Chapter O

SEQUENTIAL AND TAPE SAMPLERS

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Introduction

Definition

Sequential and tape samplers collect a series of samples or a continuous sample using a timer or programmer to control all of the necessary operations. These may include the starting and stopping of an air moving pump, the manipulation of a sampling medium, or the switching of flow of air sample from one path to another.

Tape samplers

All tape samplers use tape as the collecting medium. The tape may be advanced periodically to produce a circular spot or a band which represents an integrated sample. This sample can be evaluated at the end of the sampling period to give a time-weighted average for that period. This manner of operation produces a series of discrete values. A sampler operating in this way could be considered as a type of sequential sampler. It is, however, customarily referred to as a tape sampler.

The sample collected by periodic tape advance can be evaluated continuously as sampling proceeds. For example, reflected light can be monitored using a reflectometer contained in the sampling head. The rate of darkening of the spot is related to the concentration of the contaminant in the air sample. The cumulative change is related to the time-weighted average. By equipping such a sample with a recorder it becomes a direct reading continuous monitor.

Some tape samplers are designed for continuous tape advance. The sample appears as a trace of gradually changing appearances or as a series of spots or bands. If the contaminant concentration changes gradually, the sample appears as a trace. If the concentration changes are abrupt, the tape resembles one produced by periodic movement. Continuous advance is suggested for monitoring of high concentrations such as may be found in mines, road tunnels, or in stack monitoring.

Tapes obtained by continuous movement may be evaluated concurrently with collection. Such samplers are also direct reading continuous monitors. It may be necessary to delay evaluation until sampling has been completed and perhaps the tape has been removed from the sampler. It is still possible to obtain a profile of the concentration even though it is not in real-time. Such a system can be thought of as a delayed-reading continuous monitor.

In most tape samplers the air sample passes through the tape. Particulate matter is collected by filtration. Tapes impregnated with chemical reagents are used in the determination of gases and vapors. Sometimes the air sample passes over the surface of the tape rather than through it. The tape is very often composed of paper but plastic filtration membranes, glass fiber, and other materials are also used. The tape must have sufficient mechanical strength and have purity and other physical and chemical properties consistent with both sampling and analytical needs.

Basic components of a tape sampler

In the tape samplers with periodic advance, the tape is tightly clamped in the air sampling train and the tension is released while the tape is pulled forward. In the samplers with continuous advance, the tape slides between polished surfaces. The tape may be reel-to-reel, cassette, or card-mounted. All tape movement is controlled by the timer or programmer.

The air sample is pulled through or across the surface of the tape by a vacuum pump. A flow meter and flow control device are usually located between the pump and the tape. A pulsation dampener is desirable and should be located between the tape and the flow meter. The sampled air may be used to pressurize the compartment in which the tape is contained. A probe may bring the sample into the sampling head.

Sequential Samplers with Automated Media Advance

A number of samplers are similar to the tape samplers in that they consist of a single sampling train in which the sampling medium is advanced periodically or continuously.

Automated impactors

The RDM 301 marketed by GCA collects particulate matter by impaction on a thin Mylar® film coated with an adhesive. The film is mounted on a circular metal ring. The ring is rotated slightly and advanced a short distance linearly between each collection period. A spiral of sample spots result. At the end of each sampling period the newly formed spot is evaluated by beta attenuation. The instrument is a sequential sampler with a shortly delayed periodic direct printout. It can also be considered as a direct reading analyzer for particles.

The RDM 101 is a less automated sampler and requires manual advance of the sampling disc and manual initiation of each sampling. The sampling result is displayed but must be recorded manually. It is not strictly a sequential sampler but lends itself readily to repetitive sampling with a minimum of operator involvement.

Other automated impaction samplers include those which collect on the surface of a drum or cylinder wrapped with adhesive coated tape. The drum is advanced periodically or continuously. Another type of impaction sampler uses a linearly advancing microscope slide. Moving slides have also been used in conjuction with thermal precipitation. These "rotating drum samplers"and moving slide samplers are partly of historical interest and are described in more detail in previous editions of *Air Sampling Instruments* (*ASI*)[(3-5)] and in the *Encyclopedia of Instrumentation for Industrial Hygiene*.[(6)] Impaction sampling has often been used in conjunction with microscopy.

Automated impingers

One of the earliest important sequential samplers was developed by Thomas and his coworkers. Thomas and Cross(7) described an automated impinger in 1928. Thomas and Ivie(8) wrote in 1952 that some of these instruments were still operating after 20 years of continous service. At that time Thomas was also developing a direct reading continuous monitor which became known as the Thomas Autometer. In later years he directed most of his efforts to the direct reading instruments. This is somewhat indicative of a general trend away from sequential samplers for a number of applications.

Wilson(9) reviewed the work of Thomas and also described his own work. Wilson developed a sampler similar to that of Thomas. This Wilson version was marketed as the Air Sampling Equipment Company (ASECO) Automatic Impinger. An impinger was used to collect the air sample. At the end of each period it was drained into a storage tube positioned on a turntable. The impinger was then automatically refilled from a reservoir of absorbing reagent and the turntable was advanced. This arrangement of reservoir-impinger-turntable was most often used in sampling for sulfur dioxide but was used for other gases as well. The ASECO Automatic Impinger was last included in *ASI* instrument descriptions in the 3rd edition.(3)

Automated dichotomous samplers

A dichotomous sampler, a form of virtual impactor, separates and collects particles in two fractions according to their aerodynamic size. Presently the size cuts are 2.5 μm and 15 μm, although the upper limit will probably be reduced to 10 μm.

Tape collection

Macias and Husar(10) described a TWOMASS sampler which collects coarse particles by impaction on glass fiber filter tape and fine particles by filtration. The tapes are advanced every 2 hours to avoid clogging. The tapes are evaluated by beta attenuation concurrently with sampling.

Jaklevic, Loo and Fujita(11) use a dichotomous sampler in conjuntion with X-ray fluorescence analysis. In this sampler the particles are separated by a virtual impacter. Coarse particles are collected on a 37 mm diameter cellulose filter. This fraction is not analyzed. Fine particles are collected on a Teflon® membrane filter which is incorporated into a 35 mm wide paper tape.

Individual filters

Jaklevic, Gatt, Goulding and Loo(12) describe an automated dichotomous sampler which collects particulate matter on individually mounted membrane filters. The filter pairs are contained in two traps and are automatically inserted into the sampling position and removed at the completion of sampling.

The Process Instruments Division of Beckman Instruments Inc. introduced an automated dichotomous sampler, the Envirosamp, in the mid-seventies. It was later withdrawn because of lack of a sufficient market. The Envirosamp used two rectangular trays to carry the paired filter sets. Sierra-Andersen markets an automatic dichotomous sampler that uses a turntable or carousel to carry the filter pairs.

These dichotomous samplers separate coarse and fine particles by virtual impaction. The air is drawn into the sampler through an acceleration nozzle. The sample then divides into two streams. One stream is pulled through a collection nozzle which directly faces the incoming air. A larger second stream is pulled past the collection nozzle. The coarse particles are carried by their greater inertia into the collection nozzle. The fine particles are carried by the larger volume which flows past the collection nozzle. Both fractions are collected by filtration.

The Sierra-Misco Model 7800 is a two-staged stacked head dichotomous air sampler which is equipped with two filter pairs. After 24 hours of sampling the pairs are automatically switched. This enables the operator to visit the site the following day and collect the previous day's sample while a current sample is being collected. Stevens, Dzubay, Russwurm and Rickel(13) used both manual and automated dichotomous samplers in a Regional Air Pollution Study (RAPS). Sulfates and related species were determined in 6 cities. Dichotomous samplers have been used quite regularly in recent years in many air pollution studies, and can have utility in area wide industrial sampling situations.

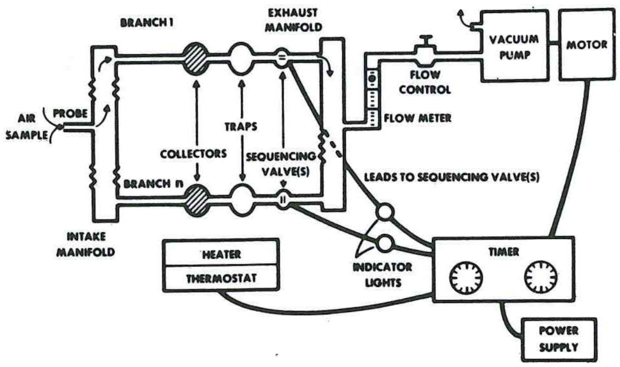

Figure 0-1 — Generalized representation of a sequential sampler.

Multibranch Sequential Samplers

The typical multibranch sequential sampler, sometimes refered to only as a sequential sampler, includes a vacuum pump, flow regulator, and flow meter. Individual collectors are connected to these downstream components by a rotary sequencing valve or a manifold connected to individual solenoid valves. Valve action and the vacuum pump are regulated by a timer or programmer. Ordinarily flow is maintained only in one branch at a time. All solenoid valves except one will be in the closed position. The collectors may be connected to an intake manifold and probe. Other devices may be included to condition the sample or to protect the downstream members. A generalized representation of a multibranch sequential sampler is shown in Figure O-1. A multibranch sequential sampler resembles a multibranch simultaneous sampler in many respects. The simultaneous sampler, however, does not contain a rotary sequencing valve or solenoid valves. In the simultaneous sampler all branches collect at the same time. Impingers or bubblers containing a liquid absorbing agent often have been used as collectors in multibranch samplers. Individually mounted filters have also been used. In 1979 a multibranch sequential sampler specifically designed to collect with detector tubes or adsorption tubes was introduced. This is the Gilian Model RD 113 Programmable Atmospheric Sampler.

Some multibranch samplers have been equipped with heaters and thermostats to allow for temperature regulation at temperatures above ambient. One sampler has a thermoelectric cooling-heating system that maintains the collecting solution at 10°C for sampling for sulfur dioxide. This assures maximum sample stability. This feature also significantly increases the purchase price of the sampler.

Multiple sampling trains (sequential bag sampler)

The Environmental Measurements Inc. (EMI) Air Quality Sampler III contains a series of pumps each connected to a matching plastic bag. The pumps are controlled by a central programmer and are powered by a single power source. All components of the system are fitted into a single container. The first model of the EMI sequential bag sampler was introduced in 1975. Sequential bag sampling has been evaluated for carbon monoxide by Polasek and Bullin.(14) This article prompted correspondence in subsequent issues of the journal cited.(15–18) In general, Tedlar bags show low reactivity with air samples and are preferred over other plastic films.

Sample Evaluation

Microscopy

Samples collected by automated impactors, such as the drum sampler or the moving slide impactor, have usually been evaluated by microscopic procedures. In these sampling procedures the particles are collected on the surface of a tape or slide. If the collecting medium is transparent, the particles can be studied by procedures using transmitted light or reflected light. Particles collected on opaque surfaces can be evaluated by reflected light only. Particles can be simply counted or they can be sized and perhaps identified.

It is also possible to use microscopy in conjunction with automated samplers which collect particulate matter by filtration. The filter should collect almost exclusively on its surface so that all particles are in the same plane and are not obscured by being imbedded within the filter. Examination using transmitted light is possible if the filter can be made transparent by using an immersion oil with a matching index of refraction or by dissolving the filter in a solvent. Heard and Wiffen(19) describe a tape sampler that collects particulate matter on an AA Millipore membrane. Samples are evaluated by electron microscopy. Methods involving microscopy require specialized skills and are time consuming. This limits the number of samples which can be processed. It can readily be appreciated that microscopy has its limitations for the evaluation of large numbers of samples that are usually generated with sequential and tape samplers.

