Oct. 15, 1963 F. C. LUXL 3,106,843

ATMOSPHERE SAMPLING PROBE

Filed Sept. 30, 1960 2 Sheets-Sheet 1

Fig. 1

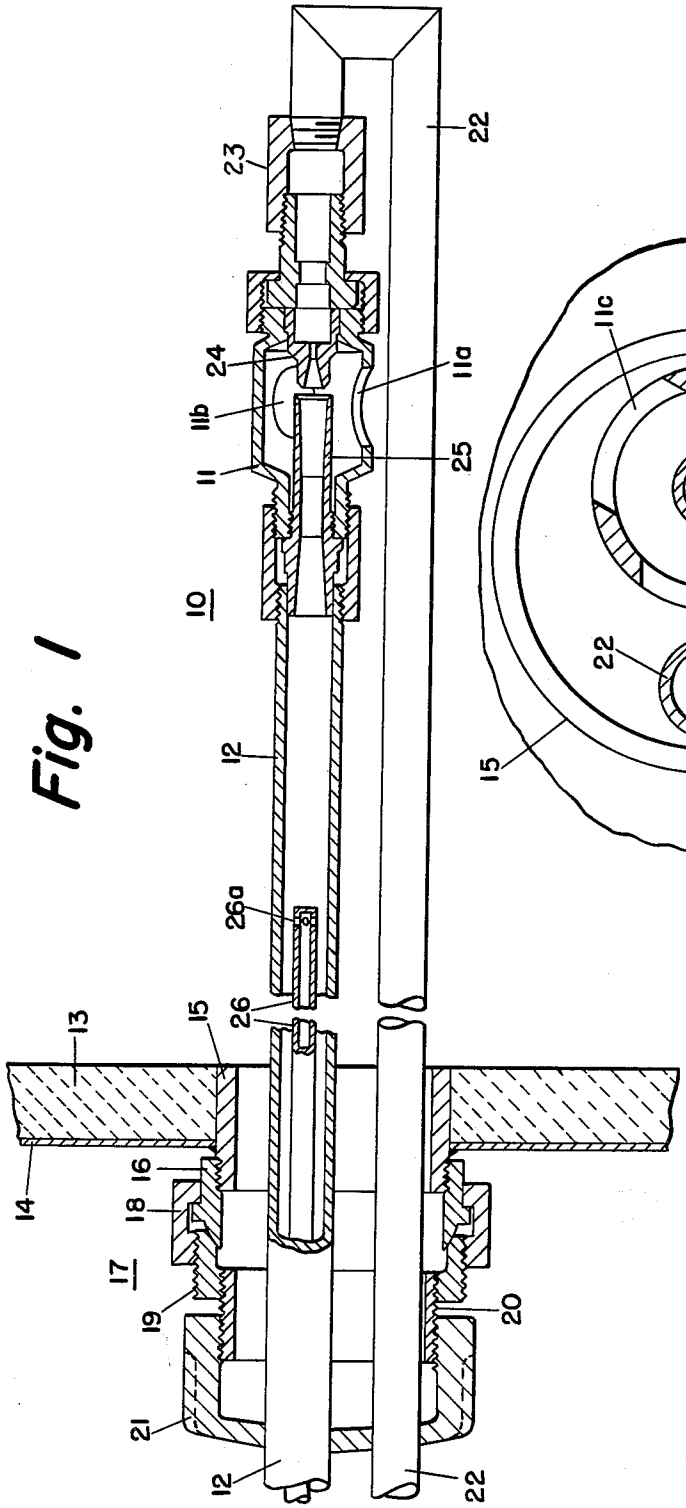
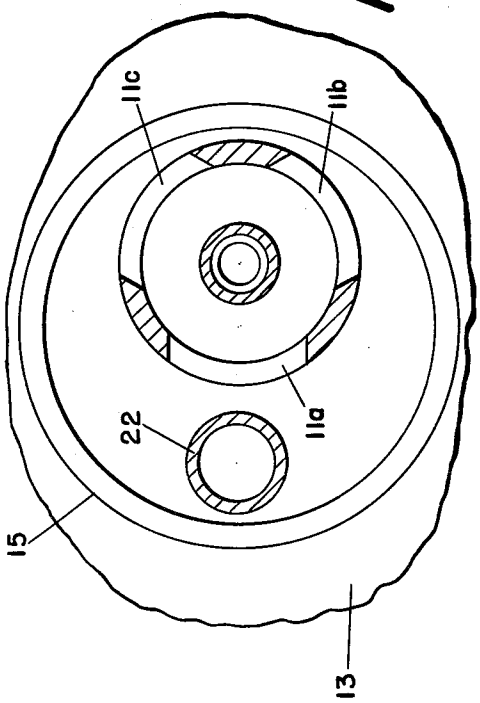


