Chapter V

DIRECT READING INSTRUMENTS FOR ANALYZING AIRBORNE GASES AND VAPORS

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Contents

Potentiometric Analyzers (liquid phase surface active sensors)

Coulometric Analyzers (liquid phase or surface active sensors)

Flame Ionization Detectors

Radioactive Gas Detectors

Thermal Conductivity Detectors

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Introduction

This discussion is confined to gaseous pollutant analyzers that detect the pollutant in the gaseous phase. These instruments make a quantitative analysis that is read out directly on an indicating meter, recorder, or other display. The distinction between these devices and nondirect reading devices is primarily that in the latter, analysis and/or measurement of an air pollutant is conducted after collection and at another location.

Physical principles of detection are discussed in this section, and current instrument systems are categorized according to these principles. In general, the input sensor that generates the electrical signal with its information content operates on one of these principles; however, this sensor may or may not be immediate to the sampling process. A gas pollutant, for example, may be detected by infrared absorption immediately upon sampling. On the other hand, there may be an intermediate step between sampling and detection as is the case in colorimetric gas analyzers in which the gas is collected in a chemical reagent, allowed to react, and then analyzed colorimetrically. Often in such a case the principle of operation may be referred to as a chemicophysical method, to indicate the intervening chemical process before physical analysis. Chemical treatment predisposes the sample to the analytical method. In this discussion, both physical and chemicophysical instrumentation are discussed, although methods are categorized explicitly in terms of physical detection and/or analysis techniques.

Principles of Detection

Several physical methods of detection and analysis are applied in the instrumentation described in this section. Physical methods in analytical instrumentation are well documented in the literature with respect to the theory, principles of operation, and application. The listing of instrument descriptions in the Table of Contents is ordered according to the various methods which may be used for gas pollutant measurements.

In the discussion in this section, these methods are not represented necessarily by specific instruments, but do indicate possible and feasible applications. In some instances, a specific device may provide a means of overcoming the limitation of the physical method involved, and thus be a more effective device than the method itself implies. Descriptions of the devices themselves usually bring out these points. On the other hand, in the application of any device, consideration should be given to the limitations normally imposed by the physical method itself or the means which utilize the method and to the evaluation of the performance specifications given to overcome these limitations.

The limitations discussed may or may not be pertinent to all applications of a device. Electrical conductivity measurements, for instance, are nonspecific in the sense that anything that ionizes will affect the measurements. However, if the application is one in which the pollutant is at relatively high concentrations and has much greater conductivity than known interferences, then lack of specificity ceases to be a significant consideration. Sulfur dioxide in a stack effluent as a result of combustion of high sulfur coal is an example.

The information being presented below should serve as background knowledge. Knowledge of the measurement problem under consideration and related ramifications, such as environmental conditions and subsequent data handling and interpretation, allow selection of an instrument most appropriate for specific situations.

Electrical

This category includes the various methods by which chemical and/or physical properties of the gas pollutant introduce changes in the electrical parameters of the input sensor so that sensor output is related to the concentration of the gas being measured.

Conductivity

Gases that form electrolytes in an aqueous solution cause a change in the electroconductivity of the solution. Since the electric conductance of the solution is a summation of the effects of all ions present, the method is not specific. Assuming that concentrations of all other electrolyzing gases are either constant or relatively insignificant, then the observed conductance can be related to the concentration of the gas being measured.

Temperature control is important in conductance measurements because, in electrolytic conduction, the temperature coefficient can be on the order of 2% per degree Centigrade. Cabinets equipped with thermostats are sometimes used to maintain temperature equilibrium.

To obviate the need for temperature control, electrical compensation is sometimes used. Variations in test solution temperature are accounted for automatically by a thermistor immersed in the test solution. The thermistor is part of the electrical circuit and is selected to have a temperature coefficient of resistance that will permit satisfactory compensation over a range of temperature variations.

Potentiometry

Gases that react with reagents in solution to change the pH of the solution produce a potentiometric change that reflects the concentration of the reacting gas. The potentiometric change is sensed by a galvanic cell commonly referred to as a "pH electrode." The galvanic cell is basically a system in which energy associated with chemical reactions is converted into electrical energy in the form of an electromotive force (emf). In analytical applications it depends primarily on concentrations of the substances involved in the electrode reactions.

To obtain a correct measure of the emf sensed by a pH electrode, a potentiometric measurement is required. This is defined as a measurement in which there is no flow of current into

or out of the cell being measured. Null balance potentiometers meet this requirement. Other techniques in use, such as vacuum tube voltmeters and pH meters, result in observations with relatively negligible current flow ranging from 10^{-6} to 10^{-14} ampere.

In principle, pH change, or potentiometry, is nonspecific. In practice, a certain amount of specificity may be introduced by the choice of reagents that are most conductive to the desired reaction for the gas to be sampled. The carbon dioxide analyzer developed by Lodge[1] is an example of potentiometric measurement of equilibrium pH in the reaction of carbon dioxide with a suspension of insoluble carbonate in the form of marble chips. The hydrogen-ion activity gives a measure of the carbon dioxide concentration.

Coulometry

Coulometry is the measurement of the number of electrons in terms of coulombs transferred across an electrode-solution interface to carry to completion the reaction of a particular substance in a sample. In instrumental applications, such as the Titrilog, the measurment involves an indirect determination of the number of coulombs required for the production of bromine that reacts with the sulfur dioxide being determined. The method is inherently sensitive since a microcoulomb equivalent corresponds to nanogram amounts and less of most simple substances.

In principle, there is no restriction in coulometry relating to the volume of the sample or to the concentration of the substance in the sample. Furthermore, since the method basically involves a measurement of the number of coulombs required for a particular reaction, it does not include provision for determining the end point of the reaction. As a result, any of the known methods of end-point detection may be utilized. The sensitivity of the end-point detection technique, however, may become the limiting factor in the ability of the coulometric system to detect very low concentrations.

Ionization

Detection by ionization is based fundamentally upon making a gas conductive by the creation of electrically charged atoms, molecules, or free electrons, and the collection of these charged particles under the influence of an applied electric field. Various ionizing reactions used for the measurement of gas concentrations have been discussed in considerable detail by Lovelock.[2] Ionization is actually a special case of electrical conductivity as a physical method of detection. Since prime consideration, however, is given to the ionizing reactions rather than the resulting conductivity, ionization is identified separately. As a conductivity measurement, the method in general is nonspecific. The nature of the ionizing reaction, however, may make the method more or less specific.

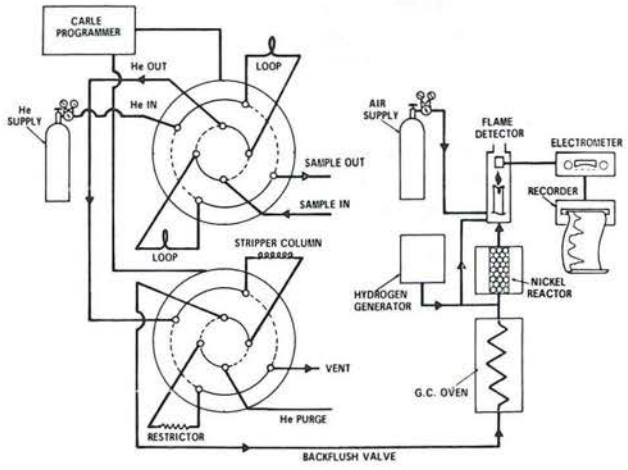

Figure V-1 — Automated-gas-chromatographic flame-ionization detection system for CO and CH_4 analysis.

Flame ionization is a method that has been applied in commercial instruments (Figure V-1). The great increase in production of ions by introducing a volatile carbon compound into a hydrogen flame burning in air provides a sensitive method of ionization detection. A satisfactory explanation of the process leading to production of ions in this manner remains to be made, although some explanations have been offered. This detector has a wide linear dynamic range and a response extending to a concentration of approximately 1.0%. It is insensitive to the presence of such contaminants as air or water vapor, but responds to most organic compounds. Response is depressed with compounds having electronegative atoms such as oxygen, sulfur, and chlorine. Changes in geometry, flow rate, and composition of the gases supplied to the flame alter the relative response of the detector to different compounds.

Special case

An electrochemical technique may be combined with a selective sampling scheme to give better discrimination. Examples of this technique are some commercial instruments that sample through a gas-permeable membrane. The membrane is selected for its capability to be highly specific in the gas or gases that can pass through it.

Radioactive (tracers)

Detection of very low levels of radioactive substances by well-developed physical methods such as scintillation and Geiger counters points to the use of a radioactive tracer in a clathrate reaction. In a device reported by Bersin,[3] SO_2 reacts with $NaClO_2$ to release ClO_2, which reacts with a clathrate in which ^{85}Kr is released. The released ^{85}Kr is detected by a Geiger counter, and the resulting count rate is related to the SO_2 concentration initiating the reaction. The method is sensitive to concentrations in the order of 1.0 ppm and specific only to the extent that the initial reaction is limited to the gas being studied. In the device cited, for example, NO and NO_2 may provide significant interference, depending upon their concentrations relative to SO_2.

Thermal

Detection of various thermal properties of gases is a widely used method of gas analysis. Two thermal properties of gas contaminants, conductivity and combustion, have served as the basis of operation of instruments currently in use.

Conductivity

The specific heat of conductance for a gas provides a physical method of quantitative measurement. The method is nonspecific, however, for a mixture of gases. Where mixtures are resolved into components, as in a chromatographic column, thermal conductivity is used extensively. Nevertheless, for a mixture of a few components in which one gas has a significantly high coefficient of thermal conductivity and occurs at a relatively larger concentration, thermal conductivity can be used with some success. Often, a differential measurement may be used to balance out the presence of other gases so that a change in concentration of the gas of interest can be detected. A combustible hydrocarbon in air, for example, is burned; the carbon dioxide is measured before and after combustion, and the change in carbon dioxide is related to the hydrocarbon content. In applying this technique, one must consider the increased water vapor as a product of combustion. It can be accounted for either by drying or saturating the sampled air stream before and after combustion. Although carbon dioxide has low solubility in water, at very low concentrations such a procedure may present additional problems.

Combustion

The heat of combustion, a particular physical characteristic of

combustible gases, is used for quantitative detection. Suffering the same limitation as thermal conductivity, this method is also nonspecific; depending upon sampling and measurement conditions, it may or may not be used appropriately to give satisfactory results.

One type of thermal combustion cell involves a resistance bridge in which the arms of the bridge are heated filaments. The principle of operation consists of introducing the sample into the gas cell in which the combustible gas ignites upon contact with a heated filament. The resulting heat of combustion changes the resistance of the filament. The change in resistance is detected by conventional bridge measurement techniques and is related to the gas concentration on the basis of calibration standards.

Another combustion method uses catalytic heated filaments or oxidation catalysts, and detection is by change in resistance in a balanced bridge or by thermocouples, respectively. Combustion can be made more or less specific by operating specified filament temperatures so as to ignite the gas of interest and/or by selection of an oxidation catalyst favoring a desired reaction such as "hopcolite" for carbon monoxide.

Electromagnetic

Electromagnetic techniques have been utilized customarily in absorption spectroscopy in which electromagnetic energy, in the form of ultraviolet (UV), visible, and infrared (IR) radiation, is absorbed by a pollutant medium. Recent advances in spectroscopy have introduced a number of techniques that are being adapted to gas analyses.[4] These include microwave radiation, correlation spectroscopy, Raman radiation, laser sources, solid-state detectors, derivative spectroscopy, and Fourier spectroscopy. Some of these techniques are being applied to emission and scattering of electromagnetic waves by pollutant gases in addition to the absorption phenomena.

These electro-optical techniques offer a broad range of applications, some of which cannot be achieved by any other methods. For example, long-path *in-situ* gas analyses as well as remote sensing can be conducted by electro-optic methods only. These methods are applicable to point sampling as well.

For this discussion, it is probably most appropriate to consider first the three basic molecular phenomena under which these methods fall, namely, absorption, emission, and scattering. Subsequently, there follows a discussion on the various spectroscopic schemes by which these phenomena are detected and analyzed.

Molecular phenomena. Molecules characteristically absorb, scatter, and emit electromagnetic radiation. The unique relationship of the radiation involved in any of these processes with the molecular structure permits qualitative identification and quantitative concentration measurements to be made of material composition.

Absorption. Gas molecules absorb incident electromagnetic energy at wavelengths corresponding to the change in energy states of a given molecule.

Emission. Gas molecules emit at wavelengths corresponding to the change in energy states of a given molecule. Absorbing wavelengths are identical to emitting wavelengths for a specific change in the energy state of a molecule. Absorption constitutes an increase in energy; and emission, a decrease in energy.

In emission, the source of energy can be internal, such as thermal emission, or external, such as chemiluminescense by chemical interaction.

Scatter. Incident radiation can be scattered as well as absorbed, or it may be absorbed and re-emitted at a different wavelength. Energy scattered by molecules at the same wavelength as the incident wavelength is referred to as Rayleigh scatter. Energy absorbed at absorbing wavelengths to raise the energy state of the absorbing molecules and re-emitted at new wavelengths is referred to as fluorescent scatter. The shift in wavelength, indicating some loss in energy, is toward longer wavelengths.

In Raman scattering, the incident radiation causes a virtual transition in the molecular energy states with re-emission of radiation at both longer and shorter wavelengths than that of the incident radiation. Raman scattering does not require the incident radiation to be at or near the absorbing wavelength of the gas and can thus take place at any wavelength. The intensity of Raman scattering, however, increases inversely as the fourth power of the wavelength of the incident radiation. Consequently, the UV region is the more attractive region for Raman scattering than the IR portion of the spectrum. Raman scattering is further enhanced by a factor of 100 or more when the incident radiation is near the absorbing wavelength of the gas. This is referred to specifically as resonance Raman scatter.

Infrared photometry

Nondispersive methods. Many pollutant gases have characteristic absorption lines in the infrared region of the electromagnetic spectrum. The nondispersive method avoids the use of dispersive optics, e.g., prisms or gratings. Selectivity in sensing the pollutant at its absorbing wavelength is achieved in one of several ways: by selective light sources (lasers), by selective detectors, by selective filtering of light sources, or by combinations of these ways.

