

[54] **METHOD AND APPARATUS FOR MEASURING PARTICULATE EMISSIONS IN GAS FLOW**

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**Related U.S. Application Data**

[63] Continuation of Ser. No. 198,779, Nov. 15, 1971, abandoned.

[52] U.S. Cl. .... **73/28, 55/270, 55/274, 55/417, 55/418, 55/467, 55/493, 55/501, 55/503, 55/DIG. 34, 73/421.5 R, 251/305**

[51] Int. Cl. .... **B01d 53/30**

[58] Field of Search ..... **55/18, 20, 21, 270, 274, 55/267, 493, 502, 503, 417, 418, 467, 501, DIG. 34; 73/23 R, 28, 211, 212, 421.5 A, 421.5 R; 251/305**

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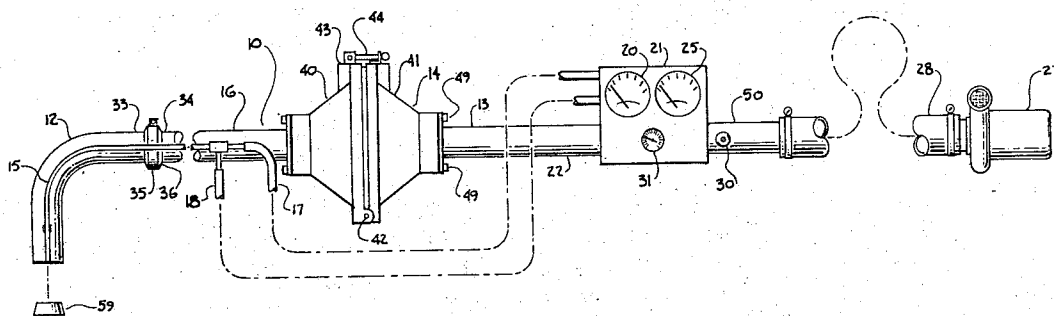
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[57]

**ABSTRACT**

A stack sampler for collecting particulate samplings in gaseous emissions includes means to match the volume rate of flow through the sampler to the flow in the stack. Filter means removably disposed in the sampler are adapted to collect particulate matter from the gaseous emission during the isokinetic flow which is obtained. The high volume capacity of the sampler permits accurate samples to be obtained during short sampling periods.