Fig. 2



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Fig. 3

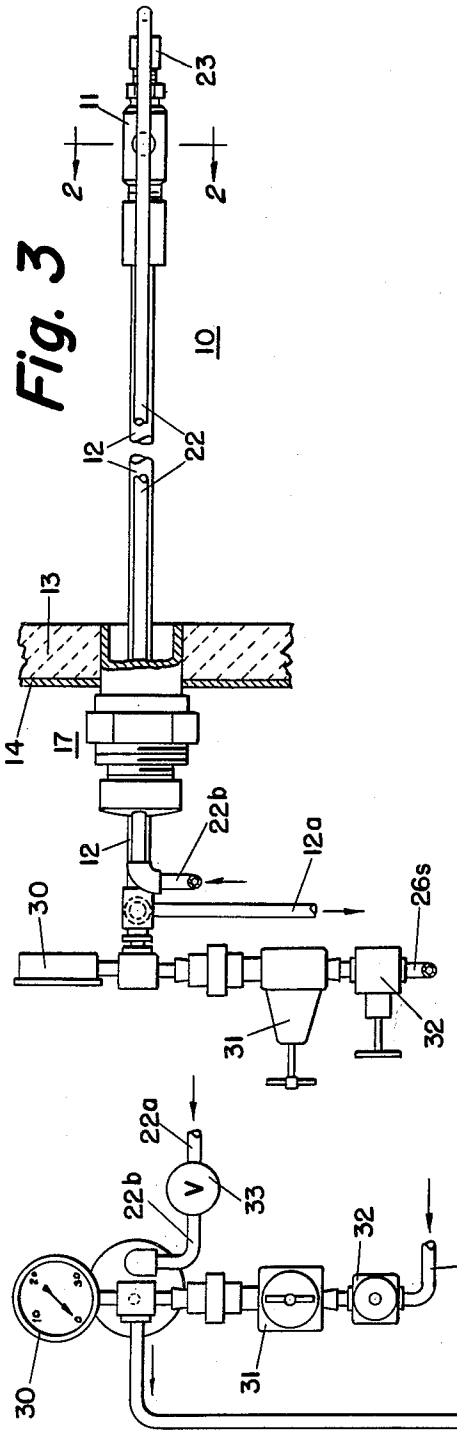
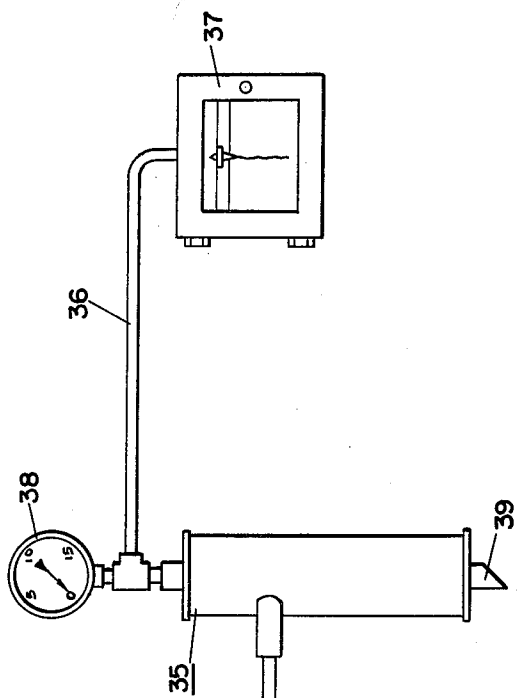


Fig. 4



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3,106,843

ATMOSPHERE SAMPLING PROBE

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This invention relates to atmosphere sampling probes of the type used in gas analysis systems to obtain continuous flow of a sample stream from atmospheres ladened with dust, contaminants, and water vapor and has for an object the provision of features which prevent the clogging of the probe during extended periods of operation.