Infrared gas analyzers are available for measurement of CO, CO_2, and some hydrocarbons (methane) by selective detection using gas filters.[5] In a typical analyzer, infrared radiation from two hot filament sources passes through parallel tubes, one a "reference" cell (containing clean air) and the other the "analysis" or "sample" cell (containing the pollutant gas, i.e., CO in air). Some of the radiation is removed by the CO in the sample cell at its absorbing wavelegths, and the remainder passes on to the detector. The detector is made selective only to the absorbing wavelengths of CO by filling it with pure CO. The detector generates an electrical signal output based on the difference in absorption between the reference and sample cells. This output becomes a quantitative measure of the concentration of CO in the sample cell based on calibration of the output readout.

A nondispersive fluorescent IR CO analyzer using a novel approach has been developed.[6] In principle, the technique consists basically of absorption spectroscopy in which the source of energy is fluorescence from a gas cell matching the pollutant gas under analysis. In principle, this gives the perfect wavelength correlation, high signal-to-noise ratio, and excellent discrimination.

In the instrument development for CO (Figure V-2), infrared radiation from the black body source stimulates the CO molecules in the sealed fluorescent cell that in turn provides the fluorescent radiation as the source of energy for the absorption measurement. The chopper cells containing $C^{16}O$ and $C^{18}O$ are part of the analytical scheme whereby the measurement is uniquely sensitive to the presence of CO in the sample tube. Briefly, if the $C^{16}O$ and $C^{18}O$ signals are defined as the "A" and "B" signals, respectively, only the "A" signal will be attenuated by the presence of CO gas in the sample tube since the natural isotopic abundance of $C^{18}O$ is

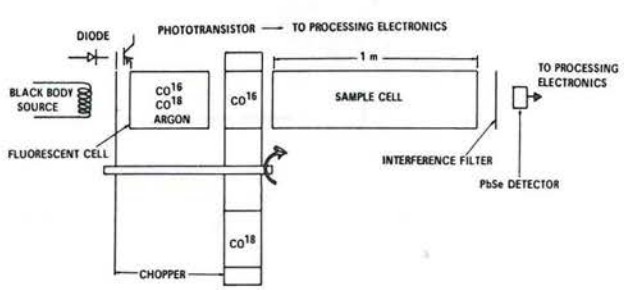

Figure V-2 — Argon fluorescent NDIR CO analyzer.

only 0.2% of $C^{16}O$. The processing electronics generate an output proportional to the quantity B-A/B. This expression shows sensitivity to differential absorption of the two signals. In addition, maintenance of the "B" signal at fixed amplitude by automatic gain control allows the measurement to be independent of variations in source power of detector response.

The arrival of laser sources, offering monochromatic wavelengths and high beam intensities is a significantly new development. Although lasers are highly selective light sources and the state-of-the-art in developing lasers for operation at various wavelengths is advancing very rapidly, there are still limitations on what wavelengths are presently available. The technique of selecting a laser line that coincides with an absorption line of a gas as a means of specific and sensitive gas analysis has been demonstrated.[7,8] Current developments in tunable dye lasers[9] in the UV and visible, and tunable solid-state diode lasers in the infrared,[10] offer great potential for a range of specific and sensitive gas analyzers with direct readout.

Selective filtering of light in nondispersive techniques can be achieved anywhere between the light source and the detector as another means of sensing a pollutant at its absorbing wavelength. It is done most effectively with filters at the detector. Optical filters are available with various specifications on transmission, bandwidth, and location of center wavelength of transmission. Interference filters provide very narrow transmission bandwidths, but do not approach the wavelength resolution capability of dispersive techniques. Prototype long-path spectroscopic instrumentation has been developed using interference filters for detection of ozone.[11]

Resolution of filtering techniques in the infrared range is in the order 10 cm^{-1} as compared to absorption linewidths that may be in the order of 0.1 cm^{-1} at atmospheric conditions. Consequently, interferences are possible because of overlapping absorption lines from other pollutant gases within the transmission band of the filter. This necessitates correcting for interferences by additional measurements in adjacent spectral regions and introduces more complexity in the analytical scheme and instrumentation.

In comparison, the use of lasers as a selective light source offers the advantage of a very narrow line (in the order of 0.001 cm^{-1}) to give high discrimination against interferences. On the other hand, selective light filtering and detection by gas filters offers the resolution of the absorbing gas itself and deletion of all the lines of the absorbing gas. This method is also referred to as gas correlation spectroscopy as compared to optical correlation spectroscopy, which will be discussed later.

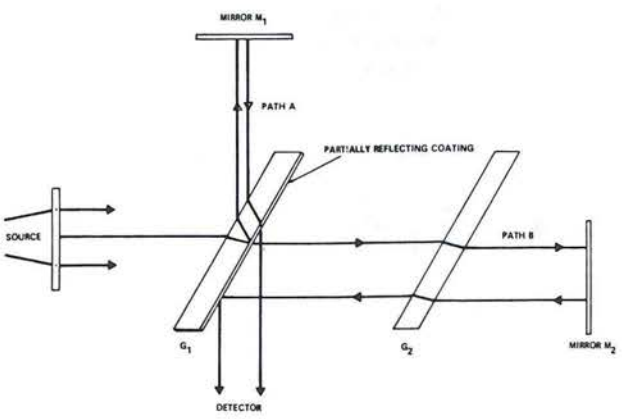

Figure V-3 — Michelson interferometer.

Dispersive methods. Dispersive methods are used in spectrophotometers having optical elements such as prisms or gratings. These elements disperse spatially the light from a broadband source so that wavelength selection may be achieved by means of proper physical placement of mechanical slit openings. Resolution is related primarily to the slit width, dispersive power of the optical element, and the optical configuration of the instrument. The limiting factor on resolution is the dispersive optical element. Gratings are available that permit resolution in the infrared in the order of 0.1 cm^{-1} and less.

The dispersive technique permits continuous scanning of the spectrum within the wavelength region of the dispersive element. This is an advantage over fixed optical filter techniques. In the infrared region, for example, a grating can cover the region from 7 to 14 micrometers. Lasers fall in between since they can have a single wavelength, or, as in the case of an isotopic CO_2 gas laser, have as many as 150 discrete lines. These lines fall within a narrow range of the spectrum, however, and being discrete, do not really permit a continuous scan.

Ultraviolet photometers

Ultraviolet photometers operate on the characterisitic of certain gases to absorb ultraviolet radiation. An appropriate wavelength is selected for the detector based on the absorption characterisitics of the pollutant of interest. Mercury, for instance, has a strong absorption at 254 nanometers. The reduction of energy at this wavelength, transmitted to the photometer as a result of absorption by vapors in the gas samples, is a measure of mercury vapor concentration. Other spectroscopic techniques such as correlation and derivative techniques, as discussed below, are also applied to UV detectors.

Other photometric techniques

Fourier interferometry. Interferometer-spectrometer is a dispersive-type instrument that permits an examination of a large portion of the spectrum, which eventually can be displayed as a function of wavelength. Unlike the grating type dispersive technique, interferometry first generates a frequency spectrum by light interference in an optical system. The frequency spectrum is converted mathematically into the conventional wavelength spectrum by Fourier transforms. A conventional scanning dispersive spectrometer generates a spectrum by serially scanning the spatially dispersed wavelengths as a function of time. The interferometer has the multiplexing capability, whereby all the wavelengths are scanned concurrently in time and are measured directly as a frequency spectrum.

The Block Engineering interferometer-spectrometer is a commercial example of the Michelson interferometer design. In principle, this design (Figure V-3) consists of two plane mirrors, M_1 and M_2, one of which is fixed, and two plane-parallel plates, G_1 and G_2. Light from an extended source is incident at 45° on plate G_1, partially silvered on the rear surface, and is divided into a reflected (path A) and a transmitted (path B) beam of equal intensity. The light reflected from M_1 passes through plate G_1 a third time before it reaches the detector. The light reflected from mirror M_2 passes back through G_2 a second time, is reflected from the surface of plate G_2, and into the detector. The two beams have a phase difference governed by the difference in the two paths. As incoming radiation is received by the interferometer, a fringe pattern is produced by interference in the two beams. When one of the mirrors is moved back and forth at a slow constant velocity, the motion is manifested as an alternate brightening and darkening of the central fringe. The detector records these signal changes. Incident radiation containing many wavelengths would generate a composite signal of all the sine waves that corresponds to all the wavelengths in the source. A Fourier wave analysis of the signal produces a wavelength spectrum.

The maximum resolution of this interferometer depends upon the maximum travel of the moveable mirror and is equal to the maximum travel distance divided by one-half the wavelength. Commercial interferometers are available with resolution approaching 0.5 cm^{-1} in the infrared wavelengths. Throughput and multiplexing capability of the interferometer offer an advantage over the conventional dispersive spectrometer in the speed with which a spectrum can be obtained. The Fourier transformation, however, is an involved procedure and adds to the complexity and cost of the instrumentation.

Correlation. Correlation techniques consist of matching a reference spectrum of the gas to be measured against the spectrum of the sampled gas to be analyzed, or what might be referred to as the sample spectrum. The reference spectrum may be generated by a photographic mask or by a gas cell whereby the techniques are referred to as optical correlation spectroscopy or gas correlation spectroscopy, respectively. The latter is also referred to as a matched filter technique or a gas filter technique and was discussed earlier under nondispersive methods. The sample spectrum may be generated by dispersive optics or by nondispersive gas filters.

A commercial instrument has been developed,[12] in which a photographic mask provides the reference spectrum, and correlation spectroscopy is the analytical scheme. This instrument may be descriptively referred to as an optical-correlation dispersive-type device and also has been described in other instrument developments.[13]

Derivative technique. The derivative technique consists simply in the processing of the transmission versus wavelength function of an ordinary spectrometer into a signal proportional to the first, second, or nth derivative of this function. The derivative signal improves the detectability of overlapping spectral lines and bands, and suppresses the effects of a fluctuating light source. Thus, it enhances the signal-to-noise ratio, the resolution of the data, and the sensitivity. Instrument designs have involved different approaches in executing the derivative output. These include sinusoidal modulation and a difference measurement of flux at two adjacent wavelengths. Theoretical work has been conducted to evaluate the accuracy with which various approaches represent the derivatives.[14] A detrimental effect found in using higher derivatives is the decrease in signal.

Hadamard transform technique. The Hadamard transform technique[15] is a new analytical technique developed to overcome the energy limitations of frequency-scanned spectrophotometers. Thus, it offers the advantages of the Michelson interferometer with its high-energy input and multiplexing capability, but does not involve the usual Fourier transforms. This new method consists of optically encoding the spectral output of a multislit spectrometer. The encoding involves sequential measurements of the total light intensity in combinations of selected spectral bands. The resulting encoded optical information is obtained as a set of simultaneous linear algebraic equations, and the spectral reconstruction is accomplished through the use of matrix inversion techniques.

Chemi-eletromagnetic

Chemi-electromagnetic techniques of gas analysis employ a chemical reaction followed by a measurement of electromagnetic radiation. They include two classes depending on whether radiation absorption or emission is used to detect the reaction product.

Colorimetry

Colorimetry is a method wherein the pollutant gas is sampled and reacted with a reagent. With selection of the proper reagent, the reaction is specific to the pollutant gas of interest and a unique color is formed. The electromagnetic-absorptive capacity in the visible wavelengths of the reacted reagent is utilized to give a quantitative analysis. In addition, the intensity distribution of a range of transmitted wavelengths (referred to as the spectral characteristic of the absorbing medium) is unique to the absorbing medium and provides a qualitative analysis.

The measurement system consists of a source of radiant energy, the sample solution to be measured, and a detector for the unabsorbed or transmitted radiation. The usual radiant energy source in the visible range is the electric bulb with an incandescent tungsten filament.

Special sources are used for UV and IR to provide sufficient energy at these wavelengths. Photocells are used as detectors and include three types: 1) photoconductive, 2) photovoltaic, and 3) photoemissive. The important point to consider with respect to the detector and source combination is that each has its own spectral characteristic; therefore, the optimum combination is one in which both have maximum response in the wavelength range of interest to obtain maximum sensitivity.

An important aspect of the instrumental design is the provision for operation in a given spectral region. This may be done in a number of ways, extending from the simple fixed-band filter to the relatively complex monochromator with an adjustable bandwidth and a wavelength drive to scan the entire spectrum. It is necessary that calibration curves be determined by the instrument operator for his own instrument under his own working conditions.

These chemicophysical systems do not have the relatively instantaneous response time of the purely physical devices because there is a certain time delay involved in the gas-scrubbing process, the chemical reaction time, and the reagent flow system. Consequently, the 90% response times are in the order of 5 to 30 minutes versus 5 to 30 seconds for the physical systems.

Photometric (chemiluminescent) methods

These methods[16] basically involve emissive radiation that is detected by photometric techniques. The emission of radiation is stimulated either chemically by a gas-solid or gas-gas chemiluminescent interaction or thermal-chemically by a gas/hydrogen-flame chemiluminescent interaction.

An ozone analyzer, based on the chemiluminescent reaction of O_3 with Rhodamine B absorbed on silica gel and on photometric detection of the resultant emission, gives a measure directly related to the mass of ozone flowing over the dye per unit of time (Figure

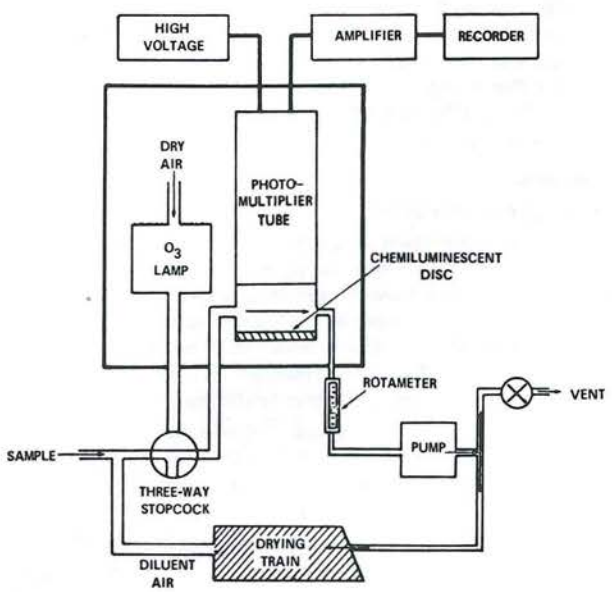

Figure V-4 — Ozone analysis by ozone-organic-dye chemiluminescent reaction and photometric detection.