In some procedures the sample is significantly altered and its use with other methods of evaluation becomes limited. Mounted slides and samples that have been chemically treated are not particularly suited for analysis by methods other than microscopy. For discussions of applications of microscopy to sample analysis see McCrone(20) and McCrone, McCrone and Delly.(21)

Visual comparsion of color changes

The Von Brand Filtering Recorder has been used to evaluate the performance of incinerators, furnaces, and engines.(22) The Von Brand instrument is described in the *Encyclopedia*(6) and all previous editions of *ASI* with the exception of the first edition. It is often sufficient to evaluate the tape by visual comparisons. For instance, the optimum combustion conditions will correspond to those which produce the least darkening of the tape. Samples obtained with detector tubes are visually evaluated by noting the length of stain or by comparisons with a printed color chart.

Transmission of light

COH values

Particulate matter samples collected by tape samplers are often evaluated by comparing the amount of light transmitted through the sampling area before and after sampling. Hemeon and his coworkers(23,24) credit the introduction of this approach to J.S. Owens. They reference a book by Shaw and Owens, *The Smoke Problem of Great Cities,* published in London in 1925.

The sample collected by filtration is intended to give an indication of the concentration of sooty fine particles in the atmosphere. These particles often enter the air as a result of incomplete combustion of fuels such as coal or oil. Such particles are usually black or gray. Fine particles are far more numerous than coarse particles. Fine particles also deposit on ceilings and walls as well as floors. The soiling of these surfaces and of clothing, draperies, and other materials is related to the concentration of fine particles in the air. Fine particles also absorb and scatter light to a much greater degree than do coarse particles. High humidity and high concentrations of fine particulate matter are responsible for reduced visibility through the atmosphere. The word "smog" is derived from smoke and fog. It must be cautioned that materials that scatter light with little absorption, such as H_2SO_4, will not be effectively measured by a tape sampler.

Hemeon, Sensenbaugh and Haines(23) described the A.I.S.I. Automatic Smoke Filter in 1953. Their work at the Industrial Hygiene Foundation at the Mellon Institute was sponsored by the American Iron and Steel Institute (A.I.S.I). Later in 1953, Hemeon, Haines and Ide(24) introduced the term COH which is an acronym for Coefficient of Haze. The COH unit is used in expressing the results of tape sampling measurements in which the sample is evaluated by light transmission.

The particulate matter collected on the filter tape is pictured as having been suspended in a cylinder whose base has the same area as that of the sample area on the tape. The length of this imaginary cylinder is such that the volume of the cylinder and volume of air sample are equal. For instance, the volume of air sampled by using a 2-hour period and a flow rate of 0.22 cfm would be 26.4 ft^3:

$$120 \text{ min} \times 0.22 \text{ cfm} = 26.4 \text{ ft}^3 \qquad (1)$$

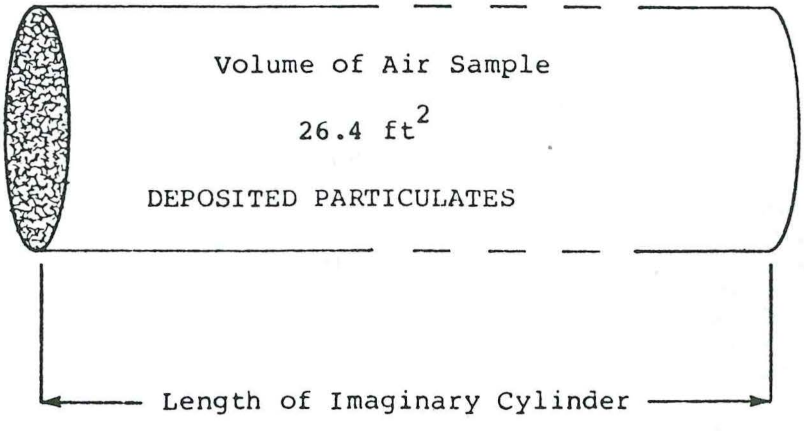

Figure 0-2 — Imaginary cylinder used in calculating COH values. Area of sample spot, 5.45×10^{-3} ft.^{2}

The area of a circular sampling area of 1.0 inch diameter is 5.45×10^{-3} ft^2. The length of the imaginary cylinder is 4850 ft:

$$\frac{26.4\ \text{ft}^3}{5.45 \times 10^{-3}\ \text{ft}^2} = 4850\ \text{ft} \qquad (2)$$

The imaginary cylinder is represented in Figure O-2.

A COH unit is defined as the quantity of light scattering solids producing an optical density of 0.01 when measured by light transmission. Optical Density is defined by the equation:

$$\text{O.D.} = \log \frac{\text{light transmitted before sampling}}{\text{light transmitted after sampling}} \qquad (3)$$

For a sample which transmits 100 units of light before sampling and 50 units after sampling, the O.D. is 0.301:

$$\text{O.D.} = \log 100/50 = \log 2 = 0.301 \qquad (4)$$

This spot is equivalent to 30.1 COH units or 30.1 COHS. If the spot is the result of sampling from a cylinder whose length is 4850 ft, the final value for the sample becomes 6.2 COHS/1000 ft:

$$30.1\ \text{COHS}/4850\ \text{ft} = 6.2\ \text{COHS}/1000\ \text{ft} \qquad (5)$$

This method of calculating COH values takes into account the volume of air sampled, the area of the tape on which the particulate matter is deposited, and the amount of light transmission lost by light absorption and scattering. This allows comparisons among results from various combinations of sampling rates, sampling times, and sampling areas.

COH values are an index of the concentration of fine particles, reduced visibility, and soiling potential. Since other factors influence the COH determination, one should not necessarily expect close correlation with other indices and measurements. Mass concentration is most directly determined by measurement of weight gain of a filter with an electrobalance. Results from beta attenuation and piezoelectric samplers are good indicators of mass and are usually expressed in mass concentration units. Forward light scattering and right angle light scattering instruments also give an indication of the mass concentration of suspended particulate matter. Various empirical methods for expressing reduced visibility have been suggested. Some of these take into account the effect of humidity on visibility.

Correlations do occur between COH values and these other measurements related to the concentration of fine particulate matter. This happens when the other important factors remain constant. Such correlation tends to be application-specific and site-specific.

One of the few recent papers concerning COH measurements is that of Heidorn.(25) The errors in transmission measurements are discussed as they relate to variations in tape thickness. Many air pollution studies have included COH measurement. This type of sampler is still used in air pollution episodes, screening studies, and locating emission sources. Holcomb and Scholz(26) describe the use of an RAC tape sampler for the evaluation of air cleaning equipment used in recirculation systems.

Impregnated tape

In 1953, Hemeon, Sensenbaugh and Haines(23) also described their A.I.S.I. Hydrogen Sulfide Sampler. Hydrogen sulfide is determined by using a tape impregnated with lead acetate. The tape darkens as lead sulfide is produced by the reaction of the air sample with the tape. The tape is evaluated by light transmission measurements. A standard curve is prepared by sampling atmospheres whose concentrations have been independently established.

Hydrogen sulfide has also been determined by a tape impregnated with mercuric chloride. In this instance the tape is exposed to ammonium hydroxide fumes to develop the spot. Evaluation is by light transmission.

Reflection of light

In 1954 Gruber and Alpaugh(27) described a method of tape evaluation in which reflected rather than transmitted light is measured. They too pictured the air sample as being contained in an imaginary cylinder.

In a sample calculation they show that sampling at 0.21 cfm for 6 hours produces a sample volume of 75.6 ft^3. A circular one inch diameter spot has an area of 5.45×10^{-3} ft^2. The length of the imaginary cylinder is 14,000 ft:

$$\frac{75.6\ \text{ft}^3}{5.24 \times 10^{-3}\ \text{ft}^2} = 14{,}000\ \text{ft} \qquad (6)$$

A "dirt shade" unit is defined by the equation:

$$\text{dirt shade} = \log_{10}\left(\frac{\%\ \text{reflectance clear paper}}{\%\ \text{reflectance soiled paper}}\right) \times 100 \qquad (7)$$

A dirt shade of zero indicates no detectable soiling has occurred during the sampling. During a two-year sampling program the darkest spot has a reflectance of 11%. A slightly darker spot with a reflectance of 10% would be equivalent to a dirt shade of 100:

$$\begin{aligned}\text{dirt shade} &= \log \frac{100\% \times 100}{10\%} \qquad (8)\\ &= \log 10 \times 100\\ &= 1 \times 100\\ &= 100\end{aligned}$$

The term RUDS was introduced to give a convenient way of expressing the final result. RUDS is an acronym for Reflectance Units of Dirt Shade. The spot, with a reflectance of 10%, has a RUDS value of 100. If the spot represents the particles collected from an imaginary cylinder 14,000 ft long, then:

$$\frac{\text{RUDS}}{10{,}000\ \text{ft}} = \frac{100\ \text{RUDS}}{14{,}000\ \text{ft}} = \frac{71\ \text{RUDS}}{10{,}000\ \text{ft}} \qquad (9)$$

This convention of expressing the results in RUDS/10,000 ft produces values ranging from zero to about 100 and avoids the use of a decimal point.

The relative advantages of transmission and reflectance measurements have been discussed by Linsky(28) and by Saucier and Sansone.(29) In most air pollution programs the soiling index has been determined by the transmission method rather than the reflectance. Evans, Ingle, Molyneux and Shart(30) obtained a semiquantitative continuous record of welding fume concentrations using the Seiger 7030 paper tape monitor. The brown stain formed on the filter is drawn past a reflectometer providing a measure of fume concentration.

Impregnated tape

The various tape samplers marketed by MDA in the United States and by UEI in Great Britain use chemically impregnated tape. The tapes are evaluated by reflected light measurements. This is true for the Series 7000 Continuous Monitors and for the Series 4000 Minature Continuous Monitors. The Model 3060 Autospot and the PSM-8/12 Multipoint Monitoring System also sample with specially formulated paper tape detection systems. Experimental details, instrument design, and applications of the MDA tape samplers are well described in various journal articles.(31-34)

The Houston Atlas, Inc. (HAI) Hydrogen Sulfide Gas Analyzers Model 825R and Model 825R/102 have built-in evaluation based on light reflection measurement. The darkening of the lead-acetate impregnated tape is measured continuously. The rate of darkening is proportional to the hydrogen sulfide concentration. The tape is advanced periodically. Several models of hydrogen sulfide monitors are available from Del Mar Scientific. These are intended primarily for monitoring natural gas and gas liquids process streams. These instruments also use lead acetate impregnated tape with evaluation by reflected light.

Beta attenuation

An application of the beta attenuation technique was reported by Nader and Allen(35) in 1960. In this approach, the particulate matter sample is collected on a filter or on an impaction film. The filter or film must be thin enough and of such composition as to transmit beta radiation to an acceptable degree. A beta source is located on one side of the collecting area and a detector is located on the opposite side facing the source. As particles collect, the amount of radiation reaching the beta detector decreases.

Macias and Husar(10) used beta attenuation in their TWOMASS sampler. This sampler has already been briefly described in this section under the heading *Automated dichotomous samplers*. The TWOMASS sampler collects coarse particles by impaction and fine particles by filtration. In both cases the fraction is collected on a glass fiber filter tape. Each tape system has its own Carbon-14 beta source and beta detector.

Jaklevic *et al*(12) describe an instrument which is well suited for automatic mass measurements of membrane filters used in modern dichotomous samplers. The sampler is designed to hold two trays (magazines) with 36 samples each plus five standards at top and bottom. Samples can be collected on membrane filters mounted on thin frames. The same sample can be evaluated by beta attenuation and by direct weighing.

The Dasibi MPSI 100 Warning and Reference System collects on a fiberglass filter. This is referred to as a ribbon rather than as a tape. The filter zone is automatically advanced after each measurement with evaluation by beta attenuation. Dasibi Environmental Corporation (616 E. Colordo St., Glendale, CA 91205) used the terms beta-ray absorption and beta-absorption gauge rather than beta transmission or beta attenuation.

