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INERTIAL IMPACTION AIR SAMPLING DEVICE

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INERTIAL IMPACTION AIR SAMPLING DEVICE

The United States Government has rights in this invention pursuant to Contract No. DE-AC04-76DP00789 between the Department of Energy and AT&T Technologies, Inc.

BACKGROUND OF THE INVENTION

The present invention relates generally to an inertial impaction air sampling device which is small-sized for portability and self-contained allowing for remote or personal sampling, and more particularly, to a portable, personal air sampling device capable of collecting respirable organometallic particulates in room environment air and direct analysis for providing immediate results.

The collection and analysis of elemental containing particulates, especially organometallic particulates in the presence of additional organic sample components, in ambient air is becoming increasingly

important as maximum permissable exposure to toxic agents decreases. Accordingly, the relationship between the sampling method and the analytical method is becoming increasingly important. The particular analyte to be determined, as well as the particular sampling method chosen, will generally dictate the analytical procedure that can be used, and conventional sampling devices have not always proved satisfactory for providing the information desired.

Several air sampling devices are commonly known for collecting particulates in room air. Bulk or wipe samples do not yield useful information about airborne concentrations of contaminants. Filter sampling is not always reliable since filter loading can occur rapidly with membrane filters, and contaminants or oversized particles can be collected that would suggest higher than actual exposure. Also, no particle size distribution is obtainable without further analysis by electron microscopy or some other analytical technique. Further, filter samples generally require extensive treatment prior to the analysis, a process that is time consuming, expensive, and subjects the entire procedure to increased probability of errors.

Atomic absorption spectrometry offers advantages in the analysis of elemental containing particulates because it can provide low detection limits (more sensitive detection) and precise determinations for a wide variety of elements, and is thus very popular for non-real-time determinations. However, real time sampling would be optimum and would eliminate the potential problems associated with sample collection methods, sample transport, and sample preparation, and real time sampling

has heretofore not been possible with atomic absorption spectrometry. Real time sampling would require, first, that an atomic absorption spectrometer be present in the vicinity of the sample being collected and, second, that multiple instruments be available should several sites be needed to be sampled simultaneously. This is neither economical or practical where the determination of occupational exposure must be made from a breathing zone sample (b.z.s.), the "breathing zone" being commonly known as the space within one foot of the mouth and nose of the worker in an occupational environment.

Also, traditional atomic absorption methods utilize the sample in the form of a solution. Airborne particulates, however collected, must be subjected to a dissolution procedure, usually requiring acid digestion and a dilution process. These processes cause undesirable sample losses as do the pretreatment processes for filter sampling.

Additionally, specific methods for sampling and analysis using atomic absorption spectrophotometry have suffered from various specific disadvantages. Impinger samplers used with UV/VIS Absorption Spectrophotometry have been plagued with matrix interferences which preclude sensitive and precise detection of various organometallic elements, for instance hexaphenyl dilead in the presence of styrene. Filter collection methods used with Flame Atomic Absorption have been shown to have excessive loss of the sample. Because of the additional losses in the sample preparation for analysis, the overall efficiency of this method is less than 25% with poor precision.

The most precise and sensitive analytical method for sampling and detecting organometallic constituents in ambient air is inertial impaction sampling, a method which collects the sample in such a way that it can be deposited directly into the analytical measurement system, e.g. the spectrometer sample cell, combined with Graphite Furnace Atomic Absorption (GFAA) analysis. Compared with flame atomic absorption, this method of analysis offers low detection units, electrothermal atomization, more absorption, more sensitive detection--results using this method are approximately three orders of magnitude better than detection using flame atomic absorption--and the elimination of all sample pretreatment steps. However, in the past, inertial impaction has been limited to quantitative rather than qualitative analysis. Also, when inertial impaction samplers have been combined with graphite furnace impaction substrates, the furnace itself has been permanently mounted in the electrothermal atomization atomic absorption spectrometer, and a tapered collection device was inserted into the furnace for analysis. While this method is useful in the development of an area monitoring system for a workplace environment, it is not useful in the case of the determination of occupational exposure where samples must be collected in the breathing zone of the worker. Nevertheless, inertial impaction has been shown to be extremely efficient in the collection of respirable size particles (1-20 um aerodynamic diameter), with entry losses in the range of 8-16% for particles from 1-7 um aerodynamic diameter, and inertial impaction sampling plus GFAA analysis has proved to be the best sampling and analysis method for the determination of airborne organometallic particulates.

