Payload customers for the Space Shuttle have recently expressed concerns about the possibility of their payloads at an adjacent pad being contaminated by plume effluents from a shuttle at an active pad as they await launch on an inactive pad. As part of a study to satisfy such concerns a ring of inexpensive dosimeters was deployed around the active pad at the inter-pad distance. However, following a launch, dosimeters cannot be read for several hours after the exposure. As a consequence factors such as different substrates, solvent systems, and possible volatilization of HCl from the badges were studied. This observation led to the length of stain (LOS) dosimeters of this invention. Commercial passive LOS dosimeters are sensitive only to the extent of being capable of sensing 2 ppm to 20 ppm if the exposure is 8 hours. To map and quantify the HCl generated by Shuttle launches, and in the atmosphere within a radius of 1.5 miles from the active pad, a sensitivity of 2 ppm HCl in the atmospheric gases on an exposure of 5 minutes is required. A passive length of stain dosimeter has been developed having a sensitivity rendering it capable of detecting a gas in a concentration as low as 2 ppm on an exposure of five minutes.
SENSITIVITY vs AMOUNT OF DYE

LENGTH OF STAIN, Inches

DOSE, ppm-nln

FIG. 5

SENSITIVITY vs OUTER TUBE SIZE

LENGTH OF STAIN, Inches

DOSE, ppm-nln

FIG. 6
Calibration Curves, STS-42

CAL CURVES FOR 3 BATCHES,
2 TUBES FROM EACH BATCH
STANDARD DESIGN LOS TUBES

FIG. 7

Calibration Curves, 0.61" ID Outer Tubes

3 BATCHES, 2 TUBES EACH

FIG. 8
ACCURACY vs TUBE DESIGN

%STD DEV OF DOSE

0.61" ID OUTER TUBE w SCREEN

STANDARD DESIGN

DOSE, ppm-min

FIG. 9

MAXIMUM SENSITIVITY DESIGN

10 ML DYE ON .025" TUBES,
0.575" ID OUTER TUBE

STANDARD DESIGN

LENGTH OF STAIN, Inches

DOSE, ppm-min

FIG. 10
VELOCITY EFFECTS with NO BARRIER

FIG. 12

DIFFUSION BARRIER TESTS

FIG. 13
LENGTH OF STAIN DOSIMETER

ORIGIN OF THE INVENTION

The invention described herein was made by an employee of the United States Government and may be manufactured and used by or for the Government of the United States of America for Governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

This invention, in one of its aspects, pertains to the detection or measurement of hydrogen chloride gas in areas around Space Shuttle launch pads. In another of its aspects the invention relates to a length of stain dosimeter sufficiently sensitive and accurate to measure such gases, even after several hours have elapsed.

Payload customers for the Space Shuttle have recently expressed concerns about the possibility of their payloads at an adjacent pad being contaminated by plume effluents from a shuttle at an active pad as they await launch on an inactive pad. As part of a study to satisfy such concerns a ring of inexpensive dosimeters was deployed around the active pad at the inter-pad distance. Coupled with active measurements of the HCl intrusion through the air handling system on the active pad, it would then be possible to model the expected HCl concentrations at the inactive pad inside the PCR should the plume pass directly over an inactive pad during a future launch.

Initial studies involved the use of paper badge type dosimeters based on modifications of hydrazine-vanillin and bromophenol blue indicators. It was found that rapid fading of the color developed by these systems made their use difficult if not impossible. Following a launch, dosimeters cannot be read for several hours after the exposure. With the date for deployment approaching it was decided to look at the factors affecting fading in such passive dosimeters.

Factors such as different substrates, solvent systems, and possible volatilization of HCl from the badges were studied. Since interaction of the substrate with the dye formulation could be most quickly seen by dropping 100 µl of the dye (indicator reagent) test solution onto a horizontally suspended substrate and watching for color changes at the edge of the spreading drop, this method was employed. Many papers were found to be basic or acidic by using acid or base forms of bromophenol blue (BPB) dye. Even “Chromo 1” (a high purity paper used in paper chromatography) and silica gel thin layer chromatography (TLC) plates exhibited rapid fading of the developed color unless very heavy acid exposures were used. Only when Teflon and glass disks were used could light exposure colors be retained. This observation led to the length of stain (LOS) dosimeters of this invention.