The GCA samplers RDM 301 and RDM 101 are described earlier in this section as automated and partially automated impactors. In both models, particulate matter is collected on a mylar film and evaluated by beta attenuation.

Beta-attenuation results are usually reported in mg/m^3. In many applications the correlation between results from these beta-attenuation instruments and results from direct weighing has been excellent.

Radioactive contaminants

A series of tape samplers for the determination of radioactive particulate matter is described in the 5th edition of *ASI.*(3) The SA-30 series of monitors is marketed by Nuclear Measurements Corp. (NMC). Tape advance can be either periodic or continuous. Nine different models are listed. Alpha, beta, and gamma activity can all be monitored by their model AM-3F. Other models monitor only one or two types of activity.

A Radon Daughter Analyzer has been introduced by The Harshaw Chemical Company within the past few years. This analyzer is included in the instrument descriptions of tape samplers.

Pressure drop

The pressure drop across a tape increases as particulate matter loading increases. The Fleming Air Pollution Monitors described in the 4th edition of *ASI*(4) use this principle. Models that advance the tape continuously are recommended for monitoring higher concentrations encountered in stack sampling and sampling in mines and tunnels. Other models are recommended for the outdoor atmosphere and production areas in plants.

Weight gain

It has been already noted that the lightweight filters used with some of the automated dichotomous samplers permit direct determination of mass concentrations by use of an electrobalance or microbalance.

Chemical Analysis

Some of the evaluation procedures already described provide quantitative information about specific air contaminants. Particles can be identified as well as counted and sized by the skilled microscopist. Specific gases can be monitored using impregnated tapes evaluated by light reflection or light transmission. Specific isotopes can be measured quantitatively by collecting them on tape and then counting their radioactivity. Color changes or the length of stain on a detector tube also give quantitative information about specific gases or vapors.

In many determinations the sample must be subjected to chemical analysis by a support laboratory. Sometimes the analytical and sampling capability can be integrated into a unified system. For a general discussion of chemical analysis at it relates to air sampling see Eller and Crable.(36)

Emission spectrography

Rozsa, Stone, Uguccini and Kupel(37) describe a beryllium air monitor in which the sample is collected on a filter tape. The deposited particulate matter is moved forward into the analytical gas of an emission spectrograph. The energy of the beryllium line is measured by a photomultiplier. A panel meter indicates the concentration of beryllium in air. A red light and horn are actuated at 2 micrograms per cubic meter and above. This sampler is more of historical interest. The emission spectrographic procedures that were so widely used in the sixties have been replaced by atomic absorption and more recently by energy dispersive X-ray fluorescence (XRF).

Visible light spectrophotometry

Multibranch sequential samplers have been used with a variety of collectors. From the mid-fifties to perhaps the late sixties they were usually used with midget bubblers or impingers containing a solution of a chemical reagent. A color is produced during sampling or is developed subsequent to sampling.

Variations of the pararosaniline method for sulfur dioxide lend themselves to use with a sequential sampler. The absorbing reagent and samples are relatively stable. Delays of hours or days between sampling and analysis do not necessarily invalidate the result. This is particularly true if the sampler is equipped with a thermoelectric cooling-heating system.

Spectrophotometric methods have also been used to analyze particulate matter samples collected by filtration. Both individual filters and samples on tapes have been analyzed. Stevens, Dzubay, Russwurm and Rickel(13) determined sulfate in samples on membrane filters obtained with an automated dichotomous sampler. Results from the Thorin spectrophotometric procedure are compared with those obtained by ion chromatography (IC). Total sulfur is determined by XRF.

Energy dispersive X-ray fluorescence (XRF)

The samples from the study just cited were analyzed by XRF for other elements in addition to sulfur. It is noted that this method had been developed by Jacklevic. Articles from 1974, 1976, and 1977 are referenced. Jacklevic has determined as many as 35 elements on membrane filters from dichotomous samplers.

Stevens *et al*(13) used XRF to obtain mean elemental concentrations for 18 elements for both the fine and coarse fractions. The study included 6 cities. Determinations of ions were also made. Concentrations of H^+, NH_4^+, SO_4^{2-}, and NO_3^- were determined by the Gran titration, ion selective electrode, thorin spectrophotometric method, and ion chromatography (IC).

Citron and Mausner(38) reported the use of XRF in determining rare earths in air. Samples were collected on Whatman 41 filter paper. The type of air sampler is not further indicated. The analytical procedure which had been applied to 14 samples is described in detail. It was demonstrated that XRF is rapid, devoid of complicated steps and reliable for the concentrations examined. These authors point out several advantages of XRF:

1. It is nondestructive.
2. Filter deposits can be analyzed directly with little or no preparation.
3. Multielement determinations from fluorine upward are made with fairly uniform detectability.
4. Commercially available instruments permit a large number of sample irradiations in relatively short times.

Gas chromatography (GC) and high performance liquid chromatography (HPLC)

Samples collected by the Sequential Pesticide Sampler are customarily analyzed using gas chromatographic techniques. Formerly marketed by Misco Scientific, this sampler is now available from Sierra-Misco.

The Gilian Model RD113 collects gases and vapors in tubes packed with adsorbing agents. These samples can be desorbed by solvents or by heating. Many different compounds can be collected and analyzed. Gas chromatography has been widely used to analyze adsorbed samples that have been obtained by manual sampling and by personal sampling. More recently, HPLC has been applied to some of those samples which are not readily analyzed by GC. These two techniques will, no doubt, also be generally applicable to samples obtained with the RD113.

Direct reading analysis

Samples collected by the EMI sequential bag sampler have been analyzed by the Ecolyzer CO monitor. An article by Polasek and Bullin(14) and the subsequent correspondence(15–18) have already been cited under the heading of *Multiple sampling trains (sequential bag sampler).*

Recent Trends in Automated Analysis

Collection of sample

In all of the sequential and tape samplers described in this section, a sampling medium collects the gaseous or particulate contaminants. These media include plastic bags, filters, impaction surfaces, absorbing solutions, solid adsorbants, impregnated filters, and impregnated impaction surfaces. There are many samplers and monitors in which the contaminant is detected or sensed without being isolated or removed from the air in which it is dispersed. In other cases only a small fraction of the contaminant reacts with the sensor and the sample undergoes virtually no change. In still other instances the contaminant is destroyed as it is sensed. These systems which do not require the use of a sampling medium are usually more readily automated. Use of these "flow-through samplers" is preferable in many applications.

Nondestructive sensors

A number of dust monitors detect particles suspended in the air by either forward light scattering or right angle light scattering. Gases and vapors can be monitored through their absorption of ultraviolet or infrared radiation. Infrared (IR) and non-dispersive infrared (NDIR) instruments have been in use for some time. Fourier transform infrared (FT/IR) and gas filter correlation have been introduced into air monitoring more recently.

Electrochemical sensors have become widely used to determine carbon monoxide, hydrogen sulfide, and other gases. Only a small part of the contaminant in the air stream is electro-oxidized or electro-reduced. The instrument's response is concentration dependent rather than quantity dependent.

Photoionization detectors (PID) are virtually non-destructive. Sensors with higher energy lamps have a low degree of selectivity. The lower energy lamps are more selective and avoid some of the possible interferences in determining such compounds as benzene or toluene.

The piezoelectric mass detector in the Thermo Systems Inc (TSI) Model 5000 is non-destructive. The particles are collected on an oscillating quartz crystal by electrostatic precipitation. The frequency of oscillation decreases as the particles accumulate. The mass concentration is estimated from frequency determinations made before and after sampling. The crystal is cleaned when the frequency has decreased below a specified value.

Destructive sensors

The heat of combustion sensors and flame ionization detector (FID) are both destructive and non-specific. The FID is highly sensitive. It is often used to detect compounds that have been separated by a gas chromatographic column. Gas chromatographic separations require time for the resolution of the mixture. For this reason, determinations are repetitive rather than continuous. Automated gas chromatography has been successfully applied to process monitoring.(39,40)

Multicomponent capability

Gas chromatographic and infrared methods are capable of determining multiple compounds in a single sample. They are also able to identify unknown compounds when used in conjunction with each other and with mass spectrometry.

Multiprobe sampling

Automated samplers are sometimes used with multiple probes. These include tape samplers, NDIR, IR, PID, FT/IR, electrochemical, and repetitive GC systems. The MIRAN-801 has been available since 1979. It has both multiprobe and multi-component capability.(41) Both repetitive GC and FT/IR systems have been used with multiprobe monitoring for vinyl chloride monomers.(40,42) Carbon monoxide in parking garages and in industrial plants has been monitored both with electrochemical and NDIR analyzers. Suppliers of this instrumentation also supply the equipment for multiprobe monitoring.

Multisensor sampling

Combustible gas and hydrogen sulfide are often determined at multiple locations by placing a sensor at each location and transmitting the signal to a convenient area or control room. Each sensor may be connected to its own meter and alarm. An alarm may be located at both the area near the sensor and in the control room. In some installations a number of sensors are connected to the same metering, recording,and alarm system. This reduces the cost per location and results in a more compact system.

Adaptive sampling

Sawyer and Coppola(42) define adaptive sampling as the process in which areas are measured more often where worker exposures are more likely than those where exposures are less likely. The selection of areas to be sampled is governed by the probability the workers will be there, the probability of an excursion, and data from auxillary inputs. These include data about process conditions and wind direction. Adaptive sampling is also used to find leaks more quickly.

Some General Observations

On looking back from today to the early work of Moyer Thomas in this country and J.S. Owens in England, one sees a continuous evolution of sampling, analytical, and related technologies. Various procedures have been automated and integrated into highly complicated systems. The number of possible combinations of sampling, analytical, and data handling systems is enormous. Many instruments and systems are beyond the needs and resources of all but a few potential users. Instruments which are no longer actively marketed are taken off the shelf and adapted as the occasions arise.

Instruments are developed to meet changing requirements established by governmental regulatory agencies such as OSHA, MSHA, and EPA. The available instrumentation often anticipates these requirements and exceeds them. Sequential and tape samplers are a valuable group of instruments. They have a high degree of adaptability and represent an intermediate level of automation and cost. They will continue to be used in those applications where these factors are decisive.

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Instrument Descriptions

Sequential Sampler Model PV

Andersen Samplers, Inc.
4215 Wendell Drive
Atlanta, GA 30336.

The Model PV sequential sampler automatically collects a series of 12 consecutive samples over a total of up to 12 days. Sampling time for each sample can range from ½ to 23¾ hours. Time between samples can range from ¼ to 23¾ hours. The system shuts off automatically on completion of the series.

The sampler is especially designed to sample for sulfur dioxide using the pararosaniline method. Samples are collected using a liquid reagent. A thermoelectric cooling-heating system maintains a temperature of 7° to 17°C at ambient temperatures of -25° to +50°C. This temperature range is optimum for reagent stability.

Other gases can be collected with the appropriate liquid reagents. These include hydrogen sulfide, nitorgen dioxide, nitric oxide, ammonia, and aliphatic aldehydes. The sampler can also be readily adapted for use with individually mounted filters.

Operating principle

This sampler is a multibranch sequential sampler. A series of 12 samples is collected without operator attention during collection. Collectors are prepared and samples are analyzed by a support laboratory. Leak-tight closures are used during their transport.

Physical description

The sampler consists of a control module and a sampling module. The two components are connected by an electrical cord and 12 sections of rubber tubing.

The control module houses a vacuum pump, a flow regulating valve, a rotameter, a rotating plug valve, a set of 12 demister traps, and sections of connecting tubing. The programmer-timer, which controls the rotating valve and various switches, is also located in the control module. A set of 12 plastic connectors are mounted through the side of the cabinet of the control module. Its dimensions are 12" × 12" × 17", weight is 30 lbs., and power requirements are 115 VAC, 60 Hz.

