits from jacket 212 through exit conduit 216 and passes to waste. The cooling water reduces the interior temperature of chamber 206 thereby cooling the gaseous sample then in the chamber. As the sample cools, some of the water and liquid impurities in the sample condense and are trapped by the pool 208 of oil. The dense water settles through the oil pool 208 and forms a separate water pool 220 beneath the oil. An outlet conduit 222 communicates with the base of chamber 206 and the impurity water in pool 220 can be periodically withdrawn from chamber 206 through conduit 222. Some of the heavier solid impurities will settle through chamber 206 and be trapped by the oil pool 208. Once the sample has been cooled in chamber 206 and some of the liquid

and solid impurities have been removed therefrom, the sample is drawn by the sucking action of pump 14 through the exit conduit 224 of conditioner 200 and travels through conduit 224.

The first stage comprises a first chamber 58, 64. Upper hollow cylindrical chamber 58 is sealed at its upper end 60 and has an open lower end 62. Disposed directly beneath cylindrical chamber 58 is a downwardly inwardly, conically tapered, hollow chamber 64, having an open upper end 66 which is sealed at 68 with the lower open end 62 of chamber 58, and having an open lower end 70 which is submerged a short distance into the liquid 72 within the impurity trap 74, to be described further below. Chamber 58, 64 is conventionally referred to as a cyclone.

Conduit outlet 54 opens into upper chamber 58 near its upper end 60 and is directed so as to blow the entering gaseous sample substantially tangentially against the interior wall 76 of chamber 58. Outlet conduit 54 is also aimed to blow the sample slightly downward. The sample with the impurities suspended in it, therefore, whirls around wall 76 in a downward spiral.

As the impurities whirl downward through chamber 64, they are accelerated both around the interior wall and downward due to the decreasing diameter of chamber 64. Eventually, the impurities strike the pool 72 of liquid trapping medium within trap 74 and are trapped by the liquid. Pool 72 is preferably an oil bath which traps particulate impurities. Liquid impurities, which mostly comprise water, are trapped in the oil. Being heavier and denser than the oil, the liquid impurities pass through the oil and form a pool 80 beneath it. Thus, the efficiency of the oil bath as a trap is not diminished by having water impurity mixed into it. An outlet conduit 82 may be connected with the lower end of trap 74. The outlet conduit may be a permanent water runoff line, or it may have a stop cock 84 on it which is periodically opened to open conduit 82 and permit the pool 80 of water and other liquid impurities to be removed.

The reason for filling the impurity trap 74 with a liquid trapping medium, such as oil, is to enable the first stage of the conditioner 56 to operate as a monometer, or gas pressure sensing gauge. Pump 14, while operating, is drawing gaseous sample through first stage 56, and is therefore, sucking gaseous sample out of the chamber 58, 64. Chamber 58, 64 is at a slightly reduced pressure, as compared with outside pressure. Otherwise, no sample would be drawn into the chamber from chimney 10. As was noted above, the lower end 70 of tapered chamber 64 is submerged in pool 72. The reduced pressure in chamber 58, 64 causes the level 90 of pool 72 within tapered chamber 64 to rise above the level of the liquid within the rest of trap 74. This is because of the above noted pressure difference. As the pressure difference increases, level 90 rises.

Pump 14 pumps gaseous sample at a continuous rate. The conduits 51, 53 are directly exposed to the emission from chimney 10 and conduit 224, if preconditioner 200 is used, is less directly exposed. These are the conduits most likely to become internally coated with particulate impurities and to become eventually obstructed or blocked. As conduits 51, 53, 224 become progressively more obstructed, the rate of flow, i.e. flow volume per unit time, of gaseous sample into chamber 58, 64 is reduced. The constant pumping rate of pump 14 cooperates with the progressive obstruction of conduits 51, 53 to continuously decrease the gas pressure within chamber 56, and thereby causes the level 90 of liquid within tapered chamber 64 to continuously rise.

A height gauge 92 for the liquid level 90 in tapered chamber 64 is provided. If the chamber 64 is made of transparent material, the height gauge can consist of visible graduation marks on the exterior of the chamber 64. Any other conventional liquid height gauge may be used. When the pressure within pressure chamber 58, 64 decreases below a predetermined level, as measured on gauge 92, the obstruction of conduits 51, 53 is too severe for the conditioner to properly operate. At that time, the conditioner may be stopped and

conduits 51, 53 may be cleaned out. Conduits 51, 53 should be sufficiently wide that it takes a prolonged period before they become so obstructed with impurities as to cause the conditioner to cease to operate properly. Consequently, the conditioner will be operable for an extended period without requiring that its conduits be cleaned.