Length of stain dosimeters are known in the art, as exemplified by U.S. Pat. Nos. 4,348,358, 4,489,164, 4,904,449, 4,913,882 and 4,963,324. Of these U.S. Pat. No. 4,348,358 is of interest herein. That patent relates to a length of stain (LOS) dosimeter having a detecting strip disposed in a tube with at least one of its sides parallel to the longitudinal axis of the device, with sensitivity increasing when the length of the strip is decreased and when the ratio is increased. This dosimeter includes an outer hollow cylinder having an open end and a closed end, and an inner cylinder disposed within the outer cylinder. The two cylinders are arranged concentrically so that the longitudinal axis of the inner cylinder is parallel to the inner wall of the outer cylinder. Means are provided for attaching the inner cylinder to the closed end of the outer cylinder. The inner cylinder is a nonporous glass, plastic or metal cylinder capable of being coated with a thin film. Its outer wall has this thin film thereon, a thin film being one less than 1 mil thick. The thin film is a coating including a reagent which undergoes a color change when contacted by the gas being detected. The sensitivity of the device is a result of this thin film, and a ratio of the area of the end of the outer cylinder (the opening) to the surface area of the thin film. These two parameters govern the sensitivity of the device, with sensitivity increasing when the film thickness is decreased and when the ratio is increased.

DETAILED DESCRIPTION OF THE INVENTION

During the experimental stages of this development when Teflon and glass substrates were used, these substrates appeared to be saturated in areas of minute or light dye or indicator reagent concentration, and did not exhibit any fading. This observation led us to suspect that the porous hydrophilic substrates used in previous dosimeters allowed the transport of unreacted base from the interior of the substrate, causing the surface color developed during exposures to low gas concentrations (light exposures), to be converted from the acid form back to the base form. This would account for the rapid fading we observed in a variety of dosimeters which we tested. The use of nonporous substrate elements such as Teflon filter he dynamic range. Dye coatings on such substrates changed i color with very light exposures, but the exposures could not be distinguished
from much heavier doses. These effects led us to explore length of stain type dosimeters.

**BRIEF DESCRIPTION OF THE DRAWINGS**

The parameters essential to this invention can, perhaps, best be explained in conjunction with diagrammatic and graphic representations of those parameters. Hence reference will be made to the following figures in the drawings.

**FIGS. 1 thru 4** illustrate, diagrammatically, four forms of dosimeters of this invention. **FIG. 5** presents sensitivity curves relating sensitivity to thickness of film on the dosimeter detecting elements. **FIG. 6** presents sensitivity curves relating sensitivity to inner cylinder--outer cylinder size ratios. The result was three designs without a diffusion barrier. **FIGS. 7 thru 13** illustrate larger outer cylinders relative to inner cylinders, with the legend pointing out that they are more sensitive. This is demonstrated by the curves in **FIG. 6.** The outside circular cross section diameter of the inner cylinder in each case is 0.110 in. The inside diameters of the circular cross sections of the outer cylinders are given in **FIG. 6.** It can be seen that the device where the inside diameter of the outer cylinder (cross section) was 0.575 in. was more sensitive than the devices with diameters of 0.365 in. or 0.250 in. Due to the accuracy requirements, to be discussed, the 0.250 I.D. unit, shown in **FIG. 2,** is the "standard" or "STS-42" dosimeter.

The ratio of the inner tube outside diameter (OD) to the outer tube inside diameter (ID) allows the user to modify the dynamic range and sensitivity of the device. Normally this OD : ID ratio should be in the range of 1.5:1 to 100:1. It will be appreciated, then, (**FIG. 5** and **FIG. 6**) that sensitivity is increased when the film thickness is decreased, and when the OD : ID ratio is increased.

The two variables demonstrate in **FIGS. 5** and 6 do not tell the entire story. There is a trade-off between sensitivity and accuracy. It is to be appreciated that where several variables are involved, as is the case herein, it is impossible to state with precision definite parameters determining a best mode. A sensitive device utilizing some of the variables may not necessarily be the best device. Nevertheless, by following the guidelines set forth herein a device can be produced which is capable of measuring small amounts, 2 ppm, of contaminants in the gas, during short exposures, say less than five minutes. Even so, depending upon circumstances, it may be desirable to sacrifice some sensitivity for accuracy, where accuracy is tantamount to repeatability. Relative to accuracy, reference to **FIG. 2** is indicated.

**EXAMPLE 1**

To coat the outer surface of inner cylinders 2 of dosimeters 1 with a thin film of BPB, 0.200 grams of the BPB were dissolved in 100 milliters of methanol. This solution was placed in aspirator painting equipment capable of dispensing an extremely fine spray. Glass cylinders were suspended on a rotating carrier and sprayed by the aspirating apparatus using a high volume (10 liters/min) of air so that the BPB was almost dry when it contacted the glass surface of the inner cylinder. Using this method an evenly distributed thin film was deposited on the outer surface of the cylinders.