Two sampling modules are available. One of these is equipped with thermoelectric cooling-heating system for constant temperature sampling. The other is not equipped with this capability.

The thermoelectric sampling module is about the same size as the control module, but is somewhat lighter. It contains a removable rack which holds 12 polypropylene impinger/bubbler units of 100 ml capacity each. These are connected to the control module by sections of rubber tubing. The collecting units are also connected to a glass inlet manifold by Teflon tubing. A section of Teflon tubing is connected to the inlet of the glass manifold. A funnel at the inlet of the train lowers velocity at the entry. This reduces any tendency to draw in rain, snow, or large particles. The incoming air contacts only glass and Teflon before entering the gas-absorbing reagent. This sampling module is fully insulated. The solid-state thermoelectric cooling-heating system maintains a gas-absorbing reagent at the selected temperature. A separate thermostated heater and fan assembly maintains the inlet manifold at a selected temperature well above the dewpoint of the incoming air.

The sampling module which is not equipped with thermoelectric cooling-heating is designed to hold 30 ml glass impinger/bubblers. It is smaller and less expensive and is intended for

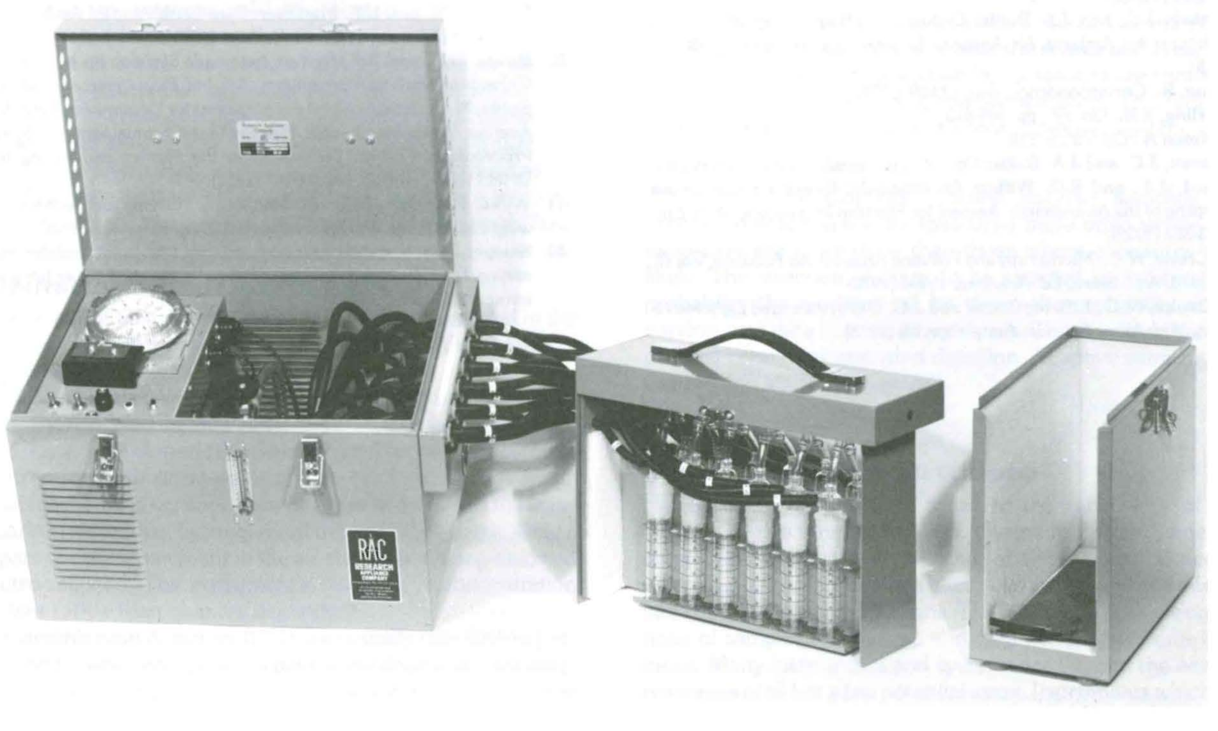

Figure O-3 — Model PV Sequential Sampler.

sampling with thermally stable reagents. A heating element for cold weather use is optional.

Performance data

The vacuum pump will maintain free flow for 30 ft^3/hr. The flowmeter mounted on the control unit is calibrated for 2 to 10 ft^3/hr. This flowmeter does not adequately measure the lower flow rates often used for this determination. Measurements should be made using some other more suitable flowmeter at the inlet of the sampling tubes. Initial and final flow rates are readily obtained in this manner.

The Model PV samplers meet or exceed EPA specifications for gas samplers of their type as well as ASTM D1605 and D1609 standards for gas sampling.

* * *

Sequential Pesticide Sampler Model 88

Sierra-Misco, Inc.
Environmental Products
1825 Eastshore Drive
Berkeley, CA 94710

This sampler is used to collect four samples of airborne pesticides over any desired 24-hour sequence.

Operating principle

Glass cloth is used in the pre-filter. Hexylene glycol is used in the impinger, and alumina is used in the absorbent tube. Pesticides are extracted from the filter, alumina, and hexylene glycol, passed through a Florisil® column clean-up step, at which time chlorinated pesticides are separated from the organophosphate pesticides. Both pesticide fractions are analyzed using gas chromatography.

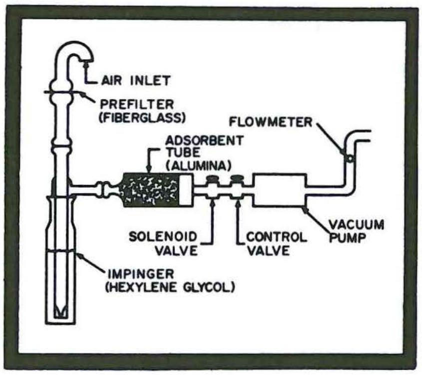

Figure 0-5 — Schematic of sampling train.

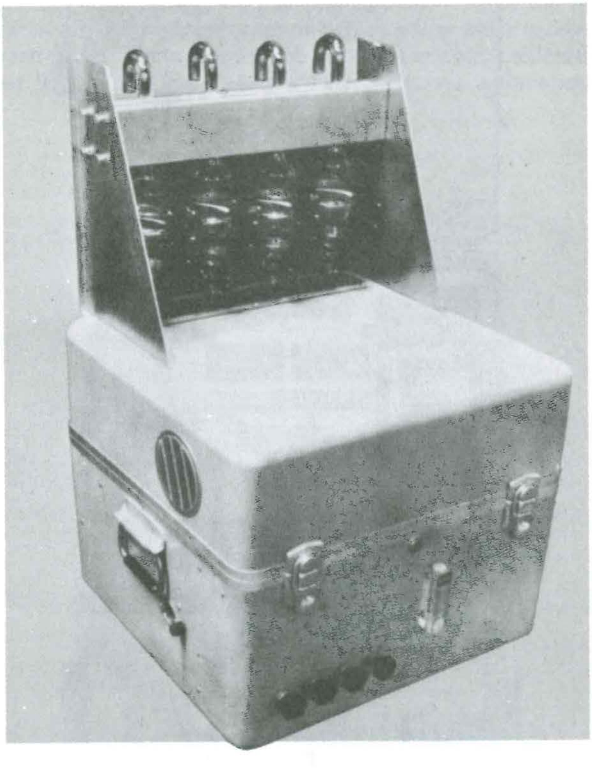

Figure 0-4 — The Sierra-Misco Sequential Pesticide Sampler, Model 88.

Physical description

Four sampling trains are supplied with a rugged weatherproof fiberglass case. Each train consists of a pre-filter, impinger, and absorption tube with a fitted rubber stopper. All glassware in the gas stream prior to the absorption tubes is borosilicate. Connections are made with glass ball and socket o-ring joints. The sampler is equipped with a positive displacement pump which is connected through a manifold to separate solenoid valves. An impinger cartridge is mounted for quick removal in the field. There is a calibration by-pass switch for each impinger and a control valve for setting the flow in each channel.

Dimensions: 34" × 22" × 22"; weight: 87 lbs; power: 115 VAC, 60 cycles, 8 amps; air mover: 2.7 cfm free air, 1.0 cfm at 21" Hg; flow meter range: 0.1 to 1.5 cfm.

Performance data

The instrument is capable of unattended operation, remains operable in inclement weather, and requires a minimum of maintenance.

* * *

Two-Stage Air Sampler, Model 7800

Sierra-Misco, Inc.
(address above)

This sampler is a 2-stage, stacked head dichotomous sampler. It is a basic low volume air sampler and can be customized to meet specific flow rates.

Operating principle and description

Two sets of heads are supplied with automatic switching after 24-hours of operation. This enables the operator to visit the site the following day and collect the previous day's sample while a current day's sample is being collected.

Pumps up to 10 cfm can be supplies. The shelter is modified hi-vol design.

Reference

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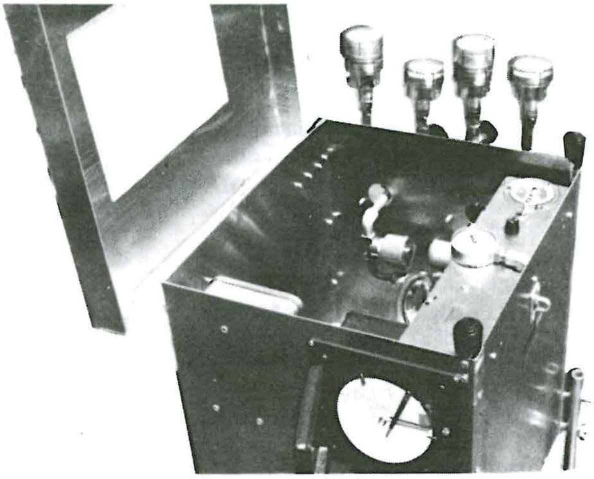

Figure 0-6 — Two-stage Air Sampler, Model 7800.

* * *

Programmable Atmospheric Sampler, Models RD113 and RD113-1

Gilian Instrument Corporation
1725 Route 23
Wayne, NJ 07470

These samplers are recommended for environmental applications including general environmental surveys, external plant surveys, and investigations of chemical dump sites where 115 VAC power is not available. In-plant uses include plant surveys, area monitoring, and chemical process hazard profiles.

Operating principle

These multi-purpose sequential samplers are designed for operation with either detector tubes or adsorption tubes. A constant volume pump draws air through each of the 23 sample tubes according to a pre-selected program. Detector tubes are evaluated either by color comparisons or by reading the tube markings. Gases or vapors collected by adsorption on activated carbon or other collecting agents are desorbed by heat or solvents. Identification and quantification are accomplished by such techniques as GC, GC-MC, or HPLC.

Physical description and performance data

The sampler consists of two modules. The interchangeable air flow module, located in the lid, contains the sample tubes, selector valve, and drive solenoid. Two lid configurations are available. The Model RD113 is designed for heat desorption sample recovery. The Model RD113-1 is intended for sample tubes using solvent extraction or visual evaluation. Sample rate can be set for 5, 10, 20, or 50 ml/min and sample time for one minute to 24 hours. An LCD shows time, day, and sample position. Printout includes time, sample tube number, and sample volume.

The power and control module, located in the base, contains the pump, printer, controls, logic and timing systems, and rechargeable batteries. The unit can operate either on these batteries or on line (115 VAC, 60 Hz). It is easily portable, weighing 15 lbs and measuring 7¾" × 14½" × 10½". The sampler collects up to 23 samples and will operate for up to 30 days on its rechargeable batteries.