Passing through the closed end 60 of upper cylindrical chamber 58 is an outlet conduit 94 which extends downward into the center of chamber 58. The particulate and liquid impurities travel around the interior wall 76 of chamber 58, 64. Consequently, the centered position of outlet conduit 94 keeps it away from the impurities, so that less contaminated gaseous sample is drawn from chamber 58, 64. The pressure at the center of chamber 58, 64 is lower than that at the periphery thereof, due to the vortex caused by the downwardly spiralling gaseous sample and impurities. However, pump 14 is able to draw enough gaseous sample out of the conditioner first stage 56 to cause proper operation.

The gaseous sample drawn out of first stage 56 travels through conduit 96, into inlet conduit 98 at the top of the second stage 100 of the conditioner. The second stage 100 comprises an electrostatic precipitator for precipitating out of the gaseous sample any remaining particulate impurities and for vaporizing and thereby eliminating the liquid impurities. The precipitator comprises a hollow cylinder 101 having closed top and bottom ends 102 and 103, respectively. This forms a precipitator chamber.

Cylinder 101 has two electrodes 104, 105 in it with a high electric potential drop across them. The particulate impurities are charged in the electric field generated by the high potential electrode 104, to be described in more detail below, are attracted and cling to the lower potential electrode 105 and are thereby removed from the gaseous sample. The liquid impurities are resistors in the electric potential field surrounding the high potential electrode, are vaporized by the high potential and are dispersed, so that their subsequent effect on the gaseous sample is minimized.

As illustrated, the interior wall 105 surrounding cylinder 101 is comprised of electrically conductive material, is electrically grounded at 106 and serves as the low potential electrode in the precipitator to which the charged particulate impurities cling.

Extending into the center and part way down through the cylinder 101 is high potential electrode 104, which may be a simple carbon electrode or a more efficient electrode, which will be described below. The high potential electrode is connected by conductor 107 to a high electric potential power supply 108, whereby a high potential electric field is established in and around the electrode 104 and within cylinder 101.

The preferred and more efficient form of high potential electrode is illustrated in FIG. 1. The electrode 104 comprises a hollow shell 109 which is preferably cylindrical, and which cylindrical shell is comprised of an electrically conductive material. Shell 109 defines an electrode chamber within itself. The upper end 110 of the shell is sealed closed. Passing through the sealed upper end is the lead 107 from high potential source 108 which lead is electrically connected to the shell 109. Also passing through the sealed end 110 and opening into the upper end of the electrode chamber within shell 109 is the outlet from second stage inlet conduit 98. Thus, the partially conditioned gaseous sample from the first stage of the conditioner initially enters the electrode chamber within cylinder 109. Shell 109 is sealed closed at its lower end by a sealing plug 111.

A plurality of small size, spaced-apart slots 112 pass completely through the shell 109. The slots 112 start near the upper end of shell 109, are located all around the periphery of the cylinder and extend downward along the upper portion of the shell. The slots preferably do not extend all the way down through the lower portion of the shell for reasons to be described.

Gaseous sample, carrying liquid and particulate impurities, enters the electrode chamber within shell 109. The liquid and water impurities are vaporized by the high potential and disperse. All of the particulate material entering this chamber is ionized by the high electric potential of electrode 104. The heavier particles drift down through the electrode chamber past slots 112 and eventually settle on the upper surface of sealing plug 111. Once the heavier particles move past the lowermost ones of slots 112, they are no longer able to move out of the electrode chamber. Locating slots 112 along the upper portion of shell 109 precludes heavier impurity particles from drifting out of shell 109, whereby they no longer can be carried along by the flow of gaseous sample.

As the gaseous sample flows into the electrode chamber within shell 109, it flows out of the only exit available to it, namely the plurality of slots 112, thereby filling the precipitator chamber within cylinder 101 with gaseous sample. The light weight electrically charged particles of particulate impurities which do not settle past slots 112 are electrically repelled by the high potential of the electrode 104 and are attracted by the low potential of electrode 105. The only avenue of escape for these particles are the narrow slots 112 out of the electrode chamber. Due to these particles being highly charged and due to their continuously entering the electrode chamber, once the particles move adjacent the small slots 112, they are propelled out with great velocity. In addition, because slots 112 are narrow and spaced-apart, the gaseous sample carrying the particles rushes through the slots with considerable speed and force. The particles of particulate impurities, therefore, are propelled out of the electrode chamber formed within shell 109 with great force arising from the combination of the repulsion by electrode 104, the attraction by the interior cylinder wall forming electrode 105, the force of the exiting gaseous sample and the narrow and few in number avenues of escape. The escaping waste particles are thrown against the electrode 105 with considerable force, whereby they readily adhere to the lower potential electrode. In this manner, the electrostatic precipitator 100 efficiently removes particulate waste from a gaseous sample.