There is an existing need for a reliable and economical air sampling device to be used for both quantitative and qualitative analysis of materials in the environment.

Also, there is an existing need for an inertial impaction device designed as a personal breathing zone sampler, capable of size selective sampling of respirable size particles in the ambient environment (1-20 microns in diameter), low detection limits, and rapid, direct analysis without the need for extended sample preparation procedures.

There is a further need for a personal breathing zone sampler that is portable and attachable to an individual in the workplace, and that operates at a flow rate which closely approximates the rate of human respiration (2.0 L/min.).

There is still a further need for a personal breathing zone sampler device using a graphite furnace as the impaction substrate.

SUMMARY OF THE INVENTION

In view of the above-described needs, it is an object of this invention to provide a portable inertial impaction sampling device with remote capability which is capable of quantitative and qualitative analysis of solid aerosol particulates in gas efficiently and sensitively and capable of providing an impacted sample for analysis which is not removed from the substrate and requires no sample preparation process.

It is also an object of this invention to provide a portable inertial impaction sampling device which may be attached to an individual for providing a breathing zone sample.

It is another object of this invention to provide a portable inertial impact sampling device that may utilize a graphite furnace as the impaction substrate.

Additional objects, advantages, and novel features of this invention will become apparent to those skilled in the art upon examination of the following description or may be learned by the practice of the invention. The objects and advantages of the invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

To achieve the foregoing and other objects and in accordance with the purpose of the present invention, as embodied and broadly described herein, there is provided a portable inertial impact sampler for detection and collection of solid aerosol particulates in gas, i.e. anything with mass suspended in a gas, including dust, vapor droplets, molecules or organometallic particulates. The sampler includes a cylindrical sample probe at one end for receiving, collimating, and expelling the gas flow, a tube arranged perpendicular to the expelling end of the probe and to the gas flow, a continuous sample collecting surface inside the perpendicular tube, and a removable mount for holding the probe and tube in a fixed position relative to each other during the collection of the sample. The mount may be adjusted for spacing the collection surface appropriately in relation to the end of the probe to allow for the collection of a particular size of particulate, because the size of particulate to be collected is controlled by this spacing, as well as the size of the end of the probe and the flow rate of the gas. The sampler arrangement according

to the invention, where the tube containing the sampling surface is held in contact with the sample probe during collection and is removable for analysis, allows the direct size-selective collection of particles as an impacted sample that is not removed from the substrate for preparation, but may be analyzed according to the chosen method immediately and directly.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and form part of the specification, illustrate an embodiment of the present invention and, together with the description, serve to explain the principles of the invention.

Figure 1 is a plan view in cross-section of the disassembled portable inertial impact sampler.

Figure 2 is a three-quarter section cutaway view of the assembled portable inertial impact sampler.

Figure 3 is a cutaway view of a tube of the sampler structure in which a sample surface is held.

DETAILED DESCRIPTION OF THE INVENTION

As shown in the figures, one embodiment of the portable inertial impact sampler 1 includes a converging sample probe 10, mount 20, and tubular flow diverter 30, and a sample collector 40.

A preferred embodiment of inertial impact sampler 1 includes the use of a graphite tube as tubular diverter 30, the interior surface 31 of which is also sample collector 40. Figures 1 and 2 depict this preferred embodiment for the tubular diverter; in Figure 1, tubular diverter 30 is shaded for clarity. Graphite tube 30 has a continuous inner surface 31 having a diameter of 6 millimeters for collection of the sample. The wall of tubular diverter 30 includes entry port 32 having a 2 millimeter diameter for introduction of the sample into the furnace. The size of the graphite tube or furnace is selected to be compatible with prior art devices for Graphite Furnace Atomic Absorption (GFAA) for single elemental analysis, or Inductively Coupled Plasma Atomic Emission (ICP) if a multi-elemental analysis is desired.

Although the preferred embodiment is described for an inertial impacter using a graphite furnace as the sample collector, persons reasonably skilled in the art will immediately recognize that alternative sample collectors with different dimensions are possible and may, under appropriate circumstances, be preferable. In fact, there are numerous possibilities for an impaction substrate to be utilized with the sampler of this invention; the material to be used for the substrate as well as the dimensions of the sampler structure may be chosen to fit the study to be performed and the analytical technique to be used.