**2 Claims, 4 Drawing Figures**



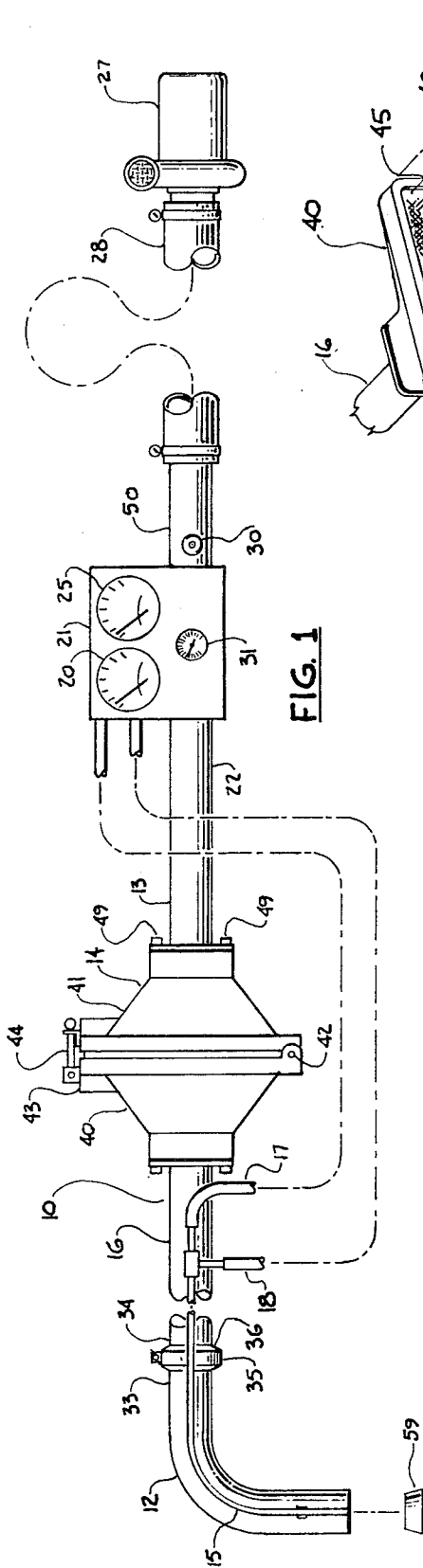


FIG. 1

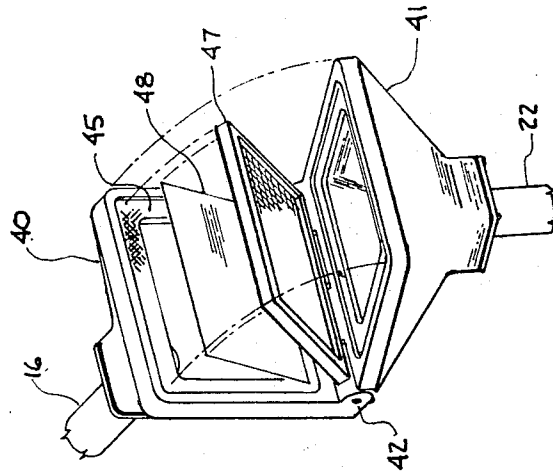


FIG. 3

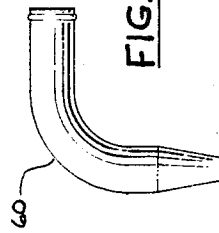


FIG. 4

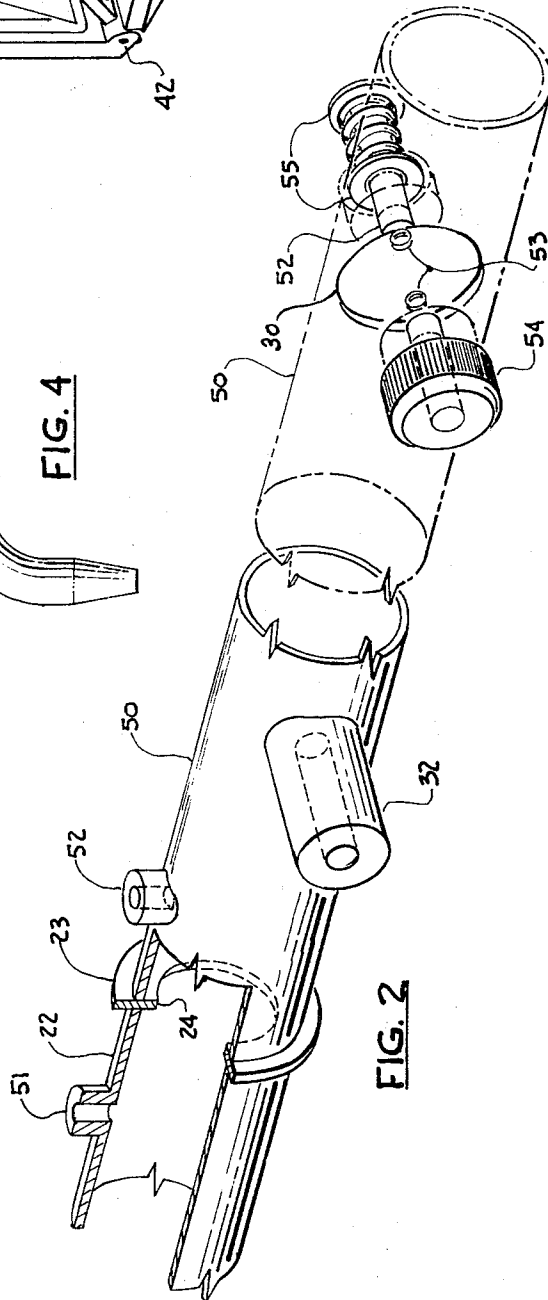


FIG. 2

## METHOD AND APPARATUS FOR MEASURING PARTICULATE EMISSIONS IN GAS FLOW

This is a continuation of application Ser. No. 198,779 filed Nov. 15, 1971 now abandoned.

### BACKGROUND OF THE INVENTION

With the passage of the Federal Clean Air Act of 1967, came the establishment of regions, ambient air standards and emission standards. The formation of the regions was done by the federal government. The ambient air standards were established at hearings during which much data from various air sampling networks was reported.

Emission standards are now being set after applying mathematical models to find the emission levels necessary to comply with the ambient air standards already adopted. Industries, municipalities and all citizens will be expected to comply with the emission standards. This will result in a massive enforcement effort for all pollution control agencies. In order for this enforcement to be effective, the agencies, industries, consultants, etc. must initiate large scale sampling programs to obtain the required emission numbers.