The electrostatic precipitator here described in detail is useful not only in the particular apparatus shown herein but is generally useful in any application requiring the removal of particulate wastes from a gaseous sample.

The electrostatic precipitator 100 specifically described above with its novel high potential electrode is more efficient than a conventional electrostatic precipitator employing a solid high potential electrode. For example, it has been found that with a solid carbon high potential electrode, in order for one embodiment of the gaseous sample conditioner of the present invention to operate properly, the electrostatic precipitator must be operated at a potential of approximately 12,000 volts. However, the same sample conditioner, using the novel electrostatic precipitator described herein, can operate efficiently at a potential of approximately 7,000—8,000 volts.

The conditioned gaseous sample within cylinder 101 is drawn by pump 14 through outlet conduit 114 and into pump inlet conduit 116. Outlet conduit 114 is centered in lower end 103 of cylinder 101. Being centered, it is away from the cylinder wall 105 of the precipitator and is thereby away from the surface to which the particulate impurities are clinging, whereby the conduit 114 draws cleaner gaseous sample from the cylinder 101.

The gaseous sample travels through pump inlet conduit 116, through pump 14, which was described above, and then out pump outlet conduit 118. The gaseous sample next passes a flow volume controlling means, e.g. needle valve 120, which can partially or totally block conduit 118 and thereby control the volume of conditioned gaseous sample which will pass to the apparatus 12. The conduit 118 continues at 122 downstream of the flow volume controlling means.

Conduit 122 has an outlet 124 into the flow dividing means 130 which apportions the flow of conditioned gaseous sample

so that sample flows at a proper rate to the apparatus 12. As illustrated, the outlet 124 enters near the top of the hollow upper cylindrical chamber 132 which with the hollow conically tapered lower chamber 134 forms a single hollow chamber.

A large volume of conditioned gaseous sample travels through conduit 122 and into the flow dividing means 130. The apparatus 12 may include a means (not shown) for drawing the gaseous sample required by the apparatus out of the flow dividing means 130. The pump 14 lends additional help in pumping the gaseous sample to the apparatus 12. The portion of the sample required by apparatus 12 exits through exit conduit 136 which extends into the chamber 132, 134. It travels through fitting 138 on housing 13 and through conduit 139 to apparatus 12.

It is expected that during operation of the conditioner, certain of its conduits and components will become coated with impurities which obstruct the flow of gaseous sample to a progressively greater extent, thereby progressively reducing the flow rate of gaseous sample. Therefore, the conditioner is designed so that the flow rate of gaseous sample into flow dividing means 130 is greater than the sample flow rate required by apparatus 12. For example, the conditioner could be producing sample at a flow rate of 5 liters per minute, when the conditioner is producing at maximum output, while the apparatus 12 only requires sample at a flow rate of 0.2 liters per minute. The excess gaseous sample produced by the conditioner, but not used by the apparatus 12, progressively decreases in flow rate as the conditioner becomes obstructed. But, because excess sample is produced, the flow rate to apparatus 12 can remain constant. Hence, by producing an excess of gaseous sample, the conditioner can be operated for a long period of time without being checked or cleaned by an operator, whereby many man hours are thereby saved.

In view of there being excess sample produced, a portion of the gaseous sample moving into flow dividing means 130 cannot be used by the apparatus 12 and will not exit through exit conduit 136. Chamber 132, 134 is vented through conduit 140 to the outside or into a closed vessel at or near atmospheric pressure so that there is no pressure buildup within the chamber 132, 134 which might establish a back pressure that would interfere with proper operation of the conditioner. The apparatus 12 always draws off sample at a constant flow rate which it requires for its operation. It is only the excess gaseous sample that is vented through conduit 140.

There has just been described a conditioner for a gaseous sample for removing particulate and liquid impurities from the gaseous sample before passing the sample on to an apparatus which operates upon or uses the now impurity free sample. The conditioner optionally uses a novel electrostatic precipitator which was also described.