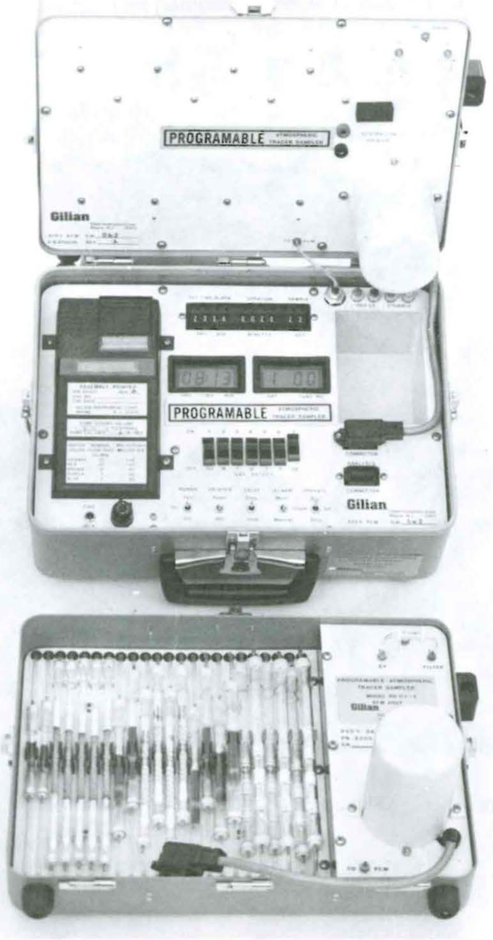

Figure 0-7 — Model RD113 with heat desorption lid is seen connected with the power and control module. The interchangeable Model RD113-1 Sample Tube Lid is seen below.

* * *

Automatic Dichotomous Sampler, Models 245-10 and 245

Sierra-Andersen
P.O. Box 909
Carmel Valley, CA 93924

Both of these samplers collect two fractions of particulate matter. The upper cut-point of the coarse fraction in the Model 245 is 15 micrometers and 10 micrometers for Model 245-10, while the upper cut-point for the fine fraction is 2.5 micrometers in both models.

The automatic filter changer allows unattended operation for weeks or months. The low-tare-weight 37 mm Teflon filters are easily weighed on a microbalance. The sampling period can be as low as one hour, giving near-continuous particle monitoring. The filters are ideal for analysis by X-ray fluorescence.

Operating principle

The flow of incoming air is directed upward so that its velocity is equal to the sedimentation velocity of the particles having the upper size limit. Larger particles settle out and do not reach the virtual impactor. Particles smaller than the 10 or 15 μm upper cut-point enter the impactor nozzle and are accelerated. Because of their greater inertia, particles larger than 2.5 μm impact into the "void" of the receiver tube. These coarse particles impact through a non-existent or "virtual" surface.

A flow of 0.1 m^3/hr is drawn through the receiver tube facing the accelerator nozzle. Coarse particles and 10% of the fine particles are uniformly collected on a 37 mm filter which is drawn around the receiver tube to a second 37 mm filter which collects the other 90% of the fine particles. Filter pairs are automatically inserted and removed from the sampling position by the rotation of the filter-holder carousel.

Figure 0-8 — Automatic Dichotomous sampler, Model 245.

Figure 0-9 — Inlet diagram of Model 245.

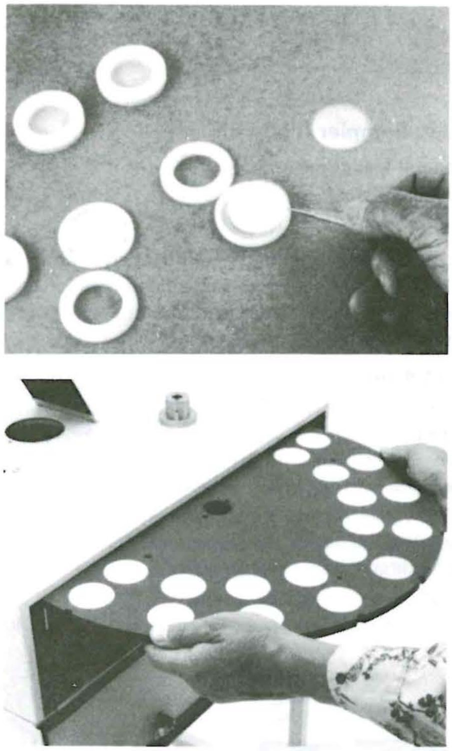

Figure 0-10 — Filter-holders and carousel of Model 245.

Physical description

The sampling module weighs 41.5 lbs and is 56" × 23½" × 21", while the control module weighs 55 lbs and is 16" × 22" × 11". The sampler requires 115 VAC, 60 Hz, 200 watts maximum. A model using 220 VAC and 50 Hz is also available. A standby battery maintains time-keeping function up to 10 days.

Performance data

The filter-holder carousel holds 20 filter pairs. The digital controller provides a sampling period of 1.0 to 99 hours and a skip time between sampling periods of 0 to 99 hours or 0 to 99 days. The LED digital display gives present time and sampling start time. A circular flow chart/event recorder gives an independent hard-copy record of both the total sampling flow and the time of the filter indexing.

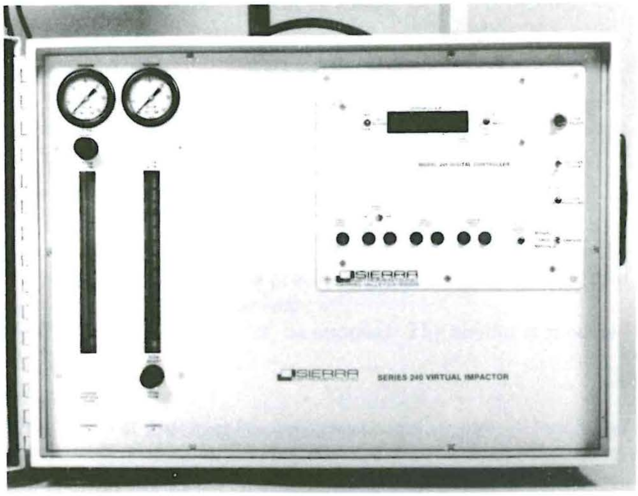

Figure 0-11 — Control module of Model 245.

* * *

Air Quality Sampler II and III

Environmental Measurements, Inc.
215 Leidesdorff Street
San Francisco, CA 94111

The Air Quality Sampler II (AQS-II) and Air Quality Sampler III (AQS-III) are used to collect whole-air samples for the determination of relatively stable gases such as carbon monoxide, sulfur hexafluoride, radon 222, and Freons®.

Operating principle

The AQS-II and AQS-III are multiple-pump samplers. They consist of a controller, power pack, a set of pumps each connected to its own plastic bag, and an enclosure. The pumps are pulse action positive displacement with a dry piston. The whole-air samples are delivered into the respective plastic bags according to a pre-programmed sequence. All operations are performed automatically as directed by the controller.

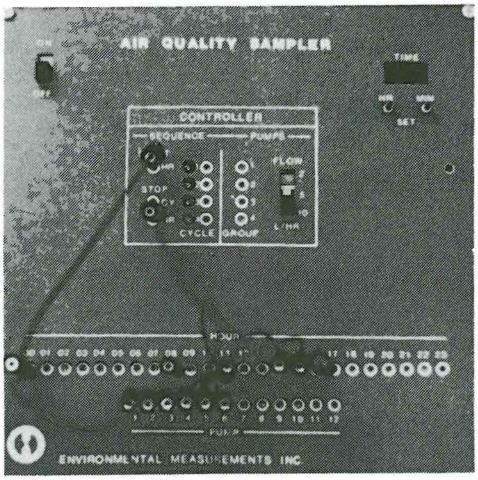

Figure 0-13 — Controller of Air Quality Sampler II.

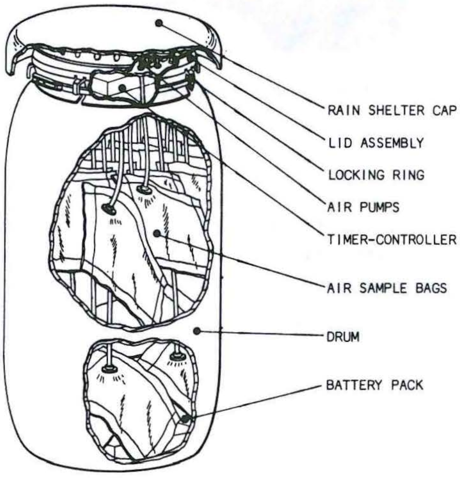

Figure 0-12 — Air Quality Sampler II.

Physical description

The AQS-II is supplied with an enclosure consisting of either a 120-liter or a 225-liter drum or without an enclosure. Both drums have an outer diameter of 60 cm (23.6"). Their respective heights are 76 cm (29.9") and 117 cm (46.1"). The 120-liter drum holds 12 2-liter bags or 8 5-liter bags. The 225-liter drum accomodates 24 2-liter bags, 12 5-liter bags, or 6 10-liter bags. Tedlar® bags, with thicknesses of either 2 or 4 mils, are supplied and available in 1, 2, 2.8, 5, 10, 15, 30, 50, or 100 liter sizes. Several different options of inlet fittings can be supplied for either sampler. The AQS-II is usually supplied with 8, 12, 16, or 24 pumps, and the standard controller is the 24-hour version, but a 96-hour model is also available. In either case, a particular pump may be activated for any desired one-hour period within the programming period. A lid assembly is used for the mounting of the time-controller and the pumps. A rain shelter cap is available for use at outdoor sampling sites. The weight is 11–14 kg (24.2–30.8 lbs).

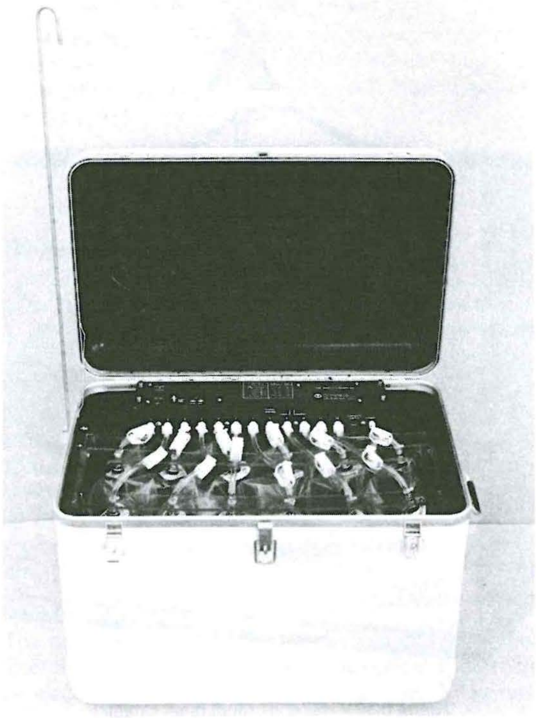

Figure 0-14 — Air Quality Sampler III.

The AQS-III is supplied with a 112-liter case which serves as the outer enclosure. This case is made of ABS plastic and is rectangular, 61 × 41 × 47 cm (24 × 16 × 18½"). The EMI Bag Box™ fits within this case and is used for the handling of the plastic bags. A mounting ring aligns the bags to the pump connectors. Use of the bag box is optional. The AQS-III is usually used with 12 2-liter bags (supplied in 2 or 4 mil thickness), and is usually supplied with 12 pumps and an inlet system for single point sampling. This sampler is furnished with two controller models, each with a 96-hour programming period. One of these is equipped with remote control for start/stop. The sampling period is selected at 10, 15, 20, 30, 40, or 60 minutes per bag. Other periods up to 16 hours are available. The weight is approximately 11 kg (25 lbs).