For example, where xray fluorescence is the chosen method of analysis, the interior surface 31 of tubular diverter 30 will not be the sample collector as is the case with GFAA or ICP (which utilize the

graphite furnace). In this case, as illustrated by Figure 3, diverter 30 may be made of plastic, copper, or other suitable material with an interior surface structured to receive a removable plate sample collector 40 made of Teflon or other suitable material, which has a top surface 41 to directly receive the sample. For other types of analyses, silicon chips may be used as sample collecting surfaces.

Figure 3 is a three-quarter cutaway view of the tubular diverter 30 containing a distinct sample collector 40 showing the use of support structure 34 in the interior wall 31 of tubular diverter 30. Preferably, in an arrangement where the sample collector 40 is a distinct structure from the tubular diverter 30, grooves will be used as support devices 34 for a sample collecting plate 40. Again, persons of reasonable skill in the art will recognize that many support devices other than grooves may be used according to the scope of the invention.

Referring again to Figures 1 and 2, probe 10 includes a cylindrical input end 11 for receiving the flow of gas, which extends one-half the length of probe 10. This cylindrical input end 11 increases inlet efficiency by significantly reducing turbulence in and around the vicinity of the inlet. Halfway down the length of probe 10, interior surface 12 tapers at an angle of approximately 55-65^{o} from the axis to an output end 13, preferably at about 60^{o}. This particular angle is important to this invention as it has been found to provide the optimum collection of particles by minimizing the effects of particle bounce from tapered surface 12, thus minimizing entry losses. Output end 13 preferably

includes a jet 14 having a length-to-width ratio of 3 or greater, which collimates the flow of gas and particles into a stream along the axis of collector 10. This length-to-width ratio of jet 14 is important as it has been found to achieve laminar flow at 3 or greater. The tip of jet 14 is directed towards, and may be inserted into, port 32 for allowing the gas flow to contact sample collecting surface 40.

Mount 20 includes an open end 21 for being connected to the output end 13 of probe 10, which may be threaded to secure the connection, and a trans verse cylindrical bore 23 centrally disposed and extending completely through mount 20 perpendicular to its axis and located just prior to the closed end 22. Tubular diverter 30 is inserted into and removed from mount 20 through bore 23. Mount 20 also includes window opening 24 in one wall opposite and aligned with bore 23 to allow the inserted tubular diverter 30 to be viewed for observation and orientation with output end 13 of probe 10. This is particularly helpful when jet 14 is to be inserted into entry port 32. Window opening 24 is preferably vacuum sealed by some appropriate covering 25, such as glass. Mount 20 further includes a flat set screw 26 in closed end 22 to hold tubular diverter 30 in a fixed position.

Tubing 50 is connected to each end of the diverter tube 40 and extends outside sampler 1. The two sections of tubing 50 are connected with T-connector 51 and air flow through the tube is regulated with a personal sampling pump. This pump is not shown, but it may preferably be a vacuum pump attached to the individual where the b.z.s. is being tested.

The connections 33 between the diverter tube 30 and the tubing 50 and connections 52 between the tubing 50 and the T-connector 51 are vacuum sealed with some appropriate means, such as with Teflon tape, and may also be threaded to effect the connection.

Finally, Figure 2 also shows a clip 2, connected to the exterior surface of input end 11 of probe 10, by which the sampler 1 may be attached to an individual for collecting an ambient air sample.

The basic operation of the invention is now apparent. In accordance with the preferred embodiment of the invention, the sampler 1 is attached by clip 2 to an individual for taking a breathing zone sample. Air flow is generated through tubes 50 which are attached to a vacuum pump on a belt pack of the individual wearing the sampler. Vacuum pump and belt pack are not shown but are standard items; the vacuum pump is typically a Gilian pump at a standardized flow rate. Air is pulled into inlet end 11 of probe 10 at a flow rate of 2 L/min., corresponding to the breathing rate of a human being. The flow is tapered in interior surface 12 and passes through jet 14 into tubular diverter 30 by entry port 32 to contact sample collector 40. Air flow then changes direction and passes out of each end of tubular diverter 30 through tubes 50, leaving an impacted, concentrated sample on the collector 40 which may be immediately analyzed without further sample preparation.