To demonstrate the importance of film thickness **FIG. 5** is given. This figure is a graph of curves wherein ppm minutes (abscissa) are plotted against the length of stain (ordinate). By curves resulting from the use of different quantities of spray, **FIG. 5** shows sensitivity versus amount of HCl indicator or dye, tantamount to film thickness. By spraying different amounts of indicator by the process of Example 1, three quantities of spray, shown in the graph were applied to the inner cylinder outer surface. The result was three film thicknesses, too thin to measure with our equipment, but known to be less than 1 mil thick. Each subsequent inner cylinder was coated with twice as much indicator as the preceding one, and the third had three times (3X) as much as the first. The three curves, X, 2X, and 3X show, based on the length of stain, that the dosimeter with thinner film x is more sensitive than dosimeters with 2X and 3X films. And the dosimeter with the 3X film is not as sensitive as the device with the 2X film.

**FIGS. 1 thru 4** illustrate larger outer cylinders relative to inner cylinders, with the legend pointing out that they are more sensitive. This is demonstrated by the curves in **FIG. 6.** The outside circular cross section diameter of the inner cylinder in each case is 0.110 in. The inside diameters of the circular cross sections of the outer cylinders are given in **FIG. 6.** It can be seen that the device where the inside diameter of the outer cylinder (cross section) was 0.575 in. was more sensitive than the devices with diameters of 0.365 in. or 0.250 in. Due to the accuracy requirements, to be discussed, the 0.250 I.D. unit, shown in **FIG. 2,** is the "standard" or "STS-42" dosimeter.

The ratio of the inner tube outside diameter (OD) to the outer tube inside diameter (ID) allows the user to modify the dynamic range and sensitivity of the device. Normally this OD : ID ratio should be in the range of 1.5:1 to 100:1. It will be appreciated, then, (**FIG. 5** and **FIG. 6**) that sensitivity is increased when the film thickness is decreased, and when the OD : ID ratio is increased.

The two variables demonstrate in **FIGS. 5** and 6 do not tell the entire story. There is a trade-off between sensitivity and accuracy. It is to be appreciated that where several variables are involved, as is the case herein, it is impossible to state with precision definite parameters determining a best mode. A sensitive device utilizing some of the variables may not necessarily be the best device. Nevertheless, by following the guidelines set forth herein a device can be produced which is capable of measuring small amounts, 2 ppm, of contaminants in the gas, during short exposures, say less than five minutes. Even so, depending upon circumstances, it may be desirable to sacrifice some sensitivity for accuracy, where accuracy is tantamount to repeatability. Relative to accuracy, reference to **FIG. 2** is indicated.
standard device illustrated in FIG. 2. It is apparent that these curves are close together (repeatable) in ppm min as high as over 350 ppm min. Referring now to FIG. 8, it is noted that the six curves begin to diverge at about 10 ppm min if the OD : ID ratio is over 5. This is also illustrated in FIG. 9 which shows a standard deviation, comparing the devices of FIG. 2 (Standard Design) and FIG. 4 (high sensitivity). The Standard Design shows a lower standard deviation (greater accuracy) at all dose levels. The increase in sensitivity is an increase in the OD : ID ratio is also shown in FIG. 10. It is to be emphasized, however, that these two can be brought into line if a diffusion barrier, say a porous disc or packing, is placed over the open end of the outer cylinder 4. The diffusion barrier, thus, is another variable to be considered.

The physical arrangement of a suitable diffusion barrier of this invention is shown in FIG. 11. The specific diffusion barrier employed is a porous membrane composed of fluorocarbon fibers, such as Zetix, manufactured by the Chemplast Division of Norton Company. Other inert, porous, and hydrophobic materials will work equally well for hydrogen chloride, with the device sensitivity being affected by the average pore size and the void volume of the diffusion barrier.

The sample velocity effects without and with the diffusion barrier are shown in FIGS. 12 and 13 respectively. As can be seen, the effects without the barrier are so large as to dominate the quantitation of any hydrogen chloride vapors. With the addition of the barrier, quite reasonable quantitation can occur despite changing sample velocities. It is also to be noted that the addition of the barrier has little effect on the low flow response, as shown by the "no barrier" line in FIG. 13. While known in the art, the use of a diffusion barrier is an important modification within the contemplation of this invention.