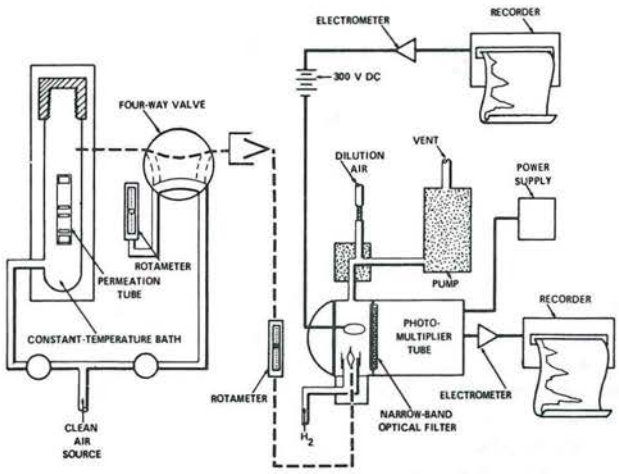

Figure V-5 — Flame photometric detector sulfur compounds.

V-4). Emission is at 585 nanometers, and sensitivity of the method is 1.0 to 10 ppb.

The gas-gas chemiluminscent reaction utilizes a similar approach in the photometric detection of the resultant emission. Ethylene-ozone and ozone-NO are reactions that have been developed for ozone and nitric oxide analyses, respectively. Sensitivities are in the 1.0 to 10 ppb range, and interferences appear to be negigible.

Flame photometric detection (FPD) based on strong luminescent emissions between 300- and 423-nanometer wavelengths has been applied to sulfur compounds introduced into hydrogen-rich flames (Figure V-5). Use of a narrow-band optical filter with transmission at 394 nanometers (± 5 nm) gives a specificity ratio of sulfur to nonsulfur compounds in the order of 10^4. The method has a sensitivity for sufur compounds (SO_2, H_2S, CS_2, CH_3SH) in the order of 1.0 to 10 ppb. Response of the method for compounds with sulfur contents in excess of 50% by weight is linear for concentrations in the range from 5 to about 1.0 ppm.

Although the FPD method gives a measure of total sulfur primarily, this method combined with gas chromatography provides the capability to separate and measure each sulfur compound in a mixture of sulfur compounds. Since the system response to the various sulfur compounds is the same for equal concentrations (Figure V-6), calibration of the system for each compound of interest is necessary.

Magnetic

Paramagnetic analyzers

The paramagnetism of oxygen, a conspicuously distinctive physical property of oxygen compared to other gases, provides a method by which it may be detected under the influence of a magnetic field. In practice, an air sample is introduced into an electrically heated cross tube of an annular chamber, half of which is exposed to the field of a strong magnet. As the oxygen molecules are attracted to the region of higher field strength, the resultant air flow partially cools the heating coil. The difference in the electrical resistances of both parts of the heating coil constitutes a measure of the oxygen concentration.

Mass spectroscopy

In principle, mass spectroscopy consists of the deflection of ionized molecules subjected to a magnetic field and their classification in accordance with their mass and charge. The current intensity detected is proportional to the number of particles in each class. The sample size required is very small, in the order of 1.0 microliter of gas. Specificity is high because individual particle classes are detected with instruments of high reduction capability. The detection limit for SO_2, for example, has been reported in the order of 0.001 microliter. Mass spectrometry has been combined with gas chromatography for the identification of chromatographic fractions and peaks.

Special case-gas chromatography

In gas absorption chromatography the components of a mixture migrate differentially in a porous sorptive medium. The method does not serve directly for the detection of substances; nor does it provide an estimate in the absolute sense. Chromatography is primarily a method of resolving complex mixtures, and this depends upon the differential migration of the components through the porous medium. This differential migration is carried out so that each component separates as a discrete substance. The separated substances appear in a carrier gas as a function of time as the carrier gas passes through the absorption column. Detection of the separated components takes place as the carrier gas emerges from the column.

As an analytical system, gas chromatography utilizes various sensitive detection techniques. The detection methods are not necessarily specific because the chromatorgraphic method itself is highly specific. Early detection was based on thermal conductivity cells. Since then, great strides have been taken to improve the sensitivity of detection so that extremely sensitive methods are now used to measure trace components in the order of 1.0 to 10^3 ppb. These include the flame-ionization method (Figure V-1), and the flame photometric method (Figure V-5) described earlier.

A chromatographic system basically consisting of an absorption column and a detection unit is selected with a number of considerations kept in mind: 1) the nature and concentration of the associated components in the mixture from which the separation is to be made; 2) the nature and concentration of the component to be measured; 3) the resolving ability of the absorbing column, its stability, contaminants, and temperature characteristics; and 4) the sensitivity of the detection cell, its reproducibility, stability, and response time.

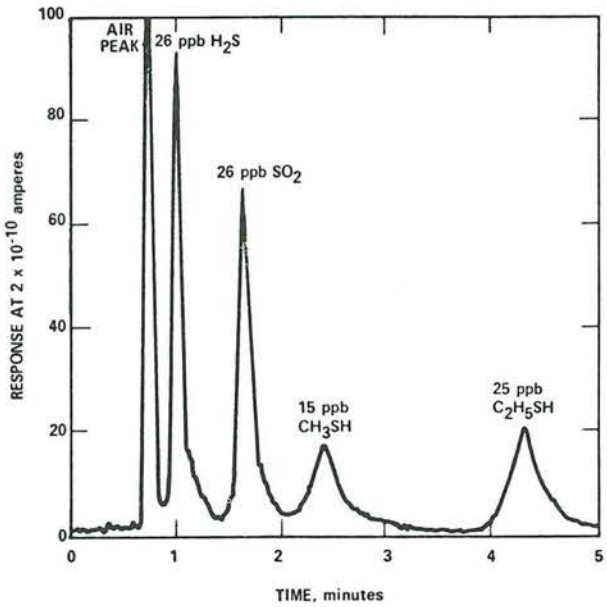

Figure V-6 — Gas-chromatographic/flame photometric detection system response to mixtures of SO_2, H_2S, CH_3SH, C_2H_5SH in air.

Analysis for a specific component requires a method, either specific or nonspecific, for the detection and identification of the isolated components of a mixture. The use of particular reference substances and the sorption time sequence technique are suitable methods. In addition, under standardized conditions the relative migration of carrier gas and components can be used.

Sampling Schemes

A gas pollutant measurement with a direct readout instrument involves some sampling scheme that is inherent in the measurement technique. The two basic parameters that define the sample are time and space. This is to say a valid interpretation of the analytical measurement requires information on the environmental sample with respect to time and the space it occupied during this time. A measurement that is made in real time and on a continuous basis, as in any monitoring devices, is considered instantaneous in time. The actual sample volume represented by the analysis depends upon the air flow rate and the response time of the analytical system. The response time may be in excess of a minute or two, or the analytical results may be integrated electronically to give an average concentration measurement over a period of time. Thus, a gas measurement can be integrated over a period of time by the sampling technique itself prior to analysis. For example, the gas may be absorbed in a reagent in a bubbler for minutes and subsequently analyzed with the cycle repeated for each measurement.

Traditionally, gas measurement involves sampling at a point or through an inlet opening at the end of a probe or tube. This constitutes point or probe sampling and represents a measurement of gas concentration of a small volume of the environment in the vicinity of the probe inlet. Longpath sampling, on the other hand, usually consisting of an eletro-optical method, involves a large spatial sample of meters to kilometers in length over a single path length. In this case, the measurement represents the instantaneous concentration over the spatial path. If point sampling is executed from a moving vehicle or over a prescribed path length, one can also arrive at an average spatial concentration. Strictly speaking, however, it is not identical to the instantaneous spatial average achieved by the electro-optical method, although under certain conditions one can closely approach the same end result.

Summary

A brief discussion has been presented on the principles of detection and measurement of gases by direct reading instruments. These techniques range from traditional methods involving well known physical principles of conductivity, coulometry, and colorimetry to advanced methods of Raman scattering and chemiluminescence, from the traditional point sampling methods to the latest long-path electro-optical schemes. The merits of any particular measurement technique have to be judged both by the performance specifications of the instrument and the conditions under which the application of the instrument is to be made.

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Instrument Descriptions

J-W Toxic Gas Alarms for NH_3, H_2S and SO_2

Bacharach Instrument Company
625 Alpha Drive
Pittsburgh, PA 15238

The Model MHO is used to detect the presence of small concentrations of ammonia, hydrogen sulfide, and sulfur dioxide in the toxic range. The small size and cost of the instrument permits its use in many areas heretofore unprotected.

Operating principle

A sample of the atmosphere to be tested is drawn from the sample point to the instrument through a length of tubing by means of a vibratory pump. If hydrogen sulfide is to be detected, a heated reactor is provided on the outside of the case, and the sample flows through the reactor before entering the instruments. Any hydrogen sulfide in the sample is oxidized to sulfur dioxide. The sample then passes through a detection cell where it contacts a flowing stream of distilled water. Any ammonia or sulfur dioxide in the sample dissolves in the water, which increases the conductivity of the water. This conductivity change is used to trigger a thyratron tube to turn on a relay and alarm signal.

Description

The case is gray textured baked enamel measuring 10" × 12" × 6" with a hinged cover. The alarm light is red and pilot light green, both located on the front cover. *Power supply requirement:* 115 VAC, 60 Hz. *Water requirement:* 0.5 gal distilled water per week. *Weight:* 15 lbs.

The Model MHO analyzes the air for toxic gases on a continuous 24 hour per day basis. The complete analyzer is housed in a small wall mounted case containing the detection cell, power supply, vibratory pump, flowmeter, alarm circuit, and all other required components. The sample is drawn through ¼" plastic tubing to the analyzer and then exhausted to atmosphere. A constant flow of distilled water is fed by gravity from a 1-gallon plastic bottle mounted on the wall above the analyzer.

Performance data

The normal detection range of the instrument is well below the toxic limit for ammonia, hydrogen sulfide, or sulfur dioxide in air, and the alarm point can be factory-set at any level within the ranges of 0–50 or 0–100 ppm for ammonia, and 0–5, 0–10, or 0–20 ppm for hydrogen sulfide or sulfur dioxide. When the concentrations reaches the set point, a red light comes on and an external audible or visual alarm can be actuated.

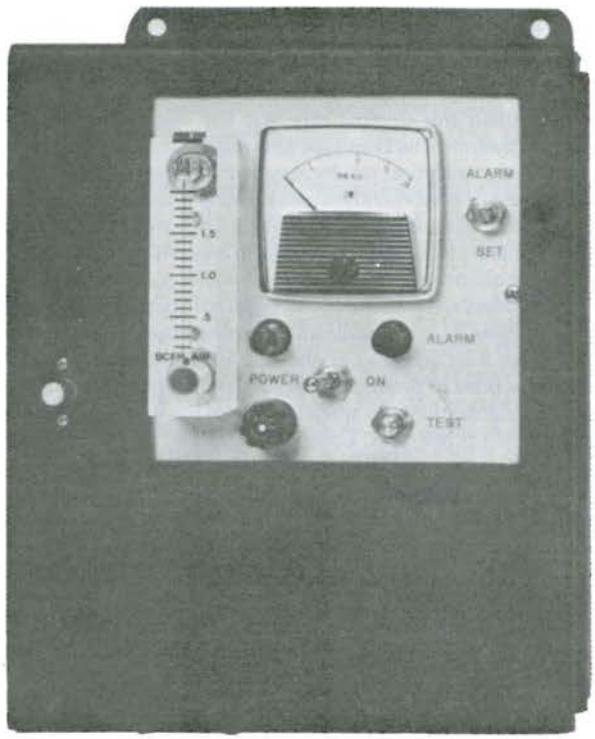


Figure V-7 — J-W Toxic Gas Alarm, Model HMO.

H_2S Sentox

Bacharach Instruments Company
(address above)

This instrument is a diffusion instrument used to detect hydrogen sulfide gas in the range of 0 to 50 ppm. The H_2S Sentox does not require active sampling. It can be used with a remote diffusion detector connected by a cable.

The H_2S Sentox is used to detect hydrogen sulfide gas in the range of 0–50 ppm, but will react to massive levels of certain other interference gases.

Operating principle

The H_2S Sentox operates on the oxidation reduction principle. When exposed to hydrogen sulfide gas, the metal oxide sensor is reduced and then returns to its normal oxide state when returned to an oxygen atmosphere. This change alters its ability to conduct electricity.

Figure V-8 — Bacharach H_2S Sentox.

Description

The instrument is powered by Ni-Cad batteries which provide approximately 10 hours of continuous use, and may be operated continuously off its own battery charger. It has a meter readout, audible alarm, alarm light indication, and provides a battery check and a functional test mode.

Performance data

Response time: 120 seconds to 90% of final reading. *Reproducibility:* ± 3 ppm to 10 ppm, ± 5 ppm to 50 ppm. *Size:* 10½" × 6¾" × 6½". *Weight:* 7 lbs.

UltraGas-U3S Sulfur Dioxide Analyzer

Calibrated Instruments, Inc.
731 Saw Mill River Road
Ardsley, NY 15020

Basically, this instrument is a sampling and analysis device for measuring the concentration of SO_2 in air by the conductivity method. Existing interference components can be eliminated in most cases through suitable absorption traps so that the measurement is selective.