Materials used in the sampler 1 may be aluminum for probe 10, typically QQ-A-225/8 Aluminum or 6061-P651 Aluminum, and brass or "half-hard" brass for mount 20, typically Type C 36000 ASTMB-16 halfhard brass. It is contemplated that future assemblies may use a great variety

of materials. In one embodiment, the length of probe 10 is approximately 75mm and the diameter is 41 mm. Jet 14 is 1.1 millimeter in diameter and is 4 millimeters in length. A 6 millimeter distance is allowed between the exit of jet 14 and the exterior wall of tubular diverter 30 for the preferred embodiment where a graphite tube is used for tubular diverter 30 as well as sample collector 40. The graphite tube itself is commercially available from Perkin-Elmer, with a 6 millimeter inner diameter and a 2 millimeter hole in its wall to be used as an entry port. Where a platform or plate 40 is used inside tubular diverter 30 to collect the sample, the distance between jet 14 and tubular diverter 30 is 3.5 millimeters. Tubing 50 through the air flow passes is typically Tygon with a 1/4 inch inner diameter.

A prototype of this invention has been constructed and tested for performance. Using the parameters described above, test results showed that the sampler according to the invention allows size selective sampling of respirable size particles of 1-20 microns in diameter; using the preferred embodiment with the graphite furnace, results showed the invention to be approximately six orders of magnitude more sensitive for lead analysis than filter sampling that has typically been used. Prior to this invention, the current detection limit has only been 1 ug at best. This increased sensitivity is primarily due to the rapid analysis time allowed because extended sample preparation procedures are eliminated, as well as to the decrease in sample loss afforded by the use of the invention because of the basic design of the sampler, again, the elimination of inherently lossy sample preparation procedures, and the use

of the metal as the sample collector which dissipates the static charge on the charged particles. Previous sampling techniques using plastic devices get a increased sample loss due to migration of the particles.

Other advantages, not previouly discussed, include the small prtable nature of the invention, which allows the sample collector itself to be sent through the mail for analysis, and which also affords the device the versatility to be used as a process sampler, a personal sampler and an environmental sampler. Not least among the advantages is its practicality and economy: the jet 14 of the invention may be of any material, rather than tantalum which is expensive but was previously required for jets used for this purpose so the equipment could withstand the 4000^{o} heat of the absorption spectrometer; and the graphite tube of the preferred embodiment no longer has to be discarded after analysis but can be cleaned and reused after the burnout that occurs during the analysis, thus bringing the cost of this sampling method into the range of gas badges or charcoal tube sampling.

The particular sizes and equipment discussed above are cited merely to illustrate particular embodiments of the invention. It is contemplated that use of this invention may involve components having different sensitivities and sizes as long as the principle described herein is followed. An inertial impaction sampler, constructed in accordance with the present invention, will provide accurate, reliable quantitative and qualitative sampling of solid aerosol particulates in gas with unusual speed, low detection limits, and versatility. It is intended that the scope of the invention be defined by the claims appended hereto.

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ABSTRACT

An inertial impactor to be used in an air sampling device for collection of respirable size particles in ambient air which may include a graphite furnace as the impaction substrate in a small-size, portable, direct analysis structure that gives immediate results and is totally self-contained allowing for remote and/or personal sampling. The graphite furnace collects suspended particles transported through the housing by means of the air flow system, and these particles may be analyzed for elements, quantitatively and qualitatively, by atomic absorption spectrophotometry.