Properly to sample just one of the emissions, i.e., particulate matter, has heretofore required at least one man week per source test. 2 man weeks have been required when the test was conducted with presently available sampling equipment operated according to accepted procedures. This is both expensive and time consuming. Questions have also been raised as to the reliability of the sampling data collected with presently available equipment on sources having rapidly changing cycles of operation.

Sampling apparatus heretofore available have consisted of many components in series. Such apparatus were expensive and involved collection in a train of many different elements in series, such as probes, cyclones, filters, thimbles and impingers. Each element had to be subjected to a separate analysis which took considerable laboratory time.

Furthermore, apparatus which collect particulate in several different train components in series cannot be used to obtain a particle size analysis. When using such apparatus, it has been necessary to run a separate sample for size analysis.

Presently available apparatus has also been limited to very low flow rates. Apparatus utilizing impingers and a wet test gas meter as part of the device have been limited to flows less than 1 cubic foot per minute. This means that the source must be sampled for a very long period of time if a large enough sample is to be obtained for accurate gravimetric analysis.

Many processes that must be sampled do not operate continuously for a long enough time to be sampled with such a low flow rate apparatus. For example, an asphalt plant dryer may only operate for 10 minutes at a time and then shut down for 2 hours. If the sample is to be valid, it must be taken during one operating cycle and in as short a time as practical.

Low flow rate samplers take such a long time to obtain a sample that they integrate the sample over a considerable time period. Where a boiler is changing load, for example, a sample should be taken rapidly in order to achieve a valid emission data point.

Furthermore, it is preferable statistically to take several short time samples of a given volume than to take only one sample of the same volume. With several short

time samples, the mean and standard deviation may be determined to indicate what portion of the time the source would be legal or illegal. Insufficient data also hampers enforcement actions against sources having large gas flows.

Furthermore, much apparatus heretofore available is developed under laboratory conditions and are awkward to use in the field.

It is thus the primary object of the present invention to provide a high volume sampler that can take an accurate sample in a relatively short period of time.

It is a further object of the present invention to provide such a sampler that can take a reliable sample from a variety of sources cheaply, quickly, and under field conditions.

It is a still further object of the present invention to provide such a sampler that will take a sample under flow conditions matched to those in the source, i.e., under isokinetic conditions.

### SUMMARY OF THE INVENTION

The sampler of the present invention comprises a generally cylindrical sampler tube, inlet nozzle means disposed at one end of the tube and adapted for insertion into a stack or like conduit through which a gas is flowing, and means to measure the volume rate of gas flowing through the stack. A flow measuring orifice is disposed in the tube, and means are associated with the orifice for measuring the volume rate of gas passing through the tube.

Suction pressure applying means are provided in communication with the downstream end of the tube. Control valve means are disposed in the tube between the orifice and the suction pressure applying means, the control valve means being adapted to adjust the volume rate of gas passing through the tube to be equivalent to the velocity of gas flowing through the stack.

Filter means are removably disposed in the tube upstream of the orifice for collecting particulate matter from the gas while the volume rate of gas passing through the tube is "matched" to the velocity of gas flowing through the stack, i.e., under isokinetic conditions. This "matching" of the gas flow through the sampler to the gas flow in the stack permits a more accurate particulate sample to be obtained.

The method of the invention comprises measuring the velocity of gas flowing in a stack or like conduit, inserting a tubular sampler into the stack to cause a portion of the gas flowing therethrough to pass through the sampler, applying suction pressure to the downstream end of the sampler to cause the portion of gas flowing through the sampler to be the kinetic equivalent of the velocity of gas flowing through the stack, and collecting particulate matter on a filter placed in the sampler for a predetermined time under the isokinetic conditions achieved.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side view of a sampler in accordance with the present invention.

FIG. 2 is a detail view of the control section.

FIG. 3 is a perspective view of the filter housing.

FIG. 4 is a view of an alternate form of inlet nozzle.

### DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings, the sampler 10 of the present invention is made of 2-inch aluminum tubing one-sixteenth inch thick having a 1½ inch inner diameter and forming an inlet nozzle 12 and a main body portion 13, a filter housing 14 being disposed intermediate the ends of the body portion 13. A pitot tube 15 is removably attached to the side of the inlet nozzle 12 and the upstream portion or inlet section 16 of the body portion 13, total and static pressure lines 17 and 18, respectively, being connected to a first Magnehelic pressure gauge 20 mounted on a control panel 21 on the downstream portion or control section 22 of the body portion.