The need continuously to analyze the combustion or flue gases of furnaces, such as those employed in power plants, is well known to those skilled in the art. In many instances the composition of the gases, particularly the oxygen content thereof, has been used for both manual and automatic control to assure the operation of the furnaces or similar processes at high efficiency. Because the dust-ladened combustion gases may include condensable water vapor which may combine with the dust to form deposits which block the free flow of sample, efforts have been made to provide means to prevent the accumulation of solids within or on the probe to a point where it becomes necessary to shut down the analyzing system in order to open the flow path for the sample stream. For this purpose, it has been proposed to supply the probe with steam to induce the flow of a sample stream through the probe. It has also been proposed to supply the probe with a water spray designed to minimize the accumulation of solids within the region of the openings into the probe. While these prior proposals have been helpful, much has been left to be desired to extend the uninterrupted time during which a sampling stream may be obtained from a furnace atmosphere. More particularly, steam probes have been found effective in minimizing the clogging of the probes within the region of the openings for the flow of the sample stream into them. However, steam probes have not been entirely satisfactory due to corrosion and/or the accumulation of solids within the sampling line in the regions where the temperature of the sample line has caused condensation of the steam. Probes of the water-spray type while effective to prevent clogging of the flow channel of the probe itself, nevertheless produce such reductions of temperature within the regions of the access openings into the probe that cementitious products form growing solids on the outside of the probe which eventually close the openings and thus require shut-down of the system for cleaning as indicated above.

In accordance with the present invention, it has been found that uninterrupted sampling times of a new order of magnitude can be achieved by utilizing high temperature steam to operate an ejector pump for producing in the region of the access openings to the probe a low pressure for forced flow of a sample stream into the probe in combination with the introduction down-stream from the access openings of a stream of wash water which not only acts to condense the steam about the solid particles in the sample stream but also insures the presence of water in sufficient quantity to dilute corrosive materials and maintain all cementitious-forming products in solution. Thus, the combination of the steam at the probe inlet or inlets in conjuction with the stream of wash water introduced within a critical region in the probe has overcome the difficulties experienced with probes of types heretofore utilized.

For further objects and advantages of the invention,

reference is to be had to the following detailed description taken in conjunction with the accompanying drawings, in which:

FIG. 1 is an enlarged top view, partly in section, of a probe assembly embodying the invention;

FIG. 2 is a sectional view (on a larger scale) taken on the line 2—2 of FIG. 3;

FIG. 3 is a side elevation of the probe of FIG. 1 together with its associated supply lines; and

FIG. 4 is a front view of the probe assembly of FIG. 3 and includes the analyzing apparatus associated therewith.

Referring now to FIG. 1, the invention in its preferred form has been illustrated as applied to a probe **10** comprising tubular structure including a section **11** of diameter materially greater than the diameter of a tube **12**, the interior of which provides a flow channel for the sample stream from the atmosphere. The atmosphere is normally that of a furnace, one wall **13** of which has been illustrated as a refractory material which has a metal outer casing **14**. A member **15** is welded to the casing **14** and has threaded thereon one member **16** of a union **17** having a threaded ring **18** and a second threaded member **19**. A nipple **20** is threaded to the member **19** and also has threaded to it a pipe cap **21** through which the tubular member **12** extends. Also extending through the cap **21** is a steam supply line **22**, the inner end of which is threaded into a coupling **23** for connection with probe **10**. Thus, the probe as a whole is supported from the pipe cap **21** which supports the tubular member **12** and the steam line **22**.

The element **11** is made of larger diameter than the tube **12** in order that one or more access openings, three of which have been illustrated, namely, the access openings **11***a*, **11***b* and **11***c*, can be of enlarged size to contribute to long-time operation free of clogging. The element **11** also forms a housing for the steam-jet ejector pump **24** which delivers through its conical nozzle an expanding steam-stream. This steam, from steam supply line **22**, produces within the region of the inlet to a diffuser, shown as a tubular member **25**, a region of low pressure. The low pressure so produced by the ejector pump results in forced flow of a sample stream from the furnace atmosphere through the access openings **11***a*–**11***c* into the tubular member **25**. This member **25** by reason of its venturi section, that is, with gradually increasing diameters from the central portion to the respective ends thereof, provides a diffusion action for the sample stream and steam prior to delivery into the tube **12**. The diffusion action results in the thorough mixing of the steam and the sample stream and also provides forced flow of the sample stream through and outwardly of the tube **12**.