Operating principle

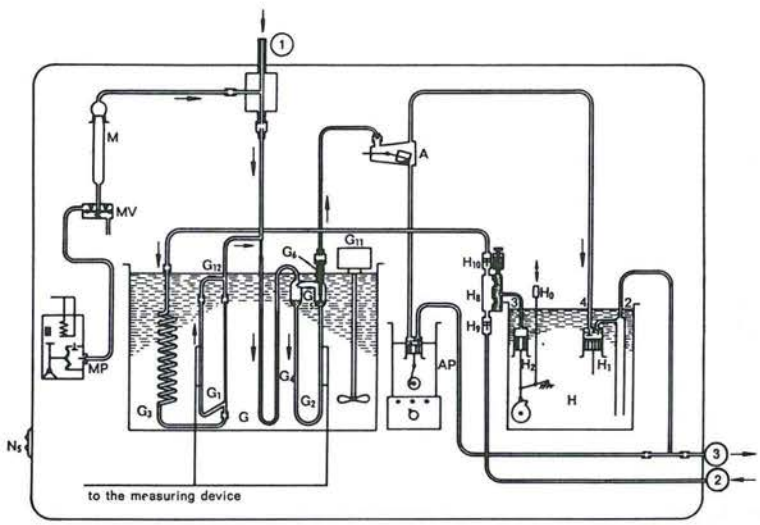
In the UltraGas-U3S, a constant and continuous stream of air and reagent mix in a reaction chamber and the conductivity of the solution is changed in proportion to the concentration of sulfur dioxide. The oxidation of sulfur dioxide takes place in a dilute solution of sulfuric acid and hydrogen peroxide according to the following reactions:

$$SO_2 + H_2O \rightarrow H_2SO_3$$

$$H_2SO_3 + H_2O_2 \rightarrow H_2SO_4 + H_2O$$

The sulfur dioxide is converted to sulfuric acid. Because of the high ionic mobility of the hydrogen ions produced, the traces of sulfur dioxide can be measured quantitatively. The change in conductivity is a function of the conversion and, therefore, a measurement of the concentration of sulfur dioxide in the air. The conductivity change is determined in the UltraGas-U3S in the detector G by two electrode sections (see Figure V-9). The conductivity of the reagent is measured first in section G_1. After reaction with sulfur dioxide, the conductivity is measured in section G_2. The difference in the two alternating currents flowing through the two electrode sections is selected electronically by the recorder.

Several components serve to achieve a high precision. Temperature changes are compensated for by a temperature dependent resistance. A similar resistance compensates for the effect of the ambient temperature and, therefore, the water vapor



Arrangement of the Analyzer Parts

A	Levelling switch	D 324175	H	Pump type NB 175/1	
AP	Suction pump	D 224227-2	H_1	Pump for the measuring gas	
G	Measuring cell	D 224622	H_2	Pump for the reaction liquid	
G_1	Electrodes measuring range for the un-used reaction liquid	D 404629	H_8	Membrane chamber	D 411840
			H_9	Suction valve	D 423489-2
G_2	Electrodes measuring range for the used reaction liquid	D 404631	H_{10}	Pressure valve	D 514593
			H_8	Hand operation of pump H_2	
G_3	Glas spiral for temperature compensation of the reaction liquid	D 404630	M	Inset with active carbon, SO_2 absorber	D 401572
			MP	Membrane pump	
G_4	Reaction tube	D 514606	MV	Check valve	D 513102
G_5	Gas seperator for G_2	D 504627	N_5	Mains connection	
G_8	Channel	D 514635	①	Gas inlet	D 514704
G_{11}	Stirrer	D 414614	②	Inlet of the reaction liquid	
G_{12}	Connection for G_1	D 504628	③	Ooutlet of the reaction liquid and residual gas	

Figure V-9 — Arrangement of the analyzer parts in the UltraGas-U3S.

pressure in the reaction zone. Continuous and constant air flow through the detector is provided by pump H_1. The same synchronous motor drives the solution pump, H_2, to provide a constant reagent flow rate. Therefore, the air and reagent flow rates remain constant. This feature is necessary to achieve accurate measurement in the detector. Since the actual conductivity increase is measured, small deviations in reagent composition have no effect on the performance of the instrument.

Description

This instrument is 16" × 14" × 20½", weighs 60 lbs, and requires less than 100 watts of power to operate. Its sampling rate is 670 ml/min and has a direct scale readout (also integrated values for 15, 30, and 60 minutes) automatically printed with day/hour/minute.

Performance data

The detection limit is 0.005 ppm. The maximum permissible surrounding temperature is +40°C with -2°C the minimum for the analyzer; 0°C for the storage containers. *Specificity:* interference by HCl, H_2S, NH_3, but not affected CO_2. *Response time:* 20 sec. *Averaging time:* 90 sec. *Calibration temperature:* 20°C. *Temperature influence for +5° to -35°C:* ± microG at zero point (independent of the measuring range). An independent study of its performance has been conducted.[1]

Reference

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Figure V-10 — Calibrated Instruments, Inc., UltraGas-U3S Sulfur Dioxide Analyzer.

SO_2 Sampler

Casella London Limited
Regent House, Britannia Walk
London N1 7ND, England

This instrument is used to measure airborne sulfur dioxide. It has an operating range from 500 ppm down to 0.005 ppm and was designed for ambient portable use.

Operating principle

Its operating principle is the measurement in change of conductivity of an electrolyte through which air contaminated with SO_2 has been bubbled. Absorption of SO_2 and its production of H_2SO_4 produces a directly proportional change in conductivity to SO_2 present in the volume of air drawn through. The change in conductivity is measured by a simple sequence of switch operations and a meter reading. Temperature compensation from 0 to 40°C is provided and the sampling period can be varied from a few minutes up to 24 hours.

Description and performance data

Aspiration rate is 1.0 lpm. Power source is Ni-Cad rechargeable battery which will run the sampler for a full 24 hours. *Size and weight:* 11" × 8" × 5", 13 lbs. There is a matching programmer/recorder, also battery operated, which is connected to the sampler by a multi-pin socket on the front panel. This programs the sampler to operate unattended at preset intervals of 1, 2, 4, and 8 times per hour. Running time of 30 hours when set for 8 recordings/hour; chart capacity, 62 hours at recording rate.

SO_2 Ultra Portable Analyzer, Model U2-D5

CEA Instruments, Inc.
15 Charles Street
Westwood, NJ 07675

The lightweight U2-D5 portable analzyer measures the electrical conductivity resulting from the reaction of SO_2 and H_2O_2. It can be used for industrial hygiene and air pollution measurements.

Operating principle

The chemical technique employed is $SO_2 + H_2O_2 = H_2SO_4$. Buffering effects from CO_2 are eliminated because the analyzer operates on an acidified peroxide solution. The peroxide oxidizes sulfur dioxide into sulfuric acid.

To operate, the plunger is fully depressed powered by two main springs. In this position the sample cell assembly is submerged into the liquid reservoir where the sample cell assembly piston hits a stop and is forced upward, expelling its spent liquid. Simultaneously, the exhaust check valve opens.

Upon release of the plunger, the main piston and sample cell assembly raises abruptly out of the reservoir while the sample cell piston draws in a fresh charge of solution. The main piston returns to its present point. The check valve closes and, thus, the air sample can enter only through the critical orifice.

Air impingement on the cell's surface causes a depression which serves to mix the gas and liquid. Carbon electrodes, conforming to opposite walls of the cell, form the conduction path through the solution of the signal current applied by the oscillator circuit. The signal is then amplified, rectified and fed to the meter.

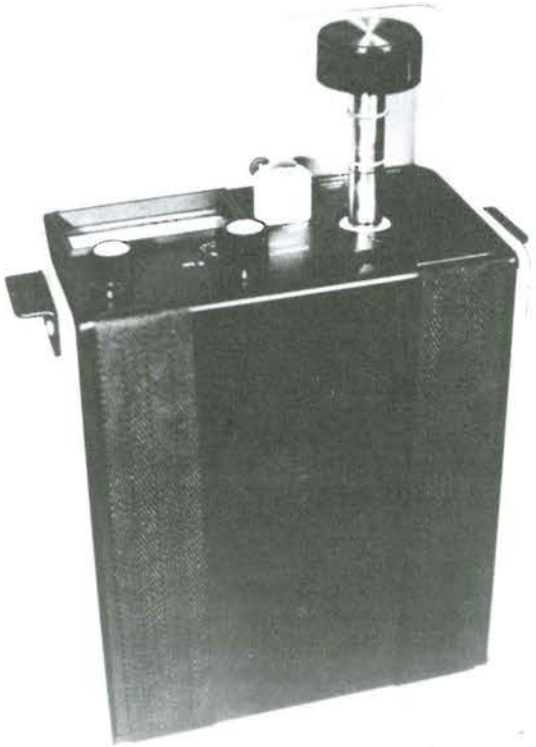


Figure V-11 — Model U2-D5 portable SO_2 analyzer.

Description and performance data

Chassis and case are made of aluminum, thermoplastics, stainless steel, viton, buna-n, and carbon. *Size:* 12" × 8"× 4". *Weight:* net, 5 lbs; shipping, 7 lbs.

Operating range: 0 to 0.5 v/ppm, adjustable up to 20 v/ppm in six steps (0–0.5, 0–1.0, 0–2, 0–5, 0–10, and 0–20 v/ppm), with a sensitivity of 0.02 ppm. *Precision:* ± 3% or 0.02 ppm, whichever is greater. *Initial response time:* one second, complete; integrated readout, approximately 3 min. *Operating temperature range:* 35° to 120°F. *Sample cell volume:* 0.3 ml. *Reservoir volume:* approximately 150 ml. *Air sample volume:* 100 cc. *Power supply:* pen cell batteries, +6V, -6V. *Readout:* 2.5" taut-band, 1 mA DC meter.

Gas Analyzer System, Series 9000

Devco Engineering, Inc.
Control Systems Division
36 Pier Lane West
Fairfield, NJ 07006

The Devco Engineering Series 9000 Parts Per Million Gas Analyzer System is designed specifically for the continuous monitoring of toxic gases or vapors in the atmosphere or trace concentrations of contaminants in process streams. It responds to gases or vapors such as hydrogen sulfide, chlorine, carbon dioxide, ammonia, sulfur dioxide, halogenated hydrocarbons, etc. Typical applications include: monitoring for carbon dioxide, freon, or ammonia in refrigeration plants; continuous monitoring for ppm sulfur dioxide in air pollution studies; automatic bed cycling by continuously monitoring of effluent in solvent recovery systems; measuring hydrogen sulfide in air and hydrocarbon streams in petroleum refineries; continuous monitoring for ppm toxic gases and vapors in air for safety control; continuous measurement of hydrogen sulfide in air in sewage treatment plants or chlorine in air in water treatment plants, etc.

Operating principle

Analysis is based on measurement of electrical conductance due to ionization, in water, of the gas or vapor being monitored. The sample to be analyzed is drawn to the analysis cell at a regulated flow rate where it is thoroughly mixed with pure, ion free, water from the reservoir. As a sample gas, which is capable of forming ions in water, is mixed with the water, the electrical conductance of the water is increased in proportion to the concentration of that gas in the sample. The mixture then passes between two platinum electrodes having an AC potential across them permitting measurement of the conductance of the solution. The output from the measuring circuit is rectified and transmitted directly to a millivolt recorder or meter and solidstate alarm circuit. A dual zener diode regulated constant voltage supply is used to provide the AC potential for the analysis cell.

After measurement, the water-air mixture is transferred to the reservoir by means of a highly reliable sample pump, where the air is separated and exhausted and the water is recirculated through the deionizing filter reservoir.

Certain gases such as hydrogen sulfide or the halogenated hydrocarbons are not directly ionized in water. Other gases such as chlorine do not ionize sufficiently to permit measurement of very small concentrations. The gases are treated prior to analysis by thermal decomposition or oxidation in a pyrolysis train and the

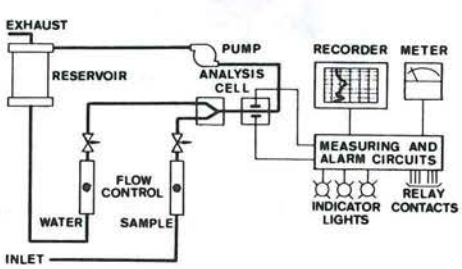


Figure V-12 — Component and flow schematic for the Devco Series 900 gas analyzer.

emanating combustion products are then passed on to the analysis cell.

The condition of the water and the ion exchange resin can be easily checked by depressing the "Water Check" pushbutton. The active electrodes are, thus, removed from the measurement circuit and replaced by a pair of reference electrodes located in the water stream ahead of the water-sample mixing chamber. This permits measurement of the conductance of the water alone. The ion-exchange resin is also self-indicating in that the color of the resin changes as the resin becomes exhausted.

Description and performance data

Series 9000 systems have a full scale range of 0 to 1.0 ppm for many toxic gases with an accuracy of 2% at calibration point; 5% over range. The cell response reading is 90% in 20 seconds. No special reagents are required; two quarts water are required approximately every 30 days.

This system is furnished in wall mounting NEMA type 12 enclosures, in free standing relay rack type house, in portable packages (115 VAC, 60 Hz operated), or in fully explosion-proof construction.

Multi-point sequential sampling systems are available to monitor up to eight points on a single instrument by means of a sample program assembly.

Indication of the gas or vapor concentration may be by means of an indicating meter or recording potentiometer calibrated in terms of ppm by volume of the gas or vapor measured. Solid state alarm circuits provide audible and visual alarms at one or more preset levels within the range of the instrument. S.P.D.T Alarm relay contacts rated for 115 VAC, 5 amp resistive loads are available for field use. Systems with proportional control output may be provided for automatic process control.