It can be seen that by the practice of this invention a dosimeter can be made which is over one hundred times more sensitive than those known in the art.

Having been given the teachings of this invention various modifications in addition to the variables discussed will occur to those skilled in the art. As an example it has been emphasized that the need herein was for a sensitive dosimeter for HCI detection in an area around a launch pad. It is apparent, however, that the device herein can be utilized for the detection of other undesirable components in gas streams. It is known that the acid and base properties of a number of gases can be used to detect and quantify their occurrence in gas streams. For this purpose, any number of acid/base indicator dyes can be used. Many other reactions of various gases can also be used for their detection as well. These include a variety of reduct, precipitation, and condensation reactions. Any such reaction which produces a color change upon reaction with a sample gas can, in principle, be used with the geometry proposed herein to obtain a more sensitive and reproducible dosimeter. Selection will be within the skill of the art.

In addition, a wide range of pretreatments to convert the sought component to a measurable form or to remove potential interferences can be incorporated within the design described herein as part of the diffusion barrier or the reactant layer on the inner tube surface. For certain reactions, the inner wall of the outer tube can also serve as a pre-reaction site. By means known to these skilled in the art all such modifications can be combined with the thin film coaxial detection element described herein.

Selection of the appropriate dye can be made based on available literature. The use of the indicator dye or reagents can thus be applied in thin films, less than 1 mil in thickness, to the outer surface of the inner cylinder by means known in the art, for instance electrodeposition, vapor coating techniques and the like. Further, in order to enhance thin film binding properties, the inner cylinder, especially glass cylinders, can be coated with a resinous coating material such as an epoxy, acrylic, polyester, polyalkanol, or polyamide.

Metal inner cylinders have been mentioned. These will function the same as glass. However some judgment in their selection is necessary. Thus, a metal will not be selected with a surface which is etched by a component in the gas being detected, or one which has been fabricated with a porous surface. Moreover the inner cylinder need not be solid. It can be a hollow cylinder. So long as it has a cylindrical outer surface parallel to the inner surface of the outer cylinder for the sake of uniform results its construction is a matter of taste. As an example of another variation of the invention other closure means can be used in the closed end of the outer cylinder in lieu of the stopper shown in the drawings. The outer cylinder end can be rounded off or closed with an orifice therein for insertion of the inner cylinder. The orifice can also be provided with an O-ring if desired. Further the closed end of the outer cylinder can actually be a flat integral portion of the cylinder and the inner surface can carry a clip for the inner cylinder. The inner cylinder can also be provided with an adhesive removably holding it inside the outer cylinder. These and other ramifications will be obvious to those skilled in the art. Hence they are deemed to be within the scope of this invention.

What is claimed is:

1. A passive length of stain dosimeter having a sensitivity rendering it capable of detecting a gas in a concentration as low as 2 ppm on an exposure of five minutes, the dosimeter comprising an outer hollow cylinder having an inner wall, an open end, and a closed end, an inner cylinder selected from the group consisting of nonporous glass, plastic and metal, having on its outer wall a thin film of a reagent which undergoes a color change when contacted by the gas being detected, means for attaching the inner cylinder to the closed end of the outer cylinder, wherein the inner cylinder is concentrically disposed within the outer cylinder and having an inner wall parallel to the inner wall of the outer cylinder and so that its longitudinal axis is also the longitudinal axis of the outer cylinder, wherein the thin film is a film whose maximum thickness is less than 1 mil, and wherein the thickness of the thin film up to its maximum and a ratio of the area of the open end of the outer cylinder to the surface area of the thin film in the range of 1.5:1 to 10:1 governs sensitivity, with sensitivity increasing when the film thickness is decreased and when the ratio is increased.

2. The passive length of stain dosimeter of claim 1 wherein the ratio is 2.2:1, and the reagent is bromophenol blue.

3. The passive length of stain dosimeter of claim 1 wherein the ratio is 5:1.

4. The passive length of stain dosimeter of claim 3 wherein a diffusion barrier which covers the open end of the outer cylinder is included.
UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 5,302,351
DATED : Apr. 12, 1994
INVENTOR(S) : Dale E. Lueck

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 2, line 66, delete "he" and insert therefor -- papers and glass slides reduced the fading rate, but we lost the --.

Column 2, line 67, delete "i".

Signed and Sealed this Twenty-seventh Day of September, 1994

Attest: [Signature]

BRUCE LEHMAN
Attesting Officer

Commissioner of Patents and Trademarks