Although there has been described a preferred embodiment of this novel invention, many variations and modifications will now be apparent to those skilled in the art. Therefore, this invention is to be limited, not by the specific disclosure herein, but only by the appended claims.

We claim:

1. In an electrostatic precipitator for removing impurities from a flowing gaseous sample, comprising
 - a precipitator chamber defined by and surrounded by a wall comprised of electrically conductive material connected to a low electric potential and serving as the low potential electrode of said precipitator;
 - a high potential electrode within said precipitator chamber, spaced away from and insulated from said precipitator chamber wall and connected to a high electric potential;
 - said precipitator having an inlet; said precipitator having an outlet communicating with said precipitator chamber;
 - the improvement comprising said high potential electrode comprising an electrically conductive shell defining and surrounding a hollow electrode chamber;
 - said precipitator inlet communicating into said electrode chamber;

- said shell having a plurality of narrow slot openings therethrough connecting said electrode chamber with said precipitator chamber, thereby forming a plurality of small size outlets for both gaseous sample and the particulate impurities which are charged by the high potential field around said high potential electrode;
- whereby the particulate impurities are accelerated out of said electrode chamber and are flung against said low potential electrode.
2. In the electrostatic precipitator of claim 1, the improvement further comprising,
 - said shell having a top and a bottom portion near the respective top and bottom portions of said electrode chamber;
 - said slot openings being only through said shell top portion, whereby heavier particulate impurities can settle to the bottom of said electrode chamber without being able to exit therefrom, while lighter particulate impurities can exit.
3. A conditioner for removing particulate and liquid impurities from a gaseous sample, comprising,
 - an inlet for said conditioner, said inlet leading to an inlet for a first stage through which the gaseous sample moves; and an outlet from said conditioner;
 - a first stage including an upper hollow cylindrical chamber and a lower hollow chamber, with said upper chamber being located directly over said lower chamber, thereby forming a single continuous chamber; said single chamber being defined by a surrounding wall; said lower chamber comprising an inwardly, downwardly, tapered chamber having a lower end;
 - said conditioner inlet leading into said upper chamber near the upper end thereof and aimed so that the sample moves around the interior of said wall surrounding said continuous hollow chamber and so that the sample moves down through said continuous chamber toward said lower end of said lower chamber whereby the impurities whirl around said wall and become separated from the sample;
 - said first stage having an outlet, including a conduit extending into said continuous chamber and having an entry port spaced away from said wall around said continuous chamber and also away from said lower end of said lower chamber, thereby to draw the already conditioned gaseous sample out of said continuous chamber;
 - a trap communicating with the said lower end of said lower chamber and being filled with a liquid which catches and holds particulate impurities and liquid impurities which have moved through said continuous chamber and contacted the liquid; said lower end of said lower chamber being submerged in said liquid;
 - a second stage having an inlet connected with said outlet of said first stage; said second stage including a chamber having a first and second electrode within it, said electrodes being spaced-apart and electrically insulated from one another; said first electrode being connected to a high electric potential and said second electrode being connected to a lower electric potential thereby creating a high potential drop across said electrodes, whereby particulate impurities passing through said second stage are electrically charged and are electrically attracted and cling to said second electrode and whereby liquid impurities are caused to be vaporized; said second stage having an outlet;
 - pump means having an inlet connected with said outlet from said second stage, and having an outlet connected with the inlet to a sample dividing means, for drawing gaseous sample through said first and second stages and for pumping gaseous sample through the dividing means and out said continuous outlet;
 - said pump means operating upon said continuous chamber of said first stage to keep said continuous chamber at slightly reduced pressure, said pump means further serving to cause the liquid within said trap to move into said lower chamber of said continuous chamber a distance

proportional to the pressure reduction, whereby said continuous chamber and said trap combine to form a manometer;

a gaseous sample dividing means having an inlet and a first outlet; the inlet thereof communicating with said pump means outlet and said dividing means first outlet leading to said conditioner outlet;

said dividing means having a second outlet, so that only that part of the gaseous sample which is needed to pass through said conditioner outlet is able to do so and the rest of said sample can pass through said second flow dividing means outlet;

said gaseous sample dividing means has a closed upper end and an open lower end; said sample dividing means inlet and said first outlet therefrom communicating near said upper end thereof and said second outlet thereof communicating with said open lower end thereof and being vented to the outside.