Davis Electro-Conductivity Analyzers

Scott Aviation-Davis Instruments
P.O. Box 751, RT 29 North
Charlottesville, VA 22902

The Davis Electro-Conductivity Analyzer is a sensitive instrument for the continuous measurement of atmospheric concentrations of contaminants, such as sulfur dioxide, chlorine, carbon tetrachloride, hydrogen sulfide, oxides of nitrogen, hydrazine, and methyl chloride. In general, it will respond to gases or vapors that will ionize in water, either directly or after decomposition or oxidation by a pyrolyzing furnace. These units are available as permanently installed units, or in compact versions that are suited to mobile applications, such as air pollution survey work.

Operating principle

The measuring principle utilized is the measurement of conductivity after a gas sample ionizes in water. Conductivity is measured by a set of electrodes arranged in an AC conductivity circuit.

The analysis takes place in the analyzing cell, into which the gas sample and deionized water stream are individually metered at a constant rate. The deionized water passes a pair of water check electrodes and then goes into a mixing chamber where it is combined with the entering gas sample. After the gas sample and water are mixed, the water containing the resulting dissolved ions passes between the active electrodes. An AC voltage is provided across these electrodes. The resulting current between the active electrodes is proportional to the amount of gas that has dissolved in the deionized water stream.

Certain gases which will not ionize directly in water, require a pyrolyzing furnace to oxidize or decompose two components that will ionize in water. Typical of such gases are hydrogen sulfide and phosgene. The sample is mixed with the deionized water stream in a fixed ratio, and then passed between the active electrodes in the analyzing cell. The measured conductivity constitutes the output signal which is calibrated to read directly in ppm of the particular gas or vapor.

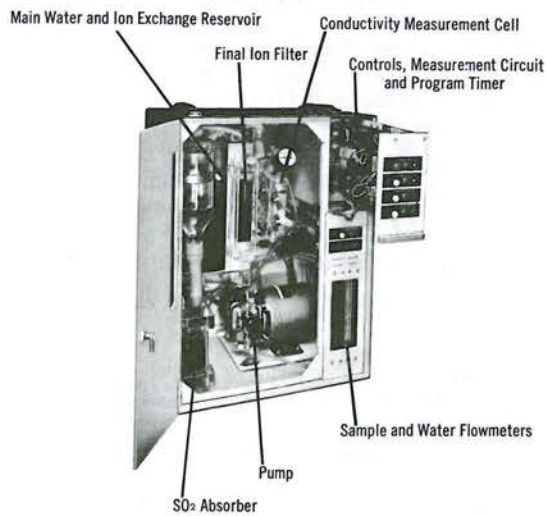


Figure V-13 — Model 11-7010-RP, portable Recording Electro-Conductivity Analyzer.

Description and performance data

A typical permanently installed cubicle constructed system (Figure V-14) is 78" × 24" × 24" and is provided with a full length rear access door. The system components are completely housed in this self-supporting cubicle, which is finished in a grey Hammertone enamel. The system power requirement is 115 volts, 60 cycles, and generally does not exceed 1000 watts.

The Portable Recording Electro-Conductivity Analyzer, Model 11-7010-RP, is intended for air pollution survey work. The analyzer is housed in a cabinet that is 20" × 15" × 13", weighing 65 lbs. The recorder is 15" × 20" × 13". This unit is available with a DC to AC converter, so that the system may be operated from a 12 VDC vehicle power supply.

This analyzer is capable of a very high sensitivity. Its response to various gases is in proportion to the ability of the gas to ionize in water. For example, its response to sulfur dioxide permits a full scale measurement range of 0–1.0 ppm of sulfur dioxide. In chlorine detection service, it is capable of providing a span of 0–10 ppm. Thus, for most gases that will readily ionize in water, the full scale

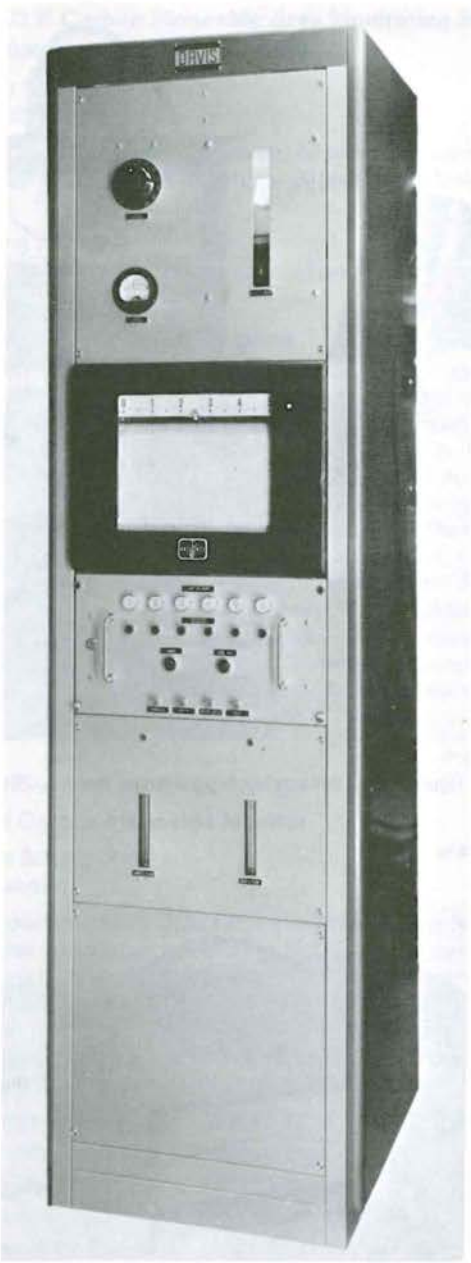


Figure V-14 — Continuous Electro-Conductivity Analyzer.

sensitivity is in the range of between 10 and 50 ppm. The greatest sensitivity is obtained when a recorder in included in the system. Somewhat wider (lower sensivity) spans must be used when an indicating meter is provided as the readout instead of a recorder. The system may also provide wide spans to accomodate application requirements. Typical would be 0–200 ppm ammonia or perchloroethylene. Accuracy in general is of the order of 10% of full scale deflection or better.

Systems are available as single or multiple point systems that will periodically check several locations for presence of the particular gas being detected.

O_2-25H Oxygen Meter

Dynamation Incorporated
168 Enterprise Drive
Ann Arbor, MI 48103

This compact oxygen detector continuously measures the oxygen level on its 0–25% O_2 meter for up to a years' time. An alarm indicates levels below 19.5%.

Operating principle

The sensor is a micro-fuel cell which has a life expectancy of a year before replacement is required. Cell replacement requires less than one minute. The O_2-25H is virtually maintenance free since no chemicals or electrolyte needs to be changed or added. The only control is a calibration adjustment which is used to set the meter at 20.9% O_2 before testing.

Description and performance

This unit, weighing only 16 ounces, is standardly equipped with a flexible cord and remote cable. This cable can be extended for 8 feet for remote sampling. An optional 25 feet extension cord is also available. Its dimensions are 2⅝" × 5⅛" × 2⅛". *Range:* 0–25% O_2 (linear). *Sensitivity:* 0.5% O_2. *Response time:* 90% in less than 10 sec. *Accuracy:* ± 1% oxygen. *Temperature range:* 32°to 125°F.

Figure V-15 — Dynamation oxygen meter, Model O_2-25H.

ECOLYZER Portable Carbon Monoxide Monitor

Energetics Science
Division of Becton Dickinson and Company
6 Skyline Drive
Hawthorne, NY 10532

The Series 2000 ECOLYZER Portable Carbon Monoxide Monitor may be used for measurement of CO in ranges from 0 to 3000 ppm. It has self-contained, rechargeable batteries, or may be operated on line voltage.

Operating principle

Electrochemical oxidation at a potential-controlled Teflon-bonded diffusion electrode.

Performance data and description

The ECOLYZER specifically measures CO gas concentration continuously. A less than 1.0 ppm signal is indicated when the following gases are present: N_2O, 103 ppm; NO, 50 ppm; NO_2, 25 ppm; C_2H_2, 0.3 ppm; C_2H_4, 5 ppm; CO_2, 1 ppm; SO_2, 100 ppm; H_2S, 50 ppm; H_2, 108 ppm; NH_3, 500 ppm; C_3H_8, 107 ppm; C_2H_6, 100 ppm. It is available in single or dual scale in the following ranges: 0–50, 0–100, 0–500, 0–600, and 0–3000 ppm; custom ranges also available. The minimum detectable sensitivity is 0.5% full scale. Its stability is as follows: noncontinuous (spot checking) — typical spot checking operation during a work day, signal decay < 1%/24 hr over the life of instrument; continuous — signal decays by < 1.5%/24 hr over the first 25 days and < 1%/24 hr subsequently. *Response time:* 25 seconds. *Precision and accuracy:* ± 1.0% full scale.

Figure V-16 — ECOLYZER Portable Carbon Monoxide Monitor.

Size: 7" × 13" × 7". *Weight:* 9 lbs. *Power requirements:* 105–125 VAC, 50–60 Hz, or four "C" and one "D" Ni-Cad batteries. *Sampling rate:* 700 cc/min. *Readout mode:* meter (110 div. full scale), and recorder.

ECOLYZER Carbon Monoxide Area Monitoring Systems, Series 3000

Energetics Science
(address above)

The ECOLYZER 3000 Series may be used as an area monitor for measuring CO in ranges from 0 to 500 ppm. It also has an alarm system.

Operating principle

Electrochemical oxidation at a potential-controlled Teflon-bonded diffusion electrode.

Performance data and description

The Series 3000 specifically measures CO gas concentration continuously. A less than 1.0 ppm signal is indicated when the following gases are present: N_2O, 103 ppm; NO, 50 ppm; NO_2, 25 ppm; C_2H_2, 0.3 ppm; C_2H_4, 5 ppm; CO_2, 1 ppm; SO_2, 100 ppm; H_2S, 50 ppm; H_2, 108 ppm; NH_3, 500 ppm; C_3H_8, 107 ppm; C_2H_6, 100 ppm. It is available in single scale in the following ranges: 0–50, 0–100, and 0–500 ppm; custom ranges also available. The minimum detectable sensitivity is 0.5% full scale. Signal decays by $<$ 1.5%/24 hr over the first 25 days and $<$ 1%/24 hr subsequently. *Response time:* 25 seconds. *Precision and accuracy:* ± 1.0% full scale.

Size: 15" × 12" × 7". *Weight:* 32 lbs. *Power requirements:* 105–125, VAC 50–60 Hz, or 4 "C" Ni-Cad batteries. *Sampling rate:* 700 cc/min. *Readout mode:* meter (110 div. full scale), and recorder.

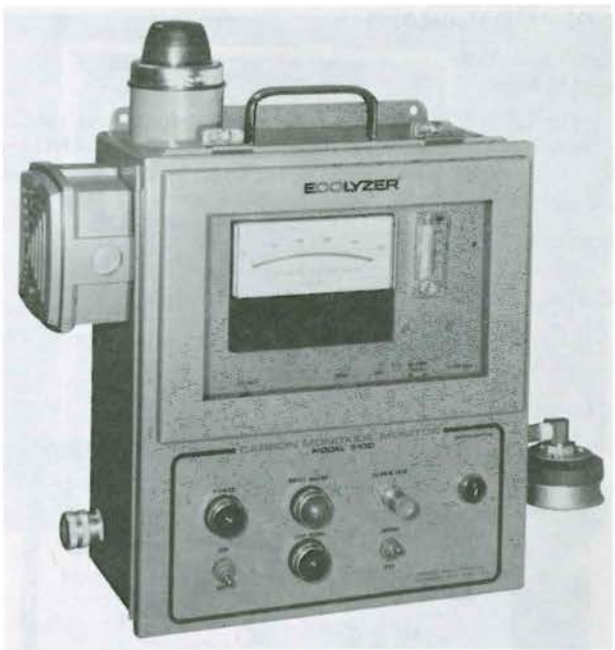


Figure V-17 — ECOLYZER Carbon Monoxide Monitor, Model 3100.

Personal Carbon Monoxide Monitor

Energetics Science
(address above)

The pocket-sized ECOLYZER Personal Carbon Monoxide Monitor for continuous monitoring of CO is designed for the personal protection of workers entering areas where there may be significant accumulations and sudden release of high concentrations of gas. The monitor features a unique adjustable stroboscopic visual alarm as well as an audible alarm. Both alarms are adjustable within the 0 to 1999 ppm range.

Operating principle

The unit employs a diffusion sensor utilizing the patented ECOLYZER three-electrode, electrochemical detection principle.

Performance data

Range: 0 to 1999 ppm. *Minimum detectable sensitivity:* 1.0 ppm. *Rise time:* $<$ 60 seconds to 90% of signal. *Accuracy:* 5% of reading or ± 1.0 ppm. *Repeatability:* ± 2% of reading or ± 1.0 ppm. *Span drift:* 2% of reading per day or 2 ppm. *Zero drift:* $<$ 5 ppm per day. *Operating temperature range:* 32°to 104°F (0° to 40°C). *Relative humidity range:* 5–90%.

Description

Dimensions: 5¼" × 3¼" × 1¼" (average). *Readout: ⅜" digital (LCD), push-button actuated. Weight:* approximately 0.75 lb. *Low battery indicator:* LED indicates low battery when display is actuated. *Power:* standard 9 volt transistor battery.

Figure V-18 — Energetics Science Model 210 personal CO monitor.

ENOLYZER Model 7100

Energetics Science
(address above)

The ENOLYZER Model 7100 is a portable, direct reading instrument of simultaneous and separate determination of NO and NO_2. The unit may be operated by rechargeable Ni-Cad batteries or line current.

Operating principle

Electrochemical reaction at potential-controlled Teflon-bonded diffusion electrodes.

Figure V-19 — Enolyzer Model 7100 for NO and NO_2.