Both samplers can be obtained for operation with either a 12 VDC rechargeable gel-cell or an AC power pack. The AQS-II can also be operated with 4 dry cell lantern batteries.

* * *

Filter Tape Sampler/Monitor Cat. No. 205035-1 with Recorder

Andersen Samplers, Inc.
4215-C Wendell Drive
Atlanta, GA 30336

This instrument is used for monitoring atmospheric particles on an hourly or other sequential basis. It is adapted to the monitoring of hydrogen sulfide by use of tape impregnated with lead acetate. Sampler networks are used for determining the source and distribution of particles or hydrogen sulfide. This model is representative of a series of Tape Sampler/Monitors. Models with other combinations of features are available.

Operating principle

This particular model is equipped with an integral densitometer, automatic standardization, a recorder, and an alarm. The densitometer reading is automatically adjusted to 100% light transmission through the clean tape at the start of each sampling interval. The tape remains in the same position throughout each cycle. The spot is monitored continuously during sampling. The densitometer output is recoreded on a strip chart. COH values can be calculated from time, sampling rate, and densitometer readings. Concentrations of hydrogen sulfide can be determined by calibration graphs or charts obtained by sampling controlled atmospheres. An alarm is activated if readings exceed a preset level.

Physical description

The unit is 11¼" × 20¾" × 12", and weighs 53 lbs, and operates on 115 V, 60 Hz. This monitor is housed in a ventilated steel case. The vacuum pump, connecting tubing, and some other system components are located behind a control panel which divides the monitor into two compartments. The power switch, flow regulator, rotameter, timer, tape feed spool, tape takeup spool, sampling nozzle, densitometer, standardizer, timer, and recorder are all mounted on this panel. A clear plastic cover seals the front chamber.

Performance data

Hydrogen sulfide concentrations from 0.02 to 20 ppm are detected by lead acetate tape under standard sampling conditions. Particles down to 3.4 micrometer diameter are collected. Retention of smaller particles occurs as filter loading increases. The monitor is capable of unattended operation for extended periods of time.

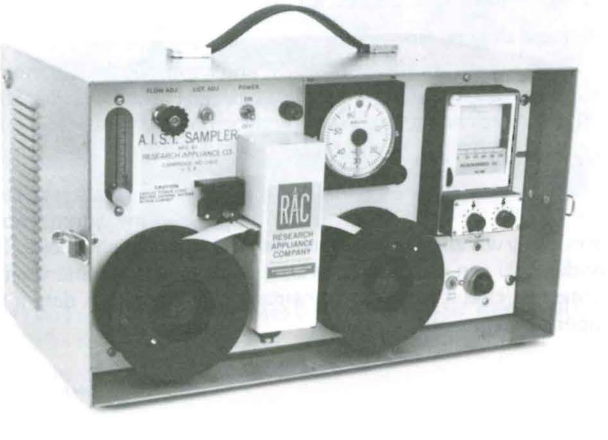

Figure 0-15 — Catalog No. 205035-1 Filter Tape Sampler/Monitor with recorder.

* * *

Fluoride (Dual Tape) Sampler

Andersen Samplers, Inc.
(address above)

Particulate and gaseous fluoride samples are obtained by sequential collection.

Operating principle

Two chemically treated tapes are indexed simultaneously through the sample nozzle. The upper tape collects particulate fluoride while the lower tape collects gaseous fluorides. Samples are evaluated by chemical analysis.

Physical description

The sampler is housed in a steel case with baked enamel finish. It is 23¾" × 20¾" × 12" and weighs 45 lbs. A panel divides the sampler into two compartments. An aluminum and clear acrylic plastic cover fits over the front compartment. The distinctive feature of this sampler is the two reel-to-reel tape sampling systems. Both of these are located in the front compartment. Both tapes are threaded through the same sampling nozzle. A push-to-test flowmeter, a flow regulator, a time, and a power switch are also mounted on the panel. A continuous rotary vane oil-less vacuum pump is mounted behind the panel. The pump exhaust is filtered and used to pressurize the front compartment. Models for operation at either 110 V, 60 Hz or 220 V, 50 Hz are available.

Performance data

The sampler can operate unattended for long intervals. Approximately 600 sample spots are obtained from each tape roll. The sampling time can be varied from 10 min to 3.5 hous in 10-min increments.

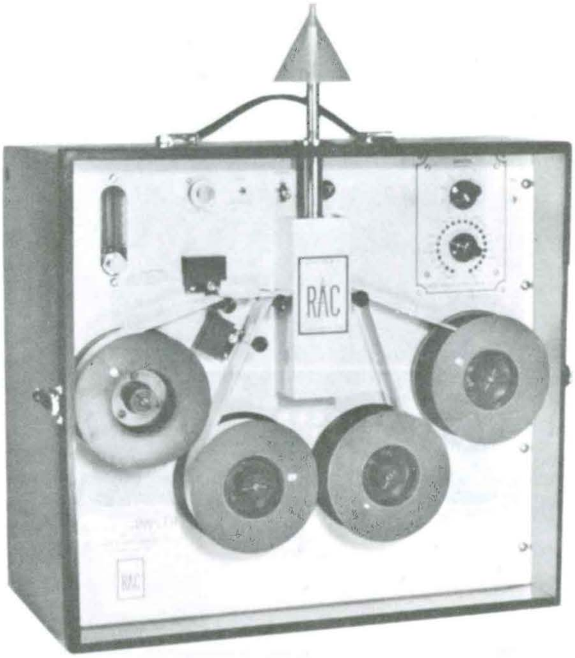

Figure 0-16 — Fluoride (dual tape) sampler.

* * *

Particulate Tape Sampler, Model 2500

Wallace•Fisher Instruments Company
P.O. Box 51, Ocean Grove Station
Swansea, MA 02777

This sampler is used for measurement of airborne particulate matter by sequential unattended sampling. Its range 0 to 10 COH/1000 ft.

Operating principle

This model is equipped with an integral photometer. A strip chart recorder is optional. An auto-zero circuit eliminates errors caused by variations on density of the clean paper. Sampling is usually conducted at 0.5 cfm for one hour.

Physical description

The sampler is 13" × 19" × 13" and weighs 50 lbs with pump, recorder, and case. It operates on 115 V, 60 Hz and requires 50 to 200 watts depending on type of pump supplied.

Performance data

The sampling head is self aligning so that air sealing gaskets seal parallel to each other. Tape advance is measured photoelectrically without the use of microswitches or punched tape. The Model 2500 can operate for at least 30 days without attention. A protective circuit prevents transmission of erroneous data if the paper tape runs out or breaks.

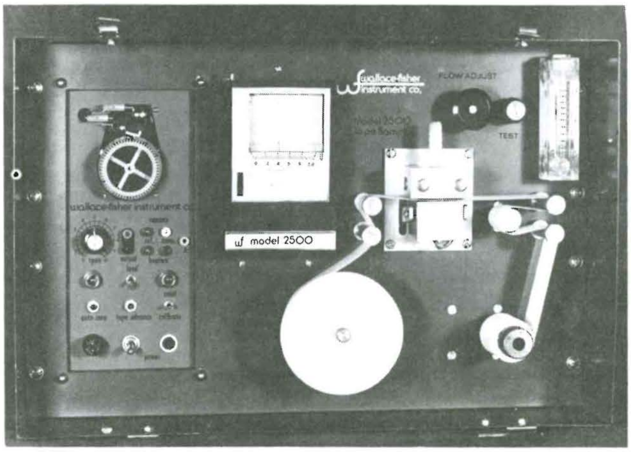

Figure 0-17 — The Wallace•Fisher Particulate Tape Sampler, Model 2500.

* * *

Hydrogen Sulfide Gas Analyzer, Model 825R

Houston Atlas, Inc.
Department AE
9441 Baythorne Drive
Houston, TX 77041

The Model 825R is used to monitor hydrogen sulfide in ambient air, in reformer recycle gas, in flare gases, and other applications.

Operating principle

The air sample passes over the surface of the lead acetate impregnated tape and the tape darkens on exposure to hydrogen sulfide. The rate of darkening is measured by comparing the light reflected from the tape with the light from the same lamp reflected by a mirror. Signals from the measuring and reference photocells are sent to the Rate Reading Electronic Console to produce a meter deflection. Zero drift and tape noise interference are eliminated by the solution of the first derivative equation in the rate electronics. The tape transport assembly is a timed-cycle system for the intermittent transport of sensing tape with the control accomplished by printed circuit cards in the rate reading electronic console.

Physical description

The major systems of the Model 825R are the sensing tape transport assembly, the flow system, the optical system, the rate reading electronic console, and the control panel. A flow regulator, flow meter, function switch, test jack, power switch, and concentration readout meter are mounted on the front panel. The cabinet opens at the top for access to the various compartments. The readout meter is a dual hydrogen sulfide indicator alarm set point meter. Adjustable low and high alarm set points can be manually positioned over the range of the meter. A strip chart recorder is available as an option. This system is 9⅝" × 20¼" × 18¾", weighs 50 lbs, and requires 115 VAC, 60 Hz, 30 watts power. A 220 VAC, 50 Hz model is also available.

Performance data

Since the air sample does not pass through the paper, the flow rate is not affected by the paper thickness or porosity and, therefore, is more nearly constant. Darkening is determined by measuring light reflected from the tape rather than transmitted through the tape. This too avoids errors that would be caused by variations in tape thickness and porosity. The sample is "bubbled" through a 5% acetic acid solution to provide constant moisture content. These features lead to an inherently stable analyzer. A line of analyzer and sampling systems is available for specific requirements.

Each instrument is factory calibrated to a requested range. A switch provides a 5 to 1 attenuation. A range of 0–20 ppb to 0–2 ppm full scale can be provided. Higher ranges require sample dilution. Calibration to a standard sample is accomplished by adjustment of the sample flow, instrument gain, and selection of reaction chamber.

* * *

Broad Range Hydrogen Sulfide Gas Analyzer, Model 825R/102

Houston Atlas, Inc.
(address above)

This model is used in a wide variety of applications. It is available in ranges from as low as 100 ppb up to 30%. It is used in monitoring hydrogen sulfide at ambient levels and in reformer recycle gas, waste gas, pipeline products, and flare gas.

Operating principle

The Model 825R/102 uses the same tape sampling system as the Model 825R and combines it with the Model 102 Range Extension Flow System. The high range capacity is obtained by precisely metering microliter volumes of the sample into a continuously flowing stream of nitrogen carrier gas.

Physical description

The analyzer is enclosed in a cabinet which is 12⅛" × 12¼" × 18" and weighs 50 lbs. A recorder is optional and separate. The readout and controls are located on the front panel. The standard model uses 115 V, 60 Hz. It can also be supplied for 220V, 50 Hz operation on request. Air usage at 60 PSIG is about 10 SCFH. Nitrogen usage at 15 PSIG is about 1 SCFH.

Performance

The performance is basically the same as that of the Model 825R with the added capability of determining concentrations as high as 30% hydrogen sulfide.

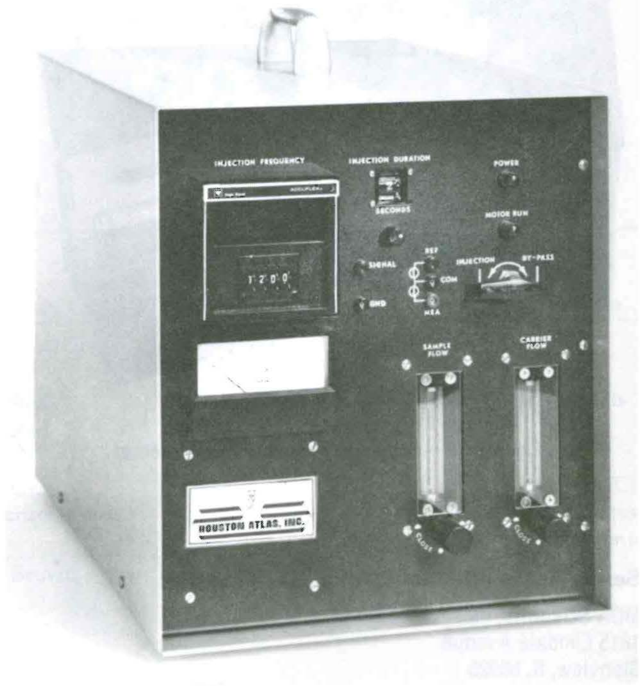

Figure O-18 — Broad Range Hydrogen Sulfide Gas Analyzer, Model 825R/102.