An orifice meter 23 in the form of 1½ inch diameter sharp-edged orifice 24 is disposed intermediate the control section 22, pressure connections being provided on both sides thereof for attachment to the pressure and suction posts respectively of a second Magnehelic pressure gauge 25 also mounted on the control panel 21.

A suction blower 27 is provided separate from the main body portion 13, being connected to the downstream end thereof by a length of flexible hose 28. A butterfly control valve 30 is disposed in the control section 22 downstream of the orifice meter 23 for controlling the rate of flow through the sampler.

A temperature gauge 31 insertable in a fitting 32 in the control section 22 is also mounted on the control panel 21 for determining the temperature of the flow through the control section 22.

The inlet nozzle 12 is elbow shaped for ready insertion in a stack or like conduit and, as mentioned hereinabove, is made of two inch diameter aluminum tubing, one-sixteenth inch thick, having an inner diameter of 1½ inches. Its downstream end 33 is attached to the upstream end 34 of the inlet section 16 by a clamp 35 and sleeve 36.

The pitot tube 15 is mounted exteriorly of the nozzle 12 and the inlet section 16 and is provided with total and static pressure lines 17 and 18 for connection to the pressure gauge 20. The latter is mounted on the control panel 21 attached to the control section 22. Gauge 20 has a range of zero to four inches of water.

Mounted on the downstream end of the inlet section 16 of the sampler is the cast aluminum housing 14 for the removable filter. The housing 14 comprises an upstream section 40 attached to the inlet section 16 and flaring outwardly in the downstream direction, and a mating downstream section 41 of similar shape. The sections 40 and 41 are connected together by a hinge pin 42 at their lower ends. The upper ends 43 are closed by means of pivotal catches 44. A rubber support gasket 45 is mounted in the downstream end of the section 40 and an aluminum framed screen support 47 is positioned in the downstream section 41 as shown. A sheet of filter material 48 is inserted in the housing 14 on the upstream side of the screen support 47, being easily inserted and removed when the housing is open.

The downstream end of the section 41 is connected to the control section 22 of the sampler by means of wing nuts 49, as shown. The orifice plate 23 is welded to the downstream end of the control section 22 as

shown, and a final tube section 50 is provided. Pressure connections 51 and 52 consisting of taps and hose fittings are positioned on both sides of the orifice plate 23 and are connected to the pressure and suction posts, respectively, of the second Magnehelic gauge 25 by means of rubber tubing. The gauge 25 has a range of zero to two inches of water.

The one-sixteenth inch thick aluminum circular butterfly valve 30 is mounted on a rotatable shaft 52 by means of screws 53. The shaft 52 is journaled in the tube section 50 adjacent the downstream end thereof and is provided with a knurled knob 54 at one end and spring-loaded friction washers 55 at the other for retaining the valve 30 in any desired position.

The suction blower 27 communicates with the sampler through the length of flexible hose 28, being separated from the sampler to lighten the assembly.

A plug 59 is provided to close the inlet nozzle for a purpose to be hereinafter described.

A second inlet nozzle 60 is provided where the stack velocity is sufficiently high to exceed the suction capacity of the blower 27. Nozzle 60 has an inlet area equal to one-quarter of the inlet area of nozzle 12 to permit the sampler to match a stack flow four times that possible with nozzle 12.

### OPERATION

Before using, the sampler 10 is thoroughly cleaned with a suitable solvent to remove any residual particulate matter. Filter papers 48 for a test are conditioned at room temperature in a desiccator for at least 12 hours before initial weighing.

The sampling procedure at a source comprises measuring the temperature of the gas flowing therethrough and then inserting the inlet nozzle 12 and the pitot tube 15 into the effluent stream with the plug 59 in place to measure the velocity pressure. Appropriate calibration curves are used to convert the reading on the Magnehelic gauge 20 into the gas velocity or the volume rate of flow through the stack.

With a blank piece of filter paper in place and the plug removed 59, the blower 27 is started and a trial sample is taken at approximately isokinetic conditions to determine the average sample temperature through the filter and the orifice 24. Once the temperature on gauge 31 is determined, appropriate calibration curves can be used to calculate a reading on pressure gauge 25 to determine the necessary flow through the sampler for isokinetic conditions. The control valve 30 can thereafter be set with the blower 27 operating such that the reading on pressure gauge 25 is the calculated value.