4. The conditioner for a gaseous sample of claim 3, wherein said second electrode comprises a wall spaced away from and surrounding said first electrode;

said first electrode comprises an electrically conductive shell defining and surrounding a hollow electrode chamber; said shell having a top and bottom portion near the respective top and bottom portions of said electrode chamber;

said second stage inlet communicating into said electrode chamber;

said shell top portion having a plurality of narrow slot openings therethrough connecting said electrode chamber with said second stage chamber, thereby forming a plurality of small size outlets from said electrode chamber for both the gaseous sample and the electrically charged particulate impurities whereby the particulate impurities are accelerated out of said electrode chamber and are flung against said second electrode;

said second stage outlet communicating with said second stage chamber.

5. The conditioner for a gaseous sample of claim 4, further including

said conditioner inlet communicating with a chimney for receiving gaseous sample holding impurities requiring conditioning;

a sample preconditioner for cooling the gaseous sample before it enters said first stage inlet; said preconditioner moving a gaseous sample inlet communicating with said conditioner inlet and a gaseous sample outlet communicating with said first stage inlet; said preconditioner including a cooling chamber through which said gaseous sample passes;

said preconditioner cooling chamber having a pool of liquid therein for trapping particles which settle into the pool and for trapping liquid impurities which condense in said cooling chamber; and an impurity removal conduit communicating with said pool in said cooling chamber for permitting removal of impurities from said pool;

cooling means communicating with said cooling chamber for cooling said cooling chamber and the gaseous sample therein; said cooling means comprises a jacket around said cooling chamber; said jacket having a cooling medium passed into it;

said conditioner inlet having heating means positioned with respect to it to heat the gaseous sample as and before it moves into the conditioner inlet;

an impurity removal conduit communicating with said impurity trap of said first stage for permitting removal of impurities trapped in said trap;

an adjustable flow volume control means between said pump outlet and said flow divider means inlet for varying the flow along the path between these elements.

6. The conditioner for a gaseous sample of claim 3, further including

said conditioner inlet communicating with a chimney for receiving gaseous sample holding impurities requiring conditioning;

a sample preconditioner for cooling the gaseous sample before it enters said first stage inlet; said preconditioner having a gaseous sample inlet communicating with said conditioner inlet and a gaseous sample outlet communicating with said first stage inlet; said preconditioner including a cooling chamber through which said gaseous sample passes;

said preconditioner cooling chamber having a pool of liquid therein for trapping particles which settle into the pool and for trapping liquid impurities which condense in said cooling chamber; and an impurity removal conduit communicating with said pool in said cooling chamber for permitting removal of impurities from said pool;

cooling means communicating with said cooling chamber for cooling said cooling chamber and the gaseous sample therein; said cooling means comprises a jacket around said cooling chamber; said jacket having a cooling medium passed into it;

said conditioner inlet having heating means positioned with respect to it to heat the gaseous sample as and before it moves into the conditioner inlet.

7. A conditioner for removing particulate and liquid impurities from a gaseous sample, comprising,

an inlet for said conditioner, said inlet leading into an inlet for a first stage through which the gaseous sample moves;

a first stage including a hollow chamber surrounded by a wall; said conditioner inlet leading into the upper end of said hollow chamber and being aimed so that the gaseous sample moves around the interior of said wall and down through said hollow chamber whereby the impurities whirl around said wall and become separated from the sample; said first stage having an outlet leading to the inlet of a second stage;

a second stage having an inlet connected with said outlet of said first stage; said second stage including a chamber having a first and second electrode within it, said electrodes being spaced-apart and electrically insulated from one another;

said first electrode being connected to a high electric potential and comprising an electrically conductive shell defining and surrounding a hollow electrode chamber; said shell having a top and bottom portion near the respective top and bottom portions of said electrode chamber;

said second stage inlet communicating into said electrode chamber;

said shell top portion having a plurality of narrow slot openings therethrough connecting said electrode chamber with said second stage chamber, thereby forming a plurality of small size outlets from said electrode chamber for both the gaseous sample and the electrically charged particulate impurities, whereby the particulate impurities are accelerated out of said electrode chamber and are flung against said second electrode;

said second electrode being connected to a lower electric potential thereby creating a high potential drop across said electrodes, said second electrode comprising a wall spaced away from and surrounding said first electrode;

whereby particulate impurities passing through said second stage are electrically charged and are electrically attracted and cling to said second electrode and whereby liquid impurities are caused to be vaporized;

said second stage having an outlet leading from said second electrode wall;

said conditioner having an outlet; means joining said second stage outlet to said conditioner outlet, from which conditioner outlet the now conditioned gaseous sample can pass to where it is to be operated upon.