* * *

MPSI 100 Warning and Reference System

Dasibi Environmental Corp.
616 E. Colorado Street
Glendale, CA 91205

The MPSI 100 is used to monitor particulate matter in ambient air.

Operating principle

Particulate matter is collected on the sampling tape and the spot is evaluated by beta-attenuation.

Performance data

A programmed logic handles all sequencing, adapts to ambient dust conditions, and processes the mass-volume data. Results are given as a printout which includes date and concentration in micrograms per cubic meter.

* * *

Radon Daughter Analyzer, Model 101

The Harshaw Chemical Company
Crystal and Electronics Products
6801 Cochran Road
Solon, OH 44139

This analyzer determines atmospheric concentrations of Radon daughters and computes the working level from these concentrations and the defining equation.

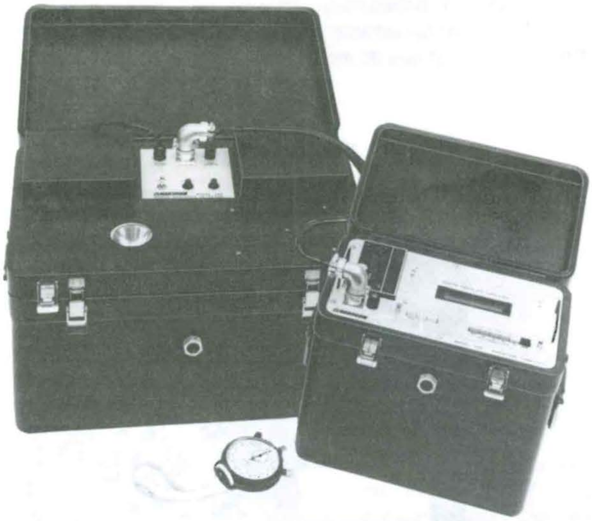

Figure O-19 — Radon Daughter Analyzer, Model 101

Operating principle

The air sample is drawn through the sampling area on the filter tape at a nominal rate of 32 lpm. At the end of the sampling time (2 min) the tape is advanced precisely between a solid state diffused junction (DJ) detector and a Harshaw CaF_2:Eu scintillation (CaF_2) detector. The DJ detector is mounted at the air inlet side of the filter for maximum alpha counting efficiency. The CaF_2 detector is mounted directly under the filter media opposite the DJ detector. It has a window thick enough to stop alphas. The thin CAF_2:Eu crystal has excellent efficiency for betas and yet is relatively insensitive to gamma rays which would contribute to background.

Alpha and beta counts are measured for two minutes. Radium A and C prime alphas are separated by energy. The computer determines disintegration rates from measured counts and known detector efficiencies. Concentrations and working level are computed automatically. The printout format is: radium A net counts; radium B net counts; radium C' net counts; radium concentration (picoCuries/L); radium B concentration (PicoCuries/L); Radium C' concentration (picoCuries/L); working level.

Physical description

Each Model 100 Radon Daughter Analyzer consists of a Model 101 Radon Daughter Detector and a Model 100 Radiation Computer.

Performance

The system provides live-time measurements (4+ minutes) with programmable automatic operation. It has a high detectability and wide dynamic range (10^{-3} to 10^{2} working levels).

* * *

Series 7000 Continuous Toxic Gas Monitors

MDA Scientific, Inc.
1815 Elmdale Avenue
Glenview, IL 60025

The series 7000 are used to measure organic isocyanates (0–20, 0–80 ppb), hydrogen sulfide (0–20 ppm), dinitrotoluene (0–0.4 ppm), phosgene (0–0.4 ppm), nitrogen dioxide (0–20 ppm), chlorine (0–4 ppm), hydrogen cyanide (0–20 ppm), sulfur dioxide (0–0.5, 0–20 ppm), hydrogen chloride (0–20 ppm), ammonia (0–50, 0–25 ppm), hydrazine (0–0.05, 0–1 ppm), or toluene diamine (0–0.08 ppm). Single or multipoint sampling configurations available for stack gas monitoring, as dilution systems (high flow mode) and enclosures for hazardous or corrosive atmospheres. Stack gas sampling is line operated, semi-portable in normal mode.

Operating principle

Chemically impregnated paper tape formulated for the detection of a specific compound or group of compounds. Photoelectric measurement of stain intensity when tape is exposed to toxic substance provides semi-logarithmic signal output for concentration documentation. Chemically impregnated tape is supplied in convenient Chemcassettes®, each one sufficient for one week (168 hours) of unattended operation.

Continuously moving at a constant rate, the tape develops a colored stain proportional to the toxic gas concentration in the air

Figure O-20 — Model 720 Continuous Toxic Gas Monitor.

sampled. The monitor utilizes a double beam principle in which a fiber optic light splitter produces equal beams of light to illuminate separate portions of the tape. Reference and measurement photocells in the optics block sense the light reflected from both an exposed and an unexposed portion of the tape and produces a reading in ppm or ppb on the front panel meter. A parallel signal is transmitted to the strip chart recorder, producing a permanent real time/concentration profile. The logarithmic output provides increased resolution at the lower end of the range, normally the area of greatest interest.

Self-contained audio and visual alarms are activated if a preset concentration is exceeded. In the standard monitor, the alarm point is adjustable from 10% to 100% of the instrument range. In the fast response mode, the time to alarm is three minutes or less at TLV levels, depending on the alarm point selected.

Physical description

Size and Weight: 10" × 16" × 11"; 25 lbs; *Sampling rate:* 100–500 cc/min, dependent on range. *External accessories:* strip chart recorder. *Power:* 120 VAC, 60 Hz, battery operation option available. Sample lines up to 20 feet can be used in most cases without auxiliary pump. Audio and visual alarms are normally local, relay output for remote alarm or activation of ventilation available. The analog signal is 0–1 mA DC from terminal on back of instrument; 0–100 mV or 4–20 mA options.

Performance data

See Table O-1 for specifications.

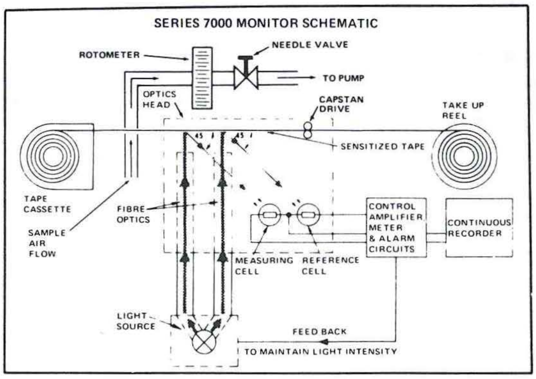

Figure O-21 — Schematic diagram of Series 7000

TABLE O-1
Series 7000 Specifications

Model Substance	PEL (Alarm Level)	Range	Minimum Detectable Level	Flowrate (cc/min.)	Stain Color	RH Range	Rise Time (95%) (Min.)	Noise (% of F.S.)	Interferences
7000 TDI/MDI	.02 ppm	0-.08 ppm	.005 ppm	500	Blue/Gray	10-95%	18	2%	—
7005 Organic Isocyanates	20 ppb	0-20 ppb (F.A.) 0-80 ppb (F.A.)	2 ppb 5 ppb	500 300	Red Red	10-95% 10-95%	5 2.5	5% 5%	High levels NO_2
7010 H_2S	10 ppm	0-20 ppm	2.5 ppm	150-200	Gray	10-95%	5	2%	10 ppm HCl = attenuates H_2S response
7015 2,4 DNT	0.1 ppm	0-.4 ppm	.02 ppm	400	Brown	25-95%	6	2%	—
7020 Phosgene	0.1 ppm	0-.4 ppm (F.A.)	.02 ppm	450	Red	10-95%	2	5%	—
7025 HCl	5 ppm	0-20 ppm (F.A.)	1.5 ppm	500	Blue	5-75%	5	5%	—
7030 NO_2	5 ppm	0-20 ppm	1.5 ppm	225	Red/Brown	10-95%	2	2%	Cl_2, NO_2 (1:1)
7040 Chlorine	1 ppm	0-4 ppm (F.A.)	.25 ppm	250	Red/Brown	10-95%	2	5%	Br_2, NO_2 (1:1)
7045 HCN	10 ppm	0-20 ppm	1 ppm	150	Red	20-80%	—	2%	—

TABLE O-1 (continued)
Series 7000 Specifications

Model Substance	PEL (Alarm Level)	Range	Minimum Detectable Level	Flowrate (cc/min.)	Stain Color	RH Range	Rise Time (95%) (Min.)	Noise (% of F.S.)	Inter-ferences
7050 SO_2	5 ppm	0-20 ppm 0-.5 ppm Available	1 ppm .025 ppm	125	Red	10-95%	6	2%	—
7060 NH_3	25 ppm	0-50 ppm	2.5 ppm	250	Blue	5-95%	5	2%	—
7065 Aliphatic Amines	—	0-10 ppm (F.A.)	—	500	Blue	5-95%	—	—	—
7080 Hydrazine (UDMH,	.1 ppm	0-1 ppm (F.A.)	.05 ppm	300	Blue	10-95%	2.5	5%	—
MMH)		0-.5 ppm (F.A.)	.025 ppm	500	Blue	10-95%	2.5	5%	—
7090 Toluene Diamine	.02 ppm	0-.08 ppm	.005 ppm	400	Red	10-95%	6	2%	Aromatic Amines

Operating Temperature Range: 0-40°

* * *

Series 4000 MCM (Minature Continuous Monitor) Personal Monitoring System

MDA Scientific, Inc.
(address above)

This system is used for breathing zone monitoring of personal exposures to TDI/MDI (0–0.08 ppm), phosgene (0–0.4 ppm), or toluene diamine (0–0.08 ppm).

Operating principle

Chemically impregnated tape formulated for the detection of a specific compound or group of compounds. Photoelectric measurement of stain intensity when tape is exposed to toxic substance provides semi-logarithmic signal output for concentration documentation.

Ambient air is drawn through a continuously moving tape which is transported past the exposure orifice at 2 cm/hour, permitting reaction with the contaminated air. After exposure of up to 8 hours, readout of the stained tape is done on a specifically designed Series 4100 Integrating Reader/Recorder. Light of equal intensity (from a common source through matched fiber optics) is directed to both the exposed and unexposed portions of the tape. Matched photoelectric detectors measure the difference in reflected light, producing a differential output signal to the strip chart recorder. Time versus ppm levels are documented and the total dose is computed. Both are displayed as a Datagram®, providing complete exposure profile in a convenient format.

Physical description

The MCM is 6" × 4" × 2", weighing 1.5 lbs, while the Integrating Reader/Recorder weighs 20 lbs and is 10" × 11" × 12". The sampling rate of 100 cc/min is electronically regulated. The rechargeable power supply unit for the MCM has a running time of 10 hr/charge. The Integrating Reader/Recorder runs on 115 V, 60 Hz. MSHA approved (No. 2G-2872); BASEEFA Certification No. EX75155 for use in hydrogen and acetylene atmospheres.