TABLE V-1
Interference Equivalents

Interfering Gas	Highest Concentration Tested	NO_2 NO Analyzer 1 ppm NO	Analyzer 1 ppm NO_2
NO	50 ppm	—	No signal
NO_2	25 ppm	No signal	—
N_2O	100 ppm	No signal	No signal
CH_4	60,000 ppm	No signal	No signal
C_2H_2	—	27 ppm	2 ppm
C_2H_4	15 ppm	No signal	No signal
C_2H_8	—	80,000 ppm	20,000 ppm
SO_2	10 ppm	No signal	No signal
H_2S	10 ppm	No signal	No signal
H_2	—	3,000 ppm	3,000 ppm
CO	—	4,000 ppm	500 ppm

Performance data and description

Detection limits: 0–10 and 0–50 ppm for NO; 0–2 and 0–10 ppm for NO_2, with custom ranges available in both. *Response time:* 90% NO, < 5 sec; 90% NO_2, < 30 sec. *Precision and accuracy:* ± 1.0% full scale for NO; ± 2% full scale for NO_2. *Stability:* non-continuous (spot checking) — typical operation of spot checking during a work day, NO and NO_2 signal decay < 1%/24 hr; continuous is under investigation. Interference equivalents are listed in Table V-1.

Series 300 Air Pollution Analyzers

Eitel Manufacturing
P.O. Box 652
Anaheim, CA 92805

These analyzers are designed to provide drift-free performance and reliability necessary for continuous, unattended monitoring. Analyzers are based on the Faristor small modules selectively sensitive for SO_2, NO_2, NO_x, or H_2S. Systems for single or multigas determinations are available in ranges covering source emissions, occupational exposures, or ambient air concentrations.

Operating principle

The gas sample flows across a membrane during its passage through the Faristor. Some gas molecules diffuse through the membrane and dissolve in a thin liquid film where they undergo electro-oxidation or reduction. An opposite reaction occurs at the reference, resulting in current flow in the load circuit proportional to the pollutant concentration.

Description

The Faristor is plugged into the slot in the rear panel of the instrument and gas connection is made through polypropylene fittings on the outside of the module. *Size:* 6½" × 12¼" × 13". *Weight:* 12 lbs. *Power:* 115 V, 150 V, 60 Hz (220 V, 50/60 Hz optional).

Performance data

Ranges: 0–100, 0–500, 0–1000, 0–5000, 0–10000 ppm; 0–1, 0–5, 0–10, 0–50, 0–100 ppm; 0–0.1, 0–0.5, 0–1.0 ppm. *Accuracy:* ± 1% of full scale at constant Faristor temperature. *Repeatability:* ± 0.5 %. *Minimum detectability:* 1.0 ppb. *Linearity:* ± 0.5%. *Zero drift:* ± 0.5%/24 hr. *Span drift:* ± 1%/wk. *Response time:* 5–15 seconds to 95%. *Ambient temperature:* 90° to 102°F. *Temperature compensation:* 40° to 125°F. *Sample pressure:* not greater than 15 psig. *Sample flow:* 1–4 SCFH. *Recorder output:* 100 mV.

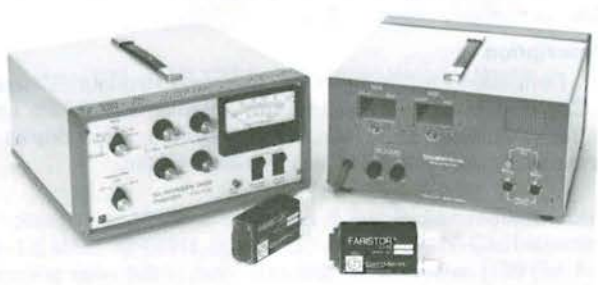


Figure V-20 — Eitel Manufacturing's SO_2/NO_x analyzer. Left to right: front view; Faristor modules; rear view, showing plug-in slots for Faristors.

Portable Gas Analyzers, Series 1000

Interscan Corporation
P.O. Box 2496
Chatsworth, CA 91311

With operating ranges from 0.1 to 10 times the TLV, these instruments measure airborne CO, SO_2, H_2S, Cl_2, NO_2, NO, and hydrazine, and are designed for ambient portable survey analysis or fixed round-the-clock use.

Operating principle

The Interscan sensor operates under the principle of an electrochemical voltammetric sensor. This is a patented long-life sensor, which does not require the use of reagents, chemical buffers, or humidifier bottles. The pattened Interscan sensor is a leak-proof, two electrode sensor, with a gel matrix inside the sensor which omits a free-floating electrolyte. A sample is pulled through the sensor via an integral pump where the gas molecles are electro-oxidized within the sensor, the sensor then puts out a millivolt signal, which is amplified through the circuit board and is directly readable in ppm.

Physical descriptions

Portable DC operated analyzers, 1000 Series: measures 7¼" × 6" × 11½" and weighs 8 lbs; recommended flow rate: 1.0 lpm; external accessories required: calibration gas or permeation tubes where disposable cylinders are not available.

Portable DC operated analyzers, 4000 Series: measures 7" × 4" × 7" and weighs 4.5 lbs; recommended flow rate: 1.0 lpm; required external accessories the same as 1000 Series. A 0–100 mV recorder output is standard on both the 1000 and 4000 Series. In *all cases,* the Interscan sensor must NOT see more than 5 psi.

LD series continuous monitor system. This unit is 20¾" high when provided with rotating beacon alarm and horn mounted on the top, and has an operating weight of 20 lbs. Recommended flow rate: 0.5 to 1.0 lpm; power requirements: 105–125 VAC, 50–60 Hz or 220 VAC, 50–60 Hz. Recorder output available in 0–100 mV or 4–20 mA. Calibration gas or permeation tube is required where disposable cylinder of gas is not available. Strip chart recorder and form "C" 4 amp relay contacts available as options.

Rackmount configured analyzers. Dimensions: 7" × 19" × 12"; 11.5 lbs when provided with pump and rotameter; sampling rate: 0.5 to 1.0 lpm; power requirements and external accessories the same and the LD Series. Form "C", 5 amp contact relays, 0–100 mV or 4–20 mA recorder output available.

Multipoint sampling-automatic stream-switching systems. Dimensions: 30" × 30" × 9¾"; operating weight: 155 lbs; sample flow rate: 0.5 to 1.0 lpm; purge flow rate: 10 lpm; power requirements: 105–125 VAC, 50–60 Hz. The external accessories are the same as needed for the LD Series and Rackmount. In all cases, regardless of application or configuration of the analyzer and gas involved, measuring range is 0.1 to 10 times the TLV.

Figure V-21 — Interscan Portable Gas Analyzer, Series 1000.

Performance data

These are general specifications which cover the entire line of Interscan analyzers. Generally, one-tenth to 10 times the TLV, analog scale provided on the VDC powered instruments and the LD Series continuous monitoring systems. LED digital displays are provided *only* on the Multi-Point Stream-Switching systems.

Analog scale: Panel meter is 100 divisions of full scale. *Accuracy:* ± 2% of full scale (this is limited to accuracy of calibration standard). *Repeatablility:* ± 0.5% of full scale. *Minimum detectability:* 1% of full scale. *Linearity:* ± 1% of full scale. *Zero drift:* ± 1% of full scale (in 24 hours, this is equilibrated and at a constant temperature with sensor properly maintained. *Span drift:* less than ± 2% of full scale (24 hours, equilibrated and at a constant temperature with sensor properly maintained. *Lag time:* less than one second. *Rise time:* 20 seconds to 90% of final value or better. *Fall time:* 20 seconds to 10% of original value or better.

Model 681 Formaldemeter

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

The Formaldemeter is a portable and pocket-size monitor for formaldehyde. The monitor utilizes a fuel cell detector and is capable of monitoring formaldehyde over a range of 0.3 to 99.9 ppm.

Operating principle

The instrument uses an electrochemical fuel cell detector, consisting of two platinum electrodes, to measure atmospheric formaldehyde vapor concentration by electrochemical reaction. This reaction causes one of the electrodes to develop a voltage in proportion to the formaldehyde concentration of the sample. The voltage is amplified and displayed on a digital meter (LCD) calibrated directly in ppm.

Description

Dimensions: 120 × 63 × 33 mm. *Weight:* 200 g. *Sample size:* 1.5 cc. *Battery operated:* 9V dry battery.

Performance data

Least detectable quantity: 0.3 ppm formaldehyde. *Range:* linear scale 0.3 to 99.9 ppm. *Sensitivity:* 0.3 ppm. *Interferences:* additive readings in presence of methanol, ethanol, formic acid, phenol, resorcinol, furfuryl alcohol under certain conditions. *Precision and accuracy:* ± 15%. *Response time:* 20 seconds. *Stability:* 2.5% drift over 6 months. *Adjustments:* zero and span potentiometers.

Figure V- 22 — Model 681 Formaldemeter.

MiniCO™ Carbon Monoxide Indicators

Mine Safety Appliance Company
600 Penn Center Boulevard
Pittsburgh, PA 15235

The MSA MiniCO Carbon Monoxide Indicators are pocket-sized devices for measuring CO concentrations in ambient air. They can detect CO in ranges of 0–100 ppm (Model I), 0–250 ppm (Model III), and 0–500 ppm (Models II and IV).

TABLE V-2
Common Interferents and the Concentration Equivalent to 1 ppm CO

Interferent	Models I, II, III [ppm]	Model IV [ppm]
Methane (CH_4)	10,000	1000
Ammonia (NH_3)	20	55
Sulfur dioxide (SO_2)	0.24	2
Hydrogen (H_2)	13	34
Hydrogen sulfide (H_2S)	0.1	0.1
Nitrogen dioxide (NO_2)	2.44	3
Propane	15	15
Nitric oxide (NO)		0.3
Ethylene (C_2H_4)	1.0	1.0
Acetylene (C_2H_2)	0.7	0.7
Ethyl alcohol (C_2H_5OH)	0.3	0.3

Figure V-23 — MiniCO™ Carbon Monoxide Indicators.

Operating principle

MiniCo Indicators operate on the principle of an electrochemical polarographic sensor cell. In operation, air samples diffuse through a gas porous membrane and a sintered metal disc to enter a chamber within the cell. The cell electro-oxidizes CO to CO_2 in proportion to the partial pressure in the chamber and the resulting signal is amplified and temperature compensated to drive the meter.

Description

An adapter for the MiniCO Indicators is available with aspirator bulb for remote sampling, using standard MSA sampling lines. Battery powered which lasts up to 12 hrs under normal use or 100 hrs of continuous operation. The MiniCO Model IV has built in audible and visual alarms factory set to trigger at 50 ppm. Alarms set point is adjustable over the range 25–500 ppm.

Performance data

Least detectable quantity: 2 ppm for Models I, II and III; 1 ppm for Model IV. *Ranges:* 0 to 100 ppm, Model I; 0–500 ppm, Models II and IV; 0–250 ppm, Model III. All models have ± 2% precision and accuracy as well as a 90% response time in 30 seconds, a span drift less than 2% FS/day, and zero drift less than 1% FS/day. All MiniCO Indicators can be field-calibrated using the MSA Calibration Check Kit, Model R. Table V-2 lists common interferents and the concentration equivalent to 1 ppm CO.

Portable Carbon Monoxide Indicator, Model 70

Mine Safety Appliances Company
(address above)

The MSA Portable Carbon Monoxide Indicator, Model 70 is designed for on-the-spot measurement of carbon monoxide in air in ranges of 0–100 or 0–500 ppm.

Operating principle

The instrument operates on the principle of an electrochemical polarographic-type cell. A sealed unit containing a sulfuric acid electrolyte, the cell is self-sustaining because it has no consumable electrode. In operation, the cell electro-oxidizes CO to CO_2 in proportion to the partial pressure of CO in the sample chamber. The resulting electrical signal is monitored, temperature compensated, and amplified to drive a meter.

Physical description

Dimensions: 8½" × 6½" × 3⅝". *Weight:* 7.5 lb. *Sampling rate:* approx. 1.5 lpm. *External accessories:* sampling lines, made of synthetic rubber and complete with complings are available in 5-, 10-, 15-, 25-, 35-, and 50-ft lengths; 4-ft probe rode is available in solid brass; 30-ft probe tube is available in solid brass or plastic; external cartridge holder for cotton filters, and external battery charger are also available. *Power requirements:* instruments powered by an integral rechargeable 2.4 V Ni-Cad battery pack sealed in plastic case; provides 8–10 hrs of sampling in a fully charged condition. The instrument provides visual and audible alarms factory set to trigger at 50 ppm low range (0–100 ppm) and 250 ppm high range (0–500 ppm). An internal adjustable potentiometer is provided for use with recorders.

TABLE V-3
Interferents and Concentrations Equivalent to 1.0 ppm CO or less

Interferent	ppm
Methane (CH_4)	10,000
Ammonia (NH_3)	1,000
Sulfur dioxide (SO_2)	500
Hydrogen (H_2)	60
Hydrogen sulfide	30
Hydrogen dioxide	12
Propane (C_3H_8)	5
Nitric oxide	3
Ethylene (C_2H_4)	2
Ethyl alcohol (C_2H_5OH)	2
Acetylene (C_2H_2)	1

Figure V-24 — Portable Carbon Monoxide Indicator, Model 70.

Performance data

Least detectable quantity: 2 ppm. *Ranges:* 0–100, 0–500 ppm. Table V-3 lists the interferents and concentrations equivalent to 1.0 ppm CO or less. An internal filter included with each sensor assembly minimizes the effects of these compounds. However, high concentrations of these contaminants may permanently poison the filter. Proper readings are obtained only when the battery has a sufficient charge. *Precision and accuracy:* ± 1% FS. *Response time:* 90% of final reading in less than 30 seconds. *Span and drift:* less than 1% FS/day. Calibration and zero adjustments are made with "lift-to-adjust" knobs. Unit is calibrated for use with an external 1 V 1000 ohm impedance recorder. The MSA Calibration Check Kit, Model R, provides a quick, convenient and economical method of checking the response of the instrument. Because testing is performed with known concentrations of pressurized gas-in-air, test results are reproducible.

Carbon Monoxide Detection System, Series 570

Mine Safety Appliances Company
(address above)

The MSA Carbon Monoxide Detection System, Series 570, is an instrument package designed to monitor ambient air continuously for carbon monoxide in ranges of 0–100 ppm or 0–500 ppm. The System is available in four models: 570, for central monitoring of multiple locations; 571, for single-location monitoring; 571 Alarm, for single-location monitoring; and 572, an explosion-proof system for monitoring a single location. In conjunction with the Models 570 and 571, the MSA Compressed Air-Line Adapter can be used to monitor CO in respirable compressed air.