8. A conditioner for removing particulate and liquid impurities from a gaseous sample, comprising,

an inlet for said conditioner, said inlet leading into an inlet for a first stage through which the gaseous sample moves;

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a first stage including an upper hollow cylindrical chamber and a lower hollow chamber, with said upper chamber being located directly over said lower chamber, thereby forming a single continuous chamber; said single chamber being defined by a surrounding wall; said lower chamber comprising an inwardly, downwardly tapered chamber; said conditioner inlet leading into said upper chamber near the upper end thereof and aimed so that the gaseous sample moves around the interior of said wall surrounding said continuous hollow chamber and so that the sample moves down through said continuous chamber, whereby the impurities whirl around said wall and become separated from the sample;

said first stage having an outlet;

a trap communicating with the lower end of said lower chamber for collecting impurities which have moved through said continuous chamber; said trap being filled with a liquid which catches and holds particulate impurities and liquid impurities which contact it;

the path from said conditioner inlet to said conditioner outlet comprises a flow path through said conditioner; pump means connected into the flow path through said conditioner for moving gaseous sample through said conditioner; said pump means being positioned past said first stage outlet to operate upon said continuous chamber to keep said continuous chamber at slightly reduced pressure;

said pump means further serving to cause the liquid within said trap to move into said lower chamber of said continuous chamber a distance proportional to the pressure reduction, whereby said continuous chamber and said trap combine to form a manometer;

a second stage having an inlet connected to said outlet of said first stage; said second stage including a chamber having a first and a second electrode within it, said electrodes being spaced-apart and electrically insulated from one another; said first electrode being connected to a high electric potential and said second electrode being connected to a lower electric potential thereby creating a high potential drop across said electrodes, whereby particulate impurities passing through said second stage are electrically charged and are electrically attracted and cling to said second electrode and whereby liquid impurities are caused to be vaporized; said second stage having an outlet;

said conditioner having an outlet; means joining said second stage outlet to said conditioner outlet, from which conditioner outlet the now conditioned gaseous sample can pass to where it is to be operated upon;

a gaseous sample dividing means having an inlet communicating with said pump means output, and a first outlet leading to said conditioner outlet;

said gaseous sample dividing means having a second outlet

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so that only that part of the gaseous sample which is needed to pass through said conditioner outlet is able to do so and the rest of said sample can pass through said second dividing means outlet.

9. A conditioner for removing particulate and liquid impurities from a gaseous sample, comprising,

an inlet for said conditioner, said inlet leading into an inlet for a first stage through which the gaseous sample moves;

a first stage including an upper hollow cylindrical chamber and a lower hollow chamber, with said upper chamber being located directly over said lower chamber, thereby forming a single continuous chamber; said single chamber being defined by a surrounding wall; said lower chamber comprising an inwardly, downwardly tapered chamber;

said conditioner inlet leading into said upper chamber near the upper end thereof and aimed so that the gaseous sample moves around the interior of said wall surrounding said continuous hollow chamber and so that the sample moves down through said continuous chamber, whereby the impurities whirl around said wall and become separated from the sample;

said first stage having an outlet;

a second stage having an inlet connected to said outlet of said first stage; said second stage including a chamber having a first and second electrode within it, said electrodes being spaced-apart and electrically insulated from one another; said first electrode being connected to a high electric potential and said second electrode being connected to a lower electric potential thereby creating a high potential drop across said electrodes, whereby particulate impurities passing through said second stage are electrically charged and are electrically attracted and cling to said second electrode and whereby liquid impurities are caused to be vaporized; said second stage having an outlet;

said conditioner having an outlet; means joining said second stage outlet to said conditioner outlet, from which conditioner outlet the now conditioned gaseous sample can pass to where it is to be operated upon;

a gaseous sample dividing means having an inlet communicating with said second stage outlet, and a first outlet leading to said conditioner outlet;

said gaseous sample dividing means having a second outlet, so that only that part of the gaseous sample which is needed to pass through said conditioner outlet is able to do so and the rest of said sample can pass through said second flow dividing means outlet;

said gaseous sample dividing means has a closed upper end and an open lower end; said sample dividing means inlet and said first outlet therefrom communicating near said upper end thereof and said second outlet thereof communicating with said open lower end thereof and being vented to the outside.