By utilizing high temperature steam, there is minimized any reduction of temperature within the region of the access openings **11***a*–**11***c*, thereby preventing condensation of components of the sample stream onto the probe walls adjacent the access openings. The forced flow of the sample stream into the sampling line, including tubes **12** and **25**, reduces to a minimum the possibility of clogging. By high temperature steam, I mean steam at a temperature at which condensation does not take place under normal operating conditions within that part of the probe located up-stream from the region of introduction of wash water. In this connection, it is to be noted that the steam line **22** is not insulated, but instead, receives heat from the interior of the furnace and to some extent its temperature may be increased by this heating action.

In order to minimize the possibility of a reduction in the temperature of the sample stream, comprising the mixture of the furnace gases and the steam prior to adequate dilution with water, it is preferred that the

wash water be introduced into the tube **12** at a region within the interior of the furnace. Thus, a water supply pipe **26** is provided with a plurality of openings **26***a* adjacent its closed end for producing a plurality of streams of water directed outwardly into the interior of tube **12** at a point not too far removed from the outlet of tube **25**, yet not close enough to produce condensation either in the pump or around or adjacent the access openings. The stream of wash water thoroughly mixes with the mixture of stem and furnace gases and performs a number of functions. First, there is initiated condensation of the steam on and about the dust particles and other foreign matter within the sample stream. The foregoing action in conjunction with a supply of wash water in relatively large quantity minimizes the formation of cementitious products and enlarged bodies of solids which if allowed to form would tend to clog tube **12** or the sample line. Corrosion is prevented by the diluting action of the wash water in respect to any acid-forming components present in the furnace gases. The overall result is a probe of extended life providing trouble-free operation over indefinitely long periods of time.

There has been shown in FIG. 3 a pressure gauge **30**, a pressure regulator **31** and a shut-off valve **32** between the wash water line **26** shown only in FIGS. 1 and 2 and the wash water supply line **26***s*. The sample stream is taken from the sample line **12***a* in communication with the interior of tube or tubular member **12**. A continuation of the steam-supply line **22** is illustrated by the short length of pipe **22***b*.

The front view of FIG. 4 of the parts just described in FIG. 3 includes a throttling valve **33** for a steam-supply line **22***a* and the sampling line **12***a* has been illustrated with its connection to a separator **35** having an outlet pipe **36** connected to an analyzing instrument **37**. A pressure gauge **38** is provided for the separator **35**. The separator **35** is preferably of the type illustrated and described in Kraftson et al. Patent 2,895,335, reference to which should be made for details of interior construction.

For the purposes of the present invention, it is sufficient to say that the sample stream tangentially enters the separator **35** and through the resulting centrifugal action within the separator, condensate is caused to flow downwardly of the separator and out an exit pipe **39** and thence to waste while a solid-acid-free gas sample flows outwardly through the line **36** to the analyzer **37**. As previously indicated, the analyzer **37** frequently includes control apparatus which by reason of any change from a preselected value of the oxygen present in the furnace modifies the furnace operation in a manner to increase its efficiency.

It is to be observed that the pressure as read by gauge **38** will be determined by the adjustment of the throttling valve **33** and the setting of the pressure regulator **31**. As already set forth, the steam-jet ejector pump **24** produces forced flow of the sample stream not only through the tube **12** but through the entire system. Thus, throughout the system there is maintained a positive pressure which prevents in-flow of gases of any and all kinds except the ingress of the sample stream through the openings **11***a*–**11***c* of FIGS. 1 and 2.

From the foregoing it will be seen that the invention broadly includes the concept of means for introducing steam into the fore end, i.e., the furnace end, of the sampling structure **10** as by means of the pipe **22** connected by coupling **23** to and forming a part of the sampling probe **10**. The steam at the delivery point in the modification shown desirably has a pressure of the order of 40 pounds per square inch, the steam prior to its passage through the throttling valve **33** having a pressure between 70 and 100 pounds per square inch, thus insuring the flow of an adequate amount of dry steam into the fore end of the probe **10**. Those skilled in the art will understand the use of the term "dry steam" to distinguish the same from so-called wet steam, i.e., having

present moisture in substantial percentage. The steam will ordinarily be at a temperature upwards of about 340° F. By reason of the flow of steam through or, as illustrated, past the access means in the form of the ports **11***a*–**11***c*, there is avoided any possibility of a reduction in the temperature of the portions of the probe in the region where the sample enters to a value producing condensation of moisture in the sample and the growth of cementitious deposits on and about the region of the ports. This is in contrast with prior probes including water sprays which cool the probe structure in the region adjacent the point of entry of sample which causes build-up of a ball-like mass of cementitious material which though not interrupting the flow of the water into the sample intake-openings has nevertheless eventually closed off the openings by encasing the entire end of the probe to prevent flow of the sample stream into the proble.