Operating principle

The Series 570 System operates on the principle of an electrochemical polarographic cell. Air samples diffuse through a gas-porous membrane and a sintered metal disc to enter a sample area within the cell, which electro-oxidized CO to CO_2 in proportion to the partial pressure of CO within the sample. The resulting electrochemical signal is amplified to drive the readout meter on the control module.

Physical description

Dimensions: Model 570, 12" × 9" × 10½" (2-unit housing); Models 571 and 571 Alarm, 6⅛" × 14¾" × 13¼"; Model 572, 6" × 16⅞" × 14¼". *Sensor life:* 12 months. *Sensor cable requirements:* 4-conductor, 14 ohms closed loop, maximum resistance (16–22 AWG). *External accessories:* diffusion heads including sensors and assemblies. *Power requirements:* 115 V, 80 VAC, 50/60 Hz; 11–15 or 19–60 VDC (220 VAC with auxiliary transformer). *Safety provisions:* tamper-resistant controls; malfunction light and relay which deactivates in the event of lost power, open sensor, severed or shorted cable; built-in short-circuit protection; built-in warning lights and alarm circuitry; optional revolving red lamp and optional self-contained horn (571 Alarm); explosion-proof system design (Model 572 only).

Performance data

Ranges: 0–100 or 0–500 ppm CO. *Precision:* ± 1%. *Response time:* 90% in 90 sec. *Zero and span drift:* 1% FS/day.

Figure V-25 — Carbon Monoxide Detection System, Series 570

Chlorine Indicator, Model 90

Mine Safety Appliances Company
(address above)

The MSA Chlorine Indicator, Model 90, is a portable instrument designed to detect low concentrations of chlorine in air.

Operating principle

The instrument operates on the principle of an electrochemical polarographic cell. During operation, a small pump draws sample air into a chamber of the cell. The cell electro-reduces Cl_2 in proportion to the partial pressure of Cl_2 in the chamber. The resulting electrical signal is amplified to drive an analog meter and an alarm comparator circuit.

Physical description

Dimensions: 8½" × 3⅝" × 6½". *Weight:* 7.5 lbs. *Sampling rate:* approximately 1.5 lpm. *External accessories:* carrying harness; charging cable. Powered by a rechargeable, 2.4 V Ni-Cad battery pack. *Safety provisions:* warning light and alarm horn.

Performance data

Least detectable quantity: 0.05 ppm. *Ranges:* 0–2, 0–10 ppm Cl_2 in air. *Precision:* ± 1% FS. *Response time:* 90% in 60 sec. *Span and zero drift:* less than 1% FS/day. *Calibration:* instrument equipped with "lift to adjust" zero and span controls.

Figure V-26 — Chlorine Indicator, Model 90

Hydrogen Sulfide Indicator Model 80

Mine Safety Appliances Company
(address above)

The MSA Model 80 Hydrogen Sulfide Indicator is a portable instrument designed to allow direct, on-the-spot measurement of hydrogen sulfide in air. The instrument is a dual-range device with one range 0–20 ppm hydrogen sulfide and the other 0–100 ppm.

Operating principle

The instrument operates on the principle of an electrochemical polarographic cell that oxidizes hydrogen sulfide in proportion to its partial pressure in the sample atmosphere.

Physical description

Dimensions: 8½" × 6½" × 3⅝". *Weight:* 7.5 lbs. *Sampling rate:* approximately 1.5 lpm. *Sensor life:* 6 months minimum. Powered by a 2.4 V Ni-Cad battery pack sealed in a plastic case. *Safety provisions:* warning light and audible alarm factory set at 10 ppm on low range, 50 ppm on high range; setpoints are field adjustable. *External accessories:* carrying straps; accessory battery charging cable; standard MSA probe rods and tubes, and sampling lines, when used in remote sensing.

Performance data

Least detectable quantity: 0.5 ppm. *Ranges:* 0–20, 0–100 ppm H_2S in air. *Precision and accuracy:* ± 1% FS. *Response time:* 90% in less than 60 sec. *Span and zero drift:* less than 1% FS/day. *Calibration:* span and zero controls located on front of instrument which may be field-calibrated using 10 ppm H_2S in air.

Figure V-27 — MSA Hydrogen Sulfide Indicator, Model 80.

Hydrogen Sulfide Detection System, Series 580

Mine Safety Appliances Company
(address above)

The MSA Hydrogen Sulfide Detection System, Series 580 is an instrument package designed to monitor ambient air continuously for hydrogen sulfide gas in a range of 0–50 ppm. The System is available in three models: 580, for central monitoring of multiple locations; 581, for single-location monitoring; and 582, an explosion-proof system for monitoring a single location.

Operating principle

The Series 580 System operates on the principle of an electrochemical polarographic cell. The cell electro-oxidizes H_2S in proportion to the H_2S partial pressure in the sample. The resulting electrochemical signal is amplified to drive the readout meter on the control module.

Physical description

Dimensions: Model 580, 12" × 9" × 10½" (2-unit housing); Model 581, 6⅛" × 14¾" × 13¼"; Model 582, 6" × 16⅞" × 14¼". *Sensor life:* 12 months. *Sensor cable requirements:* 4-conductor, 14 ohms closed loop, maximum resistance (16–22 AWG). *External accessories:* diffusion heads including sensors and assemblies. *Power requirements:* 115 V, 80 VA, 50/60 Hz; 11–15 or 19–60 VDC (220 VAC with auxiliary transformer). *Safety provisions:* tamper-resistant controls; malfunction light and relay which deactivates in the event of lost power, open sensor, severed or shorted cable; built-in short-circuit protection; built-in warning lights and alarm circuitry; explosion-proof design (542 only).

Performance data

Range: 0 to 50 ppm H_2S. *Precision:* ± 1%. *Response time:* 90% in 80 sec. *Zero and span drift:* less than 1% FS/day.

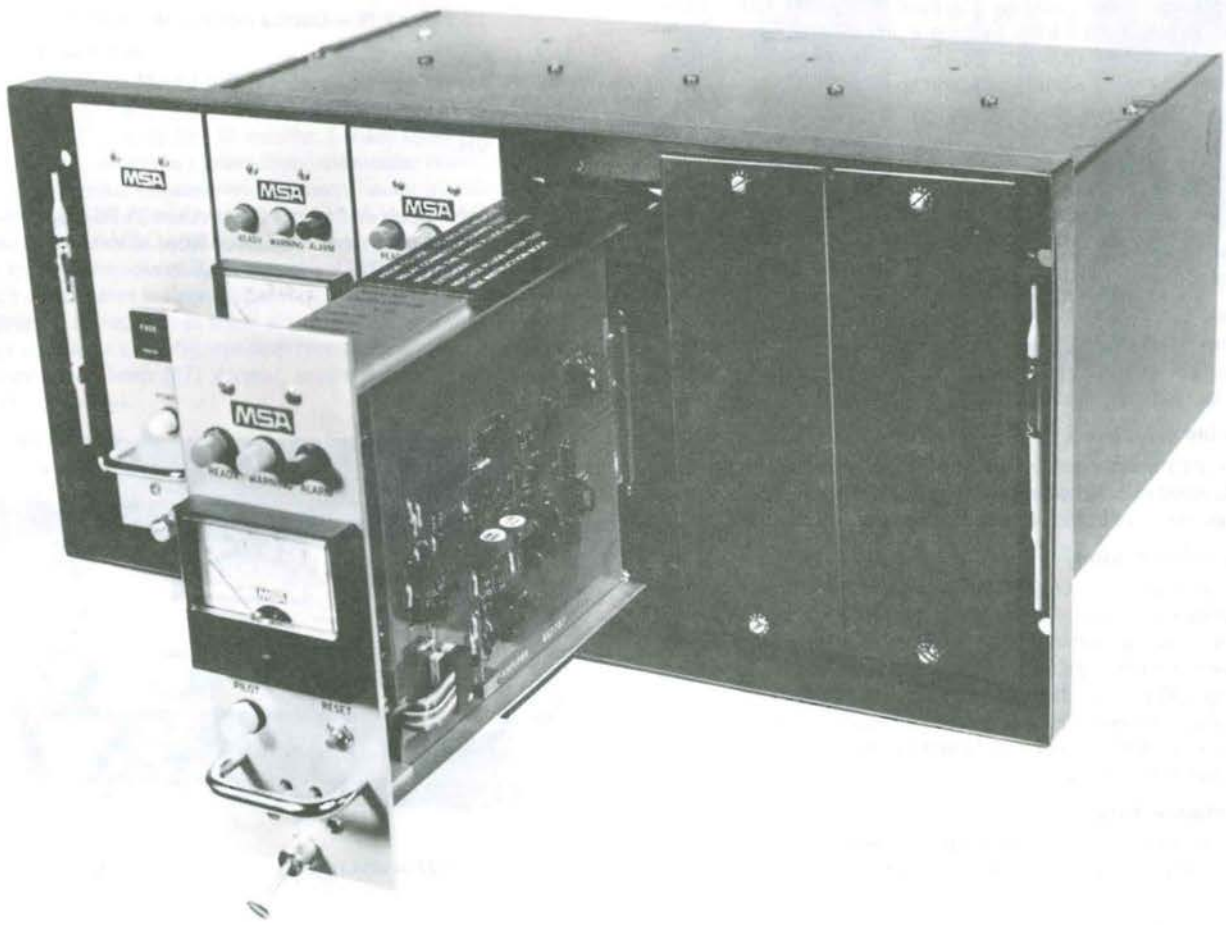


Figure V-28 — MSA Hydrogen Sulfide Detector, Model 580.

Ozone Recorder, Model 03T

Ozone Research and Equipment Corporation
3840 North 40th Avenue
Phoenix, AZ 85019

This ozone recorder is designed for atmospheric ozone measurement, ozone measurement in control rooms, laboratories, production plants, warehouses, etc.

Operating principle

Ozone measurement is based upon the iodometric principle incorporated into an electronic loop feed back servo system that allows continuous sensitive measurement of ozone concentrations to as low as 3 pphm/volume. The Model 03T samples at the rate of 4000 cc/min allowing greater unit accuracy and less dependence on slight changes in sample air flow. The instrument will operate for 3 day intervals without change in operation solution, allowing unattended operation over weekends and at night.

Physical description

Size: 24" × 15" × 13"; vacuum pump chassis, 12" × 9" × 8". *Weight:* 70 lbs. *Power requirement:* 110 volts, 60 cycles, 400 watts.

Performance data

Standard range: 1–100 pphm/volume. *Accuracy:* 3% of scale. *Response time:* normal atmospheric change, 90% of true value in 2 minutes. *Chart speed:* 1"/hr. *Chart period:* 31 days. *Options:* Alarm circuit and meter for remote signal.

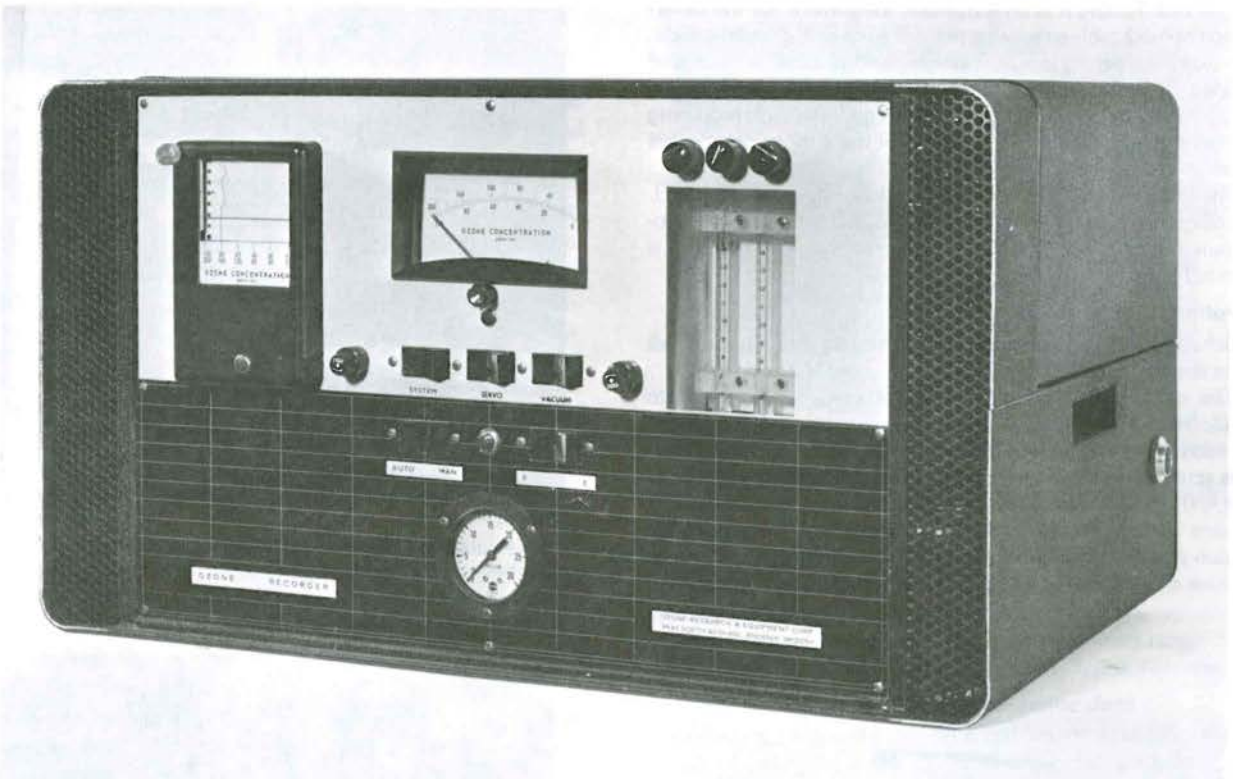


Figure V-29 — Ozone Recorder, Model 03T

Ozone Measurement Instrument, Model MSA-3

Ozone Research & Equipment Corporation
(address above)

This ozone measuring instrument is used for the determination of ozone in air or oxygen and is predominantly applied to measurement of ozone concentrations in ozone test chambers, other confined sources, process streams, and in the atmosphere. The instrument is portable and, as such, can be conveniently located near the source where the ozone is to be measured.