Once the flow through the sampler has been "matched" to the velocity in the stack, the housing 14 is opened and a piece of filter paper 48 is placed upstream of the support screen 47, the catches 44 thereafter being fastened to secure the housing 14 therearound. Particulate samples are then drawn through the filter with the blower 27 operating and the control valve 30 set such that the reading on the pressure gauge 25 is maintained at the calculated value. The sampling period is set such that it is long enough to obtain a sufficient sample for accurate weight analysis. At 0.1 grains per standard cubic foot, 1 minute is an adequate sampling time. After the particulate sample is obtained, a gas analysis is made with an Orsat analyzer, if required.

The filter material 48 is removed and a clean filter inserted for another sample.

When field tests are completed, the filters are returned to a laboratory where they are brought to the same temperature and humidity conditions at which they were originally weighed. The sampler is rinsed with solvent and the washings evaporated at 200°F. The weight gain of the washings is divided on a time weighted basis among the filters taken. The weight gains of the filters are determined, corrected for the blank filter weight change and the material washed from the sampler, and then calculated on the basis of grains per cubic foot at standard conditions and total pounds per hour based on the emission velocity and area of the stack.

The sampler of the present invention is able to handle a greater volume of flow than was possible with heretofore existing units. As such, valid sampling is possible in shorter sampling periods. Consequently, numerous valid emission data points are obtainable which is advantageous in the case of a source changing emission.

The ability of the sampler to match the velocity in the stack, that is, to sample particulate emissions under isokinetic conditions, eliminates a variable in the testing procedure and permits a more accurate sample to be obtained.

Use of the alternate nozzle 60 having a reduced intake area permits the sampler to match a flow four times that achievable using the standard nozzle. Such, obviously, increases the range of usefulness of the device.

Constructing the sampler entirely of aluminum achieves a light weight apparatus. Separating the suction blower 27 from the sampler, by means of the length of flexible hose 28, further lightens the assembly. Incorporating the pitot tube 15 as an integral part of the apparatus permits simultaneous and continuous stack gas velocity measurements during sample collection. Such is also valuable in verifying the accuracy of the sampling procedure.

Positioning the butterfly valve 30 after the filter housing 14 eliminates particulate accumulations at the valve and simplifies necessary cleaning of the sampler after each test. Mounting the two pressure gauges 20 and 25 and the temperature gauge 31 on a single control panel 21 further increases the utility of the apparatus.

I claim:

1. A sampler for measuring particulate emissions in a gas flow, comprising
  - an inlet nozzle adapted for insertion into a stack or like conduit through which a gas is flowing;
  - pitot tube means attached to said nozzle and adapted for insertion into said stack with said nozzle for measuring the velocity of gas flowing through said stack;
  - filter means disposed downstream of said nozzle for collecting particulate matter from said gas, said filtering means comprising an upstream housing sec-

tion and a downstream housing section, said upstream and downstream housing sections being removably connected together at least at one edge thereof to facilitate rinsing of the sampler upstream of said downstream section, a screen support disposed between said upstream and

said downstream sections, and a sheet of filter material supported on said screen support and removably disposed between said upstream and downstream sections;

a substantially unobstructed cylindrical tube disposed between said inlet nozzle and said filter means for conducting all said gas directly from said inlet nozzle to said filter means, whereby the entire flow of gas passing through said inlet nozzle impinges on said sheet of filter material;

suction pressure applying means disposed at the downstream end of said sampler for causing a flow of gas from said stack into said inlet nozzle and through said sampler;

tubular means disposed between said filter means and said suction pressure applying means for conducting gas through said sampler responsive to suction pressure applied by said suction pressure applying means, said tubular means comprising a rigid tubular section attached to said filter means and a flexible tubular section disposed downstream of said rigid tubular section and attached to said suction pressure applying means, said flexible tubular section being of a length sufficient to permit separation of said suction pressure applying means from the rest of said sampler to lighten and facilitate use thereof;

a flow-measuring orifice disposed in said rigid tubular section;

a control panel mounted on said rigid tubular section;

means mounted on said control panel and associated with said orifice for measuring the volume rate of gas passing through said sampler;

means mounted on said control panel and associated with said pitot tube means for measuring the velocity of gas flowing through said stack;

temperature measuring means mounted on said control panel and adapted to measure the temperature of the gas passing through said rigid tubular section; and

control valve means disposed in said rigid tubular section downstream of said orifice for adjusting the volume rate of gas passing through said sampler to make the same kinetically equivalent to said velocity of gas flowing through said stack.

2. A sampler as in claim 1 in which said control valve means comprises a shaft journaled in said rigid tubular section, a butterfly valve mounted on said shaft, means to rotate said valve with respect to said rigid tubular section and means to retain said valve in a desired position relative to said rigid tubular section.

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