The present invention includes the provision of the wash water, supplied at the rate of one to one and one-half gallons per minute, to produce rapid cooling at a location to convert the steam into condensate within a region so close to the access ports **11***a*–**11***c* that the dry steam has not the opportunity to condense in the zone between the location of the water jet openings **26***a* and the access ports **11***a*–**11***c*. On the other hand, the water spray openings **26***a* are sufficiently removed from the ports **11***a*–**11***c* that any cooling effect by conduction through the tube **12**, or otherwise, does not produce the possibility of condensation of moisture in the sample within the region of the access ports **11***a*–**11***c*. In practice, a spacing of about three inches between openings **26***a* and the near end of tube **25** has been found to meet the foregoing requirements. It is to be understood that that spacing does not represent a critical dimension. The three-inch spacing between openings **11***a*–**11***c* and openings **26***a* has proven satisfactory in a given embodiment of the invention.

With the foregoing features present, the mixture of condensed steam, sample gas including contaminants, and wash-water progress under forced flow to and through the separator **35** with the cleansed sample stream being received by the analyzer **37** through the delivery line **36**.

For additional technical information set forth not as a limitation but as illustrative of a typical operation, the valve **33** and the pressure regulator **31** were set to produce on the pressure indicater **38** a reading of 3½ pounds per square inch gauge. Such a pressure was found adequate to produce through the delivery line **36** a washed and cleansed sample stream of 30 cubic feet per minute where the line **36** was 100 feet in length and was made of one-quarter inch outside diameter copper tubing. For greater lengths of line, the pressure at the outlet of the separator **35** will be increased and for shorter lengths it may be decreased.

It is desired that the steam be supplied at a pressure which may range between seventy and one hundred pounds per square inch gauge and that the wash water be supplied at the rate of about one gallon per minute. The pressure from the water supply line **26***s* should be of the order of about 25 pounds per square inch gauge (minimum) and the regulator **31** set within the range of between 15 and 20 pounds per square inch gauge.

The foregoing technical details of a typical system including my invention include a tubular member **12** of one-half inch pipe with openings **11***a*–**11***c* of five-eighths inch diameter. The water supply tube **26** is one-quarter inch outside diameter, stainless steel, about three-sixteenths inch inside diameter. The steam line **22** is of stainless steel pipe. Preferably all the probe parts are of stainless steel.

Now that a preferred embodiment of the invention has been described with particularity, it is to be noted that modifications thereof may be made within the scope of the appended claims. For example, there may be utilized motive means other than that formed by the steam-jet ejector pump **24**. Suction can be applied to the pipe **12**

at any point in the system and as far down-stream as the analyzer 37. Regardless of where the motive means is located, however, it is understood that means such as the steam line 22 will continue to be used to inject dry steam under pressure into the probe 10 to assure its presence at the point of sample entry, such as in the region of the access ports 11*a*–11*c*, and further, that the wash-water must be provided as for example by provision of spray openings at 26*a* disposed in a region adjacent to but spaced down-stream from the point of sample entrance.

The access means in the form of openings or ports 11*a*–11*c* may be of differing structure, as for example, a spiral opening providing relatively large continuous area for inward flow of the gases into the tube 12. Where the motive means is located down-stream, the pipe 22 may direct the steam inwardly of an open ended tube.

What is claimed is:

1. An atmosphere sampling probe comprising elongated tubular structure having within a region adapted to be disposed within a chamber the atmosphere of which is to be sampled one or more relatively large access openings for flow into the tubular structure of a sample stream of said atmosphere, a steam-jet ejector pump disposed within said tubular structure and having pressure-reducing elements within the region of said access openings for producing forced flow of the sample stream into said tubular structure in mixture with steam supplied to said ejector pump, a steam line connected to said ejector pump for supplying steam thereto having a high temperature of value which prevents condensation of moisture in the region adjacent said access openings, water supply means for introducing a stream of water into said tubular structure at a region down-stream from said ejector pump thereby to condense said steam and to wash said sample, said last named region being disposed within said chamber, and a sample take-off connection from said tubular structure located down-stream of the region in which said stream of water is introduced into said tubular structure.