Performance data

Lower detection limit for Model 4000 TDI/MDI = 0.002 ppm, Model 4020 Phosgene = 0.01 ppm, and Model 4090 TDA = 0.002

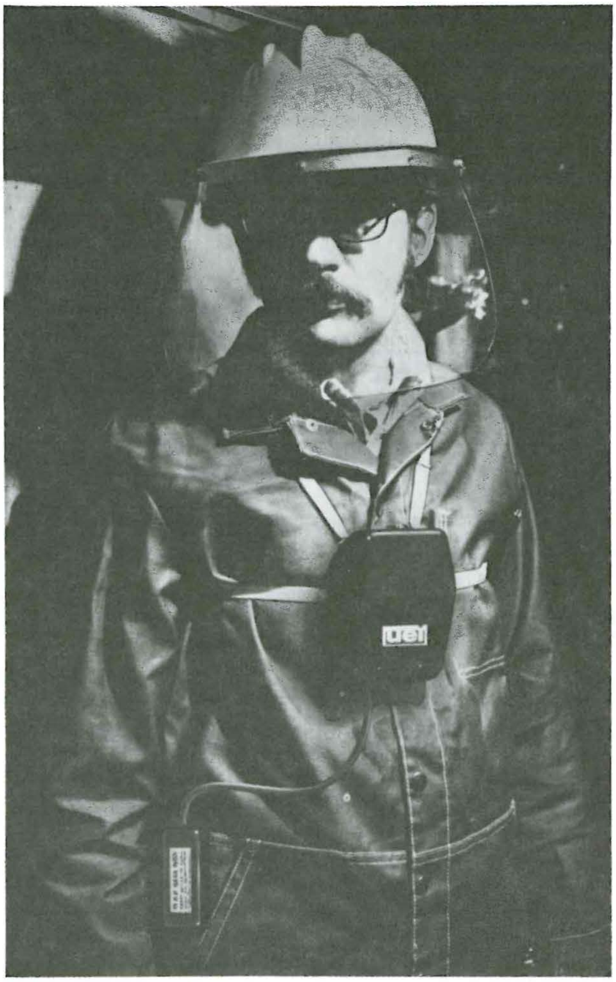

Figure O-22 — Series 4000 MCM — chest mounted.

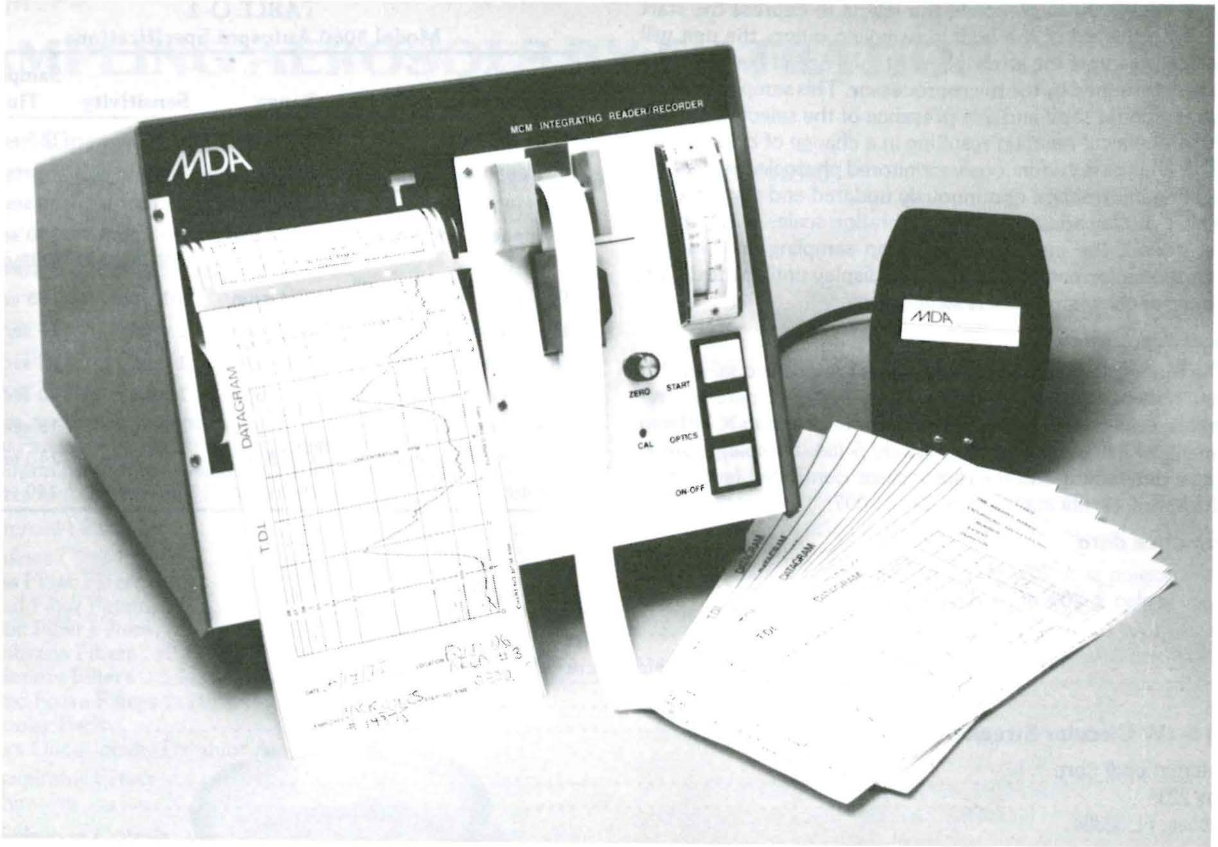

Figure 0-23 — Datagram from Series 400 MCM.

ppm. Specificity for Model 4000: no response to amines; response to high levels of NO_2; Model 4020: no response to chlorinated carbonyl compounds; and Model 4090: some response to other aromatic amines. The precision and accuracy are ± 15% and ±10%, respectively. Thirty second readout subsequent to exposure. Series 4100 — internal calibration check; manual zero adjust. Scales are semi-logarithmic.

* * *

Model 3060 Autospot — Microprocessor-based Spot Sampling Instrument

MDA Scientific, Inc.
(address above)

This instrument is designed for ambient portable use to measure toluene diisocyanate (0–0.2 ppm), hydorgen sulfide (0–20 ppm), phosgene (0–0.4 ppm), nitrogen dioxide (0–20 ppm), chlorine (0–4 ppm), ozone (0–0.5 oppm), sulfur dioxide (0–20 ppm), ammonia (0–50 ppm), hydrazine (0–1.0 ppm), diethyl amine (0–10 ppm), hydrogen cyanide (0–20 ppm), toluene diamine (0–0.8 ppm).

Operating principle

Chemically inpregnated tape formulated for the detection of a specific compound develops a colored stain when exposed to the toxic substance. Photoelectric measurement of the stain intensity produces an output signal for concentration documentation.

The chemically impregnated paper tape is supplied in a appropriate test card which contains the range and scaling information for the gas to be detected. This test card is inserted into the entry inlet located on the front of the instrument and the two digital selector switches are set according to the program code provided.

Figure 0-24 — Model 3060 Autospot Toxic Gas Detector.

All that is necessary to complete the test is to depress the start button. With the aid of the built-in sampling pump, the unit will automatically sample the atmosphere at the correct flow rate and period as determined by the microprocessor. This sample is drawn through the paper tape and any presence of the selected gas will produce a chemical reaction resulting in a change of color on the tape. This change is continuously monitored photoelectrically and the resulting information continuously updated and displayed on an LED bar display adjacent to the calibration scale. At the end of the test period, the instrument will stop sampling and the gas concentration information is held on the display until the test card is removed or the instrument is switched off.

Physical description

The Model 3060 Autospot is designed for intrinsic safety. No external accessories are needed for this battery operated (rechargeable, sealed lead/acid 6 volt), 100 mm × 210 mm × 190 mm instrument which weighs approximately 5 lbs. Sampling rate is substance dependent and microprocessor controlled (see Table O-2). Its INIEX certification No. is 80-101-007.

Performance data

Its precision is ± 20% of gas concentration reading at TLV. Accuracy is also ± 20% of reading.

TABLE O-2
Model 3060 Autospot Specifications

Substance	Range	Sensitivity	Sampling Time
Hydrazine	0-1 ppm	.1 ppm	165 seconds
Nitrogen dioxide	0-20 ppm	1 ppm	15 seconds
Ammonia	0-50 ppm	1 ppm	30 seconds
Toluene diisocyanate	0-.02 ppm	.001 ppm	240 seconds
Chlorine	0-4 ppm	.25 ppm	105 seconds
Phosgene	0-.4 ppm	.01 ppm	105 seconds
Hydrogen sulfide	0-20 ppm	1 ppm	15 seconds
Sulfur dioxide	0-20 ppm	1 ppm	15 seconds
Hydrogen cyanide	0-20 ppm	1 ppm	30 seconds
Diethylamine	0-10 ppm	.05 ppm	15 seconds
Diaminotoluene	0-.08 ppm	.005 ppm	240 seconds
Ozone	0-.5 ppm	.003 ppm	240 seconds

* * *

Model S-1W Circular Streaker

PIXE International Corp.
P.O. Box 2235
Talahassee, FL 32304

The Circular Streakers are used for unattended monitoring of airborne particulate matter at inside locations. It is designed to collect samples which can be analyzed by Proton Induced X-ray Emission (PIXE).

Operating principle

A filter is glued onto a plastic holder and is rotated by a timing motor over a 2 × 5 mm orifice. A vacuum applied at the orifice draws air through the filter so that particulate matter is collected on the filter to form a continuous track or ring which is 5 mm wide.

Physical description

This instrument is 4–7" in diameter and 6" high and weighs 2.6 lbs. It requires 115 VAC, 60 Hz, 4 watts power.

Performance data

The sampler can operate for one week on a single filter element. Analysis by PIXE can give element analysis with two hour resolution. The upper cut-off in particulate size is nominally 15 μm when the sampler is operated with the inlet facing down. The flow is approximately 1.0 lpm at 25" Hg with a 0.4 μm pore Nuclepore filter. A prefilter of 8 or 12 μm pore size Nuclepore may be easily attached to limit collection on the advancing filter to the respirable fraction. Filters other than the 0.4 μm pore can be used on the advancing filter.

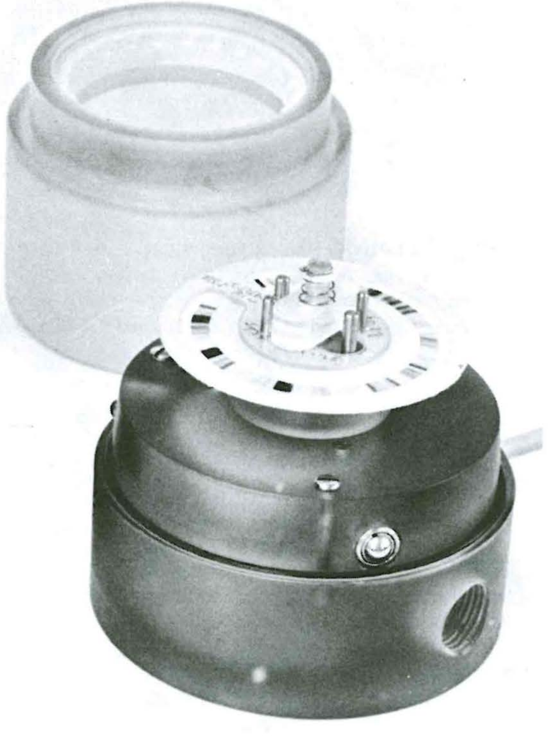

Figure 0-25 — PIXE Model S-1W Circular Streaker.

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Air sampling instruments

for evaluation of atmospheric contaminants

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