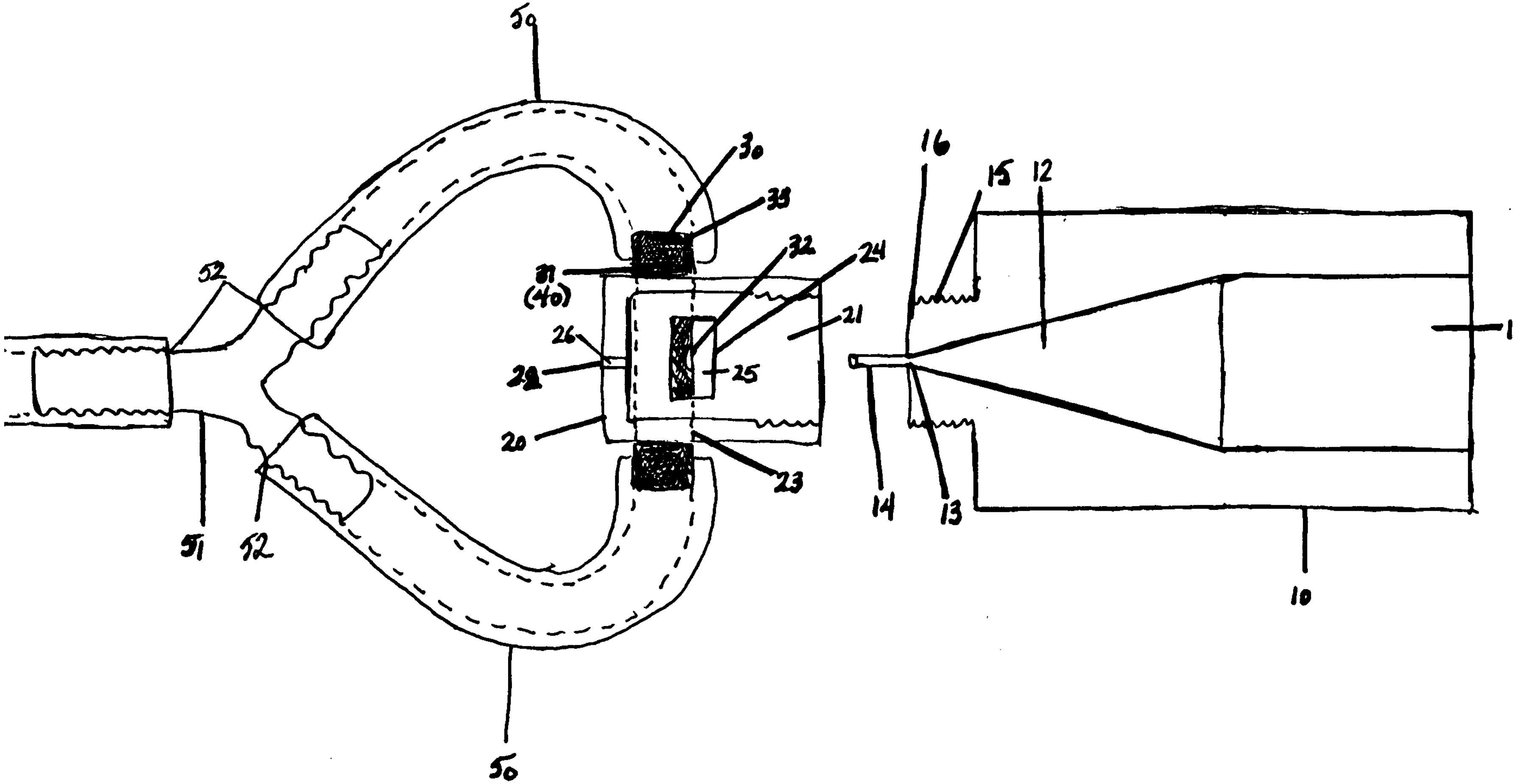

FIGURE 1

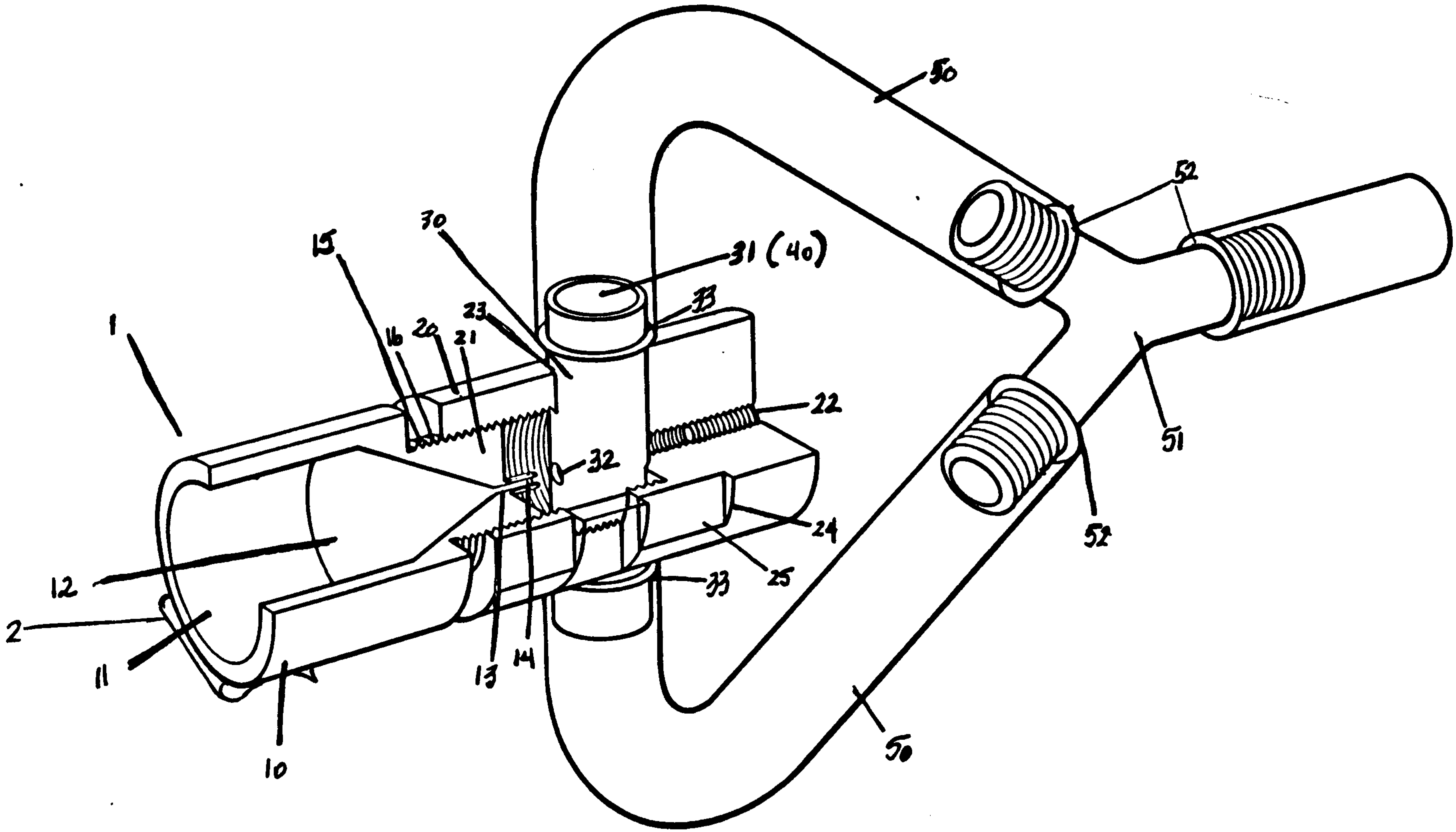