2. An atmosphere sampling probe comprising elongated tubular structure having within a region adapted to be disposed within a chamber the atmosphere of which is to be sampled one or more relatively large access openings for flow into the tubular structure of a sample stream of said atmosphere, a steam-jet ejector pump disposed within said tubular structure and having pressure-reducing elements within the region of said access openings for producing forced flow of the sample stream into said tubular structure in mixture with steam supplied to said ejector pump, a steam line connected to said ejector pump for supplying steam thereto having a high temperature of value which prevents condensation of moisture in the region adjacent said access openings, water supply means for introducing a stream of water into said tubular structure at a region down-stream from said ejector pump and at a location for introduction of said stream of water prior to the reduction of the temperature of said steam and of said sample to the dew point and sufficiently removed from said access openings to prevent cooling and condensation in said region adjacent said access openings, said region being disposed within said chamber, means for regulating the relative flow-rates of said streams of water and steam for producing rapid transformation of said steam into condensate, and a sample take-off connection from said tubular structure located down-stream of the region in which said stream of water is introduced into said tubular structure.

3. An atmosphere sampling probe comprising elongated tubuler structure having between its ends and within a region adapted to be disposed within a chamber the atmosphere of which is to be sampled one or more relatively large access openings for flow into the tubular structure of a sample stream of said atmosphere, a steam-jet ejector pump disposed within said tubular structure and having pressure-reducing elements within the region of said access openings for producing forced flow of the sample stream into said tubular structure and mixture with steam supplied to said ejector pump, means including a steam line connected to said ejector pump for supplying dry steam thereto having a high temperature of value which prevents condensation of moisture in said sample stream in the region adjacent said access openings, water-supply means for introducing a stream of water into said tubular structure at a region down-stream from said ejector pump and at a location sufficiently near said openings for introduction of said stream of water prior to up-stream reduction of the temperature of said steam and of said sample to a point where condensation of steam can occur in the zone separating said openings and said point of entry of said stream of water into said structure, said water supply means being positioned in a region in the probe disposed within said chamber, and a sample take-off connection from said tubular structure located down-stream of the region in which said stream of water is introduced into said tubular structure.

4. An atmosphere sampling proble comprising elongated tubular structure having within a region adapted to be disposed within a chamber the atmosphere of which is to be sampled one or more relatively large openings for flow into the tubular structure of a sample stream of said atmosphere, means for supplying under pressure dry steam to said tubular structure in the region of said one or more openings having a high temperature of value which prevents condensation of moisture in said sample stream in said last-named region, motive means connected with said tubular structure for producing forced flow of the sample stream into said tubular structure in mixture with said steam to form a mixture of said sample stream and of said steam, water-supply means for introducing under pressure a stream of water into said tubular structure at a region close to but down-stream from said openings and at a location prior to the reduction of the temperature of said mixture to the dew point rapidly to condense and dilute said mixture and wash it through said tubular structure, said last named region being disposed within said chamber, and a sample take-off connection from said tubular structure located down-stream of the region in which said stream of water is introduced into said tubular structure.

5. An atmosphere sampling probe comprising an elongated tubular structure forming a portion of a sampling system, said tubular structure having a fore-end for disposition within a space from which a sample of the atmosphere therein is to be taken and an aft-end having a discharge passage for location exterior of said space, means for connecting the remaining portion of the sampling system to said discharge passage, a steam-jet ejector pump connected to the fore-end of said tubular structure, said pump having a steam line connection, said tubular structure having access means for entry of said sample into said pump, said steam having a high temperature of value which prevents condensation of moisture in the region adjacent said access means; a diffusion tube for discharge of said sample into said fore-end of said tubular structure, and means for introducing water into the fore-end of said tubular structure close to but down-stream from said diffusion tube and at a location prior to the reduction of the temperature of said steam and of said sample to the dew point rapidly to condense the steam and to wash said sample during its continued flow in the sampling system.

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