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FIGURE 2

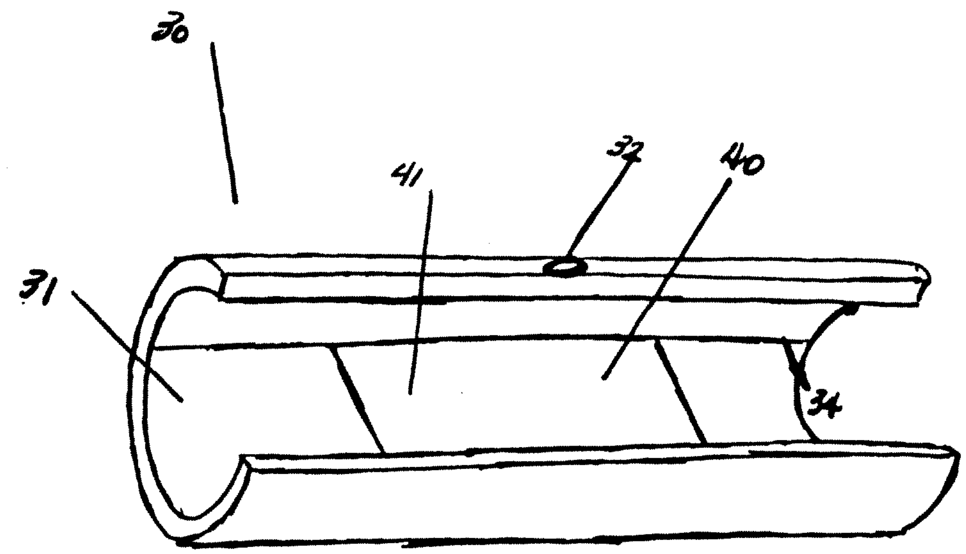

Figure 3