Operating principle

The principle of measurement is based upon the quantitative release of iodine from a buffered solution of potassium iodine in the titration with sodium thiosulfate of the released iodine according to the following formula:

$$O_3 + 2KI + H_2O \rightarrow O_2 + I_2 + KOH$$

$$I_2 + 2Na_2S_2O_3 \rightarrow Na_2S_4O_6 + 2(NaI)$$

The Model MSA-3 employs the electrometric end-point method, whereby the end-point of the titration is indicated on a meter. In operation, the instrument is supplied with potassium iodide and sodium thiosulfate solution. A sampling sequence is begun by the operator initiating the flow of air through the sampler and simultaneously starting a stop-watch. When the end-point is indicated on the meter, the stop-watch is stopped and the ozone concentration is quickly determined by dividing a predetermined constant by the stop-watch. The actual measurement is on the order of 3 to 5 minutes, depending on the normality of the sodium thiosulfate used.

With this method, there is no iodine volatilization factor since there is a fixed quantity of thiosulfate and time is the only variable.

The measurement period ends upon the appearance of iodine which is sensed electrometrically.

Physical description

Size: 17" × 12" × 10". *Weight:* 45 lbs. *Power:* 115 V, 60 Hz, 350 watts. *Vacuum pump:* dry vane. *Reaction assembly:* Pyrex unitized construction with integral platinum electrodes and spray jet.

Performance data

Sampling rate: 3000 cc/min. *Measurement range:* 5 pphm to 0.100% per volume; higher measurement range modifications of the instrument are available.

Sulfur Dioxide Analyzer/Recorder

Process Analyzers, Inc.
3 Headly Place
Fallsington, PA 19054

The PAI Titrilog II is an automatic instrument for the determination of oxidizable sulfur compounds such as hydrogen sulfide, sulfur dioxide, mercaptans, thiophene, and organic sulfides and disulfides. This instrument offers an effective and economical means of continuously, automatically, and quantitatively recording the concentration of these compounds in the atmosphere, in gas streams, and in stack gases.

The PAI Titrilog II is designed for the laboratory, plant or field. It will operate for extended periods without attention, so that installation in isolated locations is entirely practical. The Titrilog II is shown in Figure V-30.

Operating principle

Schematic diagrams of the basic circuitry and titration cell used in the PAI Titrilog II are shown in Figures V-31 and V-32.

The cell consists of an electrolyte containing potassium bromide from which free bromine is being generated electrolytically. In addition to the generating electrodes, there is a set of electrodes sensitive to free bromine. The potential of these electrodes varies with the concentration of free bromine in the solution. A reference battery provides "bucking voltage" to "buck out" the "solution pressure" potential seen by these electrodes, as well as introduce an input to the amplifier to generate as small amount of free bromine to serve as the "zero level" or null point for the potentiometric system.

The cell is made up of two chambers, an inner chamber where the reaction takes place and an outer chamber which serves as

Figure V-30 — Process Analyzers, Inc. Titrilog II.

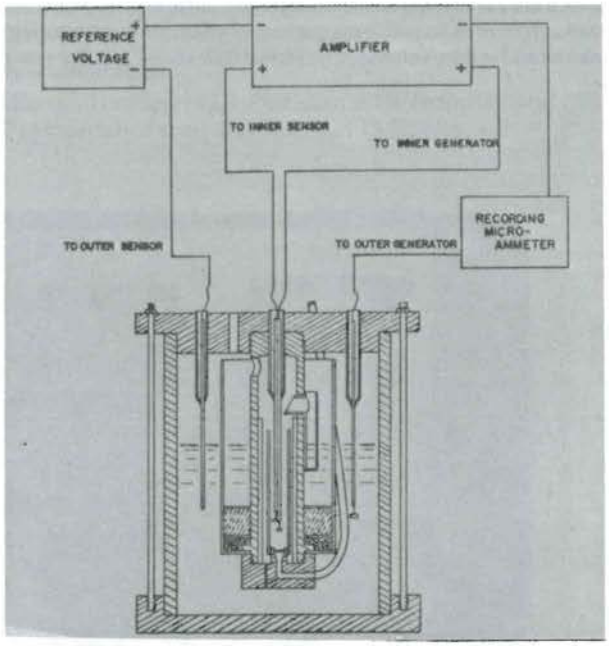


Figure V-31 — Schematic of basic circuitry used in Titrilog II.

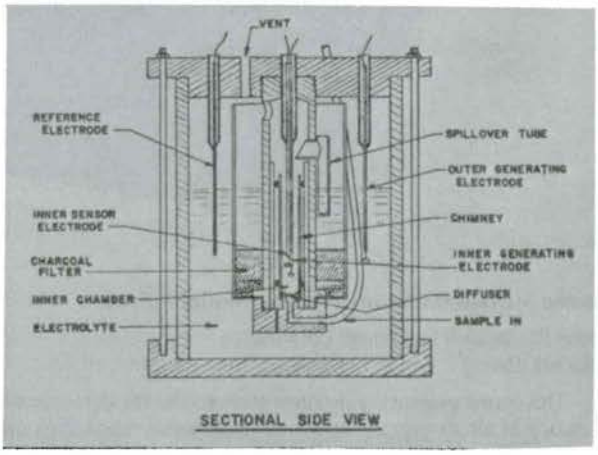


Figure V-32 — Titration cell used in the Titrilog II.

storage for fresh electrolyte. Electrolyte from the inner chamber is continuously being "pumped" through a charcoal filter into the outer chamber. The charcoal filter removes impurities and the products of reaction. Fresh electrolyte is continuously being drawn into the inner chamber as the old is "pumped" out. The electrolyte should last for many months, depending upon the sulfur concentration in the sample.

Physical description

Size: 14¼" × 14¼" × 21". *Weight:* 65 lbs. *Power requirement:* 115 VAC, 60 Hz, 50 watts. In order to distinguish between some of the different sulfur compounds, liquid absorptive filters are furnished as an accessory. These filters absorb one or more of the compounds of interest, enabling their concentration to be determined by difference. A programming system will route the sample through either of the filters, bypass the filters, and establish a zero level on an automatic repetitive cycle.

Performance data

Normal sensitivities: 0.01 ppm for H_2S and 0.02 ppm for SO_2 and mercaptans.

Portable Flue Gas Analyzer

Teledyne Analytical Instruments
16830 Chestnut Street
City of Industry, CA 91749

The Model 990 is a completely portable battery-powered flue gas analyzer designed to rapidly monitor the oxygen (O_2) and carbon monoxide (CO) content of a combustion process. When these two measurements are combined for the purpose of maximizing fuelburning efficiencies, boilers and heaters can be fine-tuned for optimum air/fuel ratios.

Operating principle

The CO trace measurement is accomplished by a maintenance-free, disposable electrochemical sensor. The sensor output is directly proportional to the CO concentration. Zero and span drifts are less than 2% in 24 hours. A 90% of full-scale response is attained in 30 seconds or less. Analyzers equipped with standard analog panel meters have dual-range measurement capability of 0 to 500 and 0 to 1000 ppm CO; analyzers with optional digital readouts have a 0 to 1000 ppm range.

Oxygen analysis is accomplished with Teledyne's patented Micro-Fuel Cell which produces an electrical signal that is directly proportional and specific to the oxygen concentration in the flue gas. A 90% of full-scale response is attained in 13 seconds or less. The Micro-Fuel Cell is completely maintenance-free and disposable, and it is calibrated with ambient air.

Physical description

Power requirements: Ni-Cad rechargeable batteries. Built-in charger requires 115 VAC, 60 Hz (220 VAC, 50 Hz also available). *Operating temperature dimensions:* 32° to 122°F (0° to 50°C). *Size:* approx. 12¼" × 13" × 6¾". *Weight:* approx. 11 lbs.

Oxygen section performance data

Analog: ranges of 0–5%, 0–10%, and 0–25% O_2; sensitivity of 2% of full scale; accuracy of ± 2% of full scale scale at constant temperature or ± 5% of full scale throughout the operating temperature range. *Digital:* ranges of 0–25% O_2; sensitivity of 0.1% O_2, absolute; accuracy of ± 1% of full scale at constant temperature, or ± 3% of full scale throughout operating temperature range. *Sensor:* Micro-Fuel Cell (electrochemical), Class B-3, one year warranty.

Figure V-33 — Teledyne Portable Flue Gas Analyzer, Model 990.

Carbon monoxide section performance data

Analog: ranges of 0–500 ppm and 0–1000 ppm CO; sensitivity of 2% of full scale; accuracy of ± 2% of full scale at constant temperature or ± 5% of full scale throughout the operating temperature range. *Digital:* range of 0–1000 ppm CO; sensitivity of 1 ppm CO, absolute; accuracy of ± 1% of full scale at constant temperature or ± 3% of full scale throughout the operating temperature range. *Calibration:* with certified gas (700–900 ppm CO in air or N_2, or 350–450 ppm CO in air or N_2); electrochemical. *Sensor:* Class F-1; 6 month warranty.

EA-1 Gas Analyzer

A.D.S. Systems, Inc.
P.O. Box 25689
Seattle, WA 98125

The EA-1 Gas Analyzer is a portable instrument for detection of flammable and non-flammable gases in the ppm and % LEL ranges.

Operating principle

The EA-1 utilizes the Cold Sensor™ element which does not burn vapor to detect gas like other analyzers using semi-conductor and other "hot-wire" type sensors. The Cold Sensor element operates on the principle of adsorption, the phenomenon which attracts and holds a molecule to the surface of a solid. The measure of this attractive force is known as the Van der Waals' constant for the specific molecule. The rapid process of gaseous diffusion carries the traces of toxic or explosive gas into contact with the adsorptive material in the sensor changing the sensor's electrical characteristics.

The sensors' monitoring system is adjustable to the level of detection desired from small concentrations on the ppm scale (toxic gases) to a percent of the lower explosive limit (combustible gases). The system can transfer data to terminals or computers. Monitoring or alarm systems can be used to trigger corrective control systems.

Physical description

Size: 8" × 10½" × 5½" (10" deep with cover). *Weight:* under 10 lbs. *Power requirements:* 90–120 VAC, 50/60 Hz or 190–240 VAC, 50/60 Hz; consumption 300 ma (5 watts)

Figure V-34 — EA-1 Gas Analyzer.

J-W Oxygen Indicators

Bacharach Instrument Company
625 Alpha Drive
Pittsburgh, PA 15238

The K series of oxygen indicators are available in various models and ranges designed to meet the need for portable, fast responding indicating devices measuring in the low and medium oxygen percentage ranges.

The Model GPK, shown in Figure V-35, is a combined oxygen/combustible gas indicating detector. The oxygen meter reads directly in the range of 0–25% oxygen. The combustibles meter reads 0–1.0 of the lower explosive limit (LEL).

Model HPK is a combination oxygen/combustible gas indicator similar to the Model GPK except that it has two combustible gas ranges, O–1.0 LEL. and 0–100% natural gas. A 0 to 4% natural gas scale on the meter face can be supplied in place of the 0.10 LEL scale. Both of the combination detectors are also available in Bureau of Mines approved versions.

Figure V-36 — J-W Model GPK combined oxygen/combustible gas detector.

Figure V-35 — J-W Model K525 dual range oxygen indicator.

Operating principle

In the Model K oxygen indicators, the sample of the atmosphere to be tested is drawn to the instrument through the inlet fitting by means of an aspirator bulb. It then passes through a Teflon membrane permeable to oxygen and into the self-generating electrolytic cell where the current produced is directly proportional

to the amount of oxygen. The oxygen content is then read directly on the meter. The oxygen cell is a small leak-proof, self-generating, electrolytic cell constructed of non-corrosive materials. The cell plugs into the instrument and may be replaced or reactivated in a matter of minutes.

In the combination instruments, the combustible gas detector components are the same as those described under J-W Combustible Gas Indicators.

Physical description

K Models. Case is 3" × 4⅜" × 5¾", weighs 2.5 lbs, and is constructed of molded fiberglass. *Meter calibration:* K25 single range — 0 to 25% O_2; K525 dual range — 0 to 5% and 0 to 25% O_2; K2500 dual range — 0 to 25% and 0 to 100% O_2. *Accuracy:* to ± 0.1% O_2. *Air mover:* aspirator bulb.

Models GPK, HPK, GK, and HK. Each measures 4" × 5½" × 7½" and weigh 5¾ lbs. *Meter calibration:* Models GPK and GK — 0 to 25% O_2; 0 to 1.0 LEL; Models HPK and HK — 0 to 25% O_2; 0 to 1.0 LEL or 0–4% natural gas, and 0–100% natural gas. *Air movers:* integral pump for Models GPK and HPK, and aspirator bulb for Models GK and HK. Detector cell life for all models is six months, and may be reactivated.

J-W Oxygen Alarms

Bacharach Instrument Company
(address above)

The J-W Oxygen Alarms and Analyzers continuously monitor working areas, process lines, pressure vessels, ship and barge holds and the like for oxygen deficiency, trace oxygen as low as 0.1 of 1% in inert atmospheres, and excess oxygen from 21% up to 100%. They are available in both sample-drawing types and remote diffusion-sampling types for one or multiple sample locations. Cabinet styles range from small fiberglass wall-mounted housings to large floor-standing steel cabinets and explosion-proof construction. A Model CDK oxygen alarm is shown in Figure V-37.

Operating principle

Both types of oxygen alarms utilize the proven and tested self-generating oxygen cell as used in the J-W Model K portable oxygen indicators. The cell is exposed to the sample either by drawing the sample through it or exposing it directly to the atmosphere to be monitored. The sample diffuses through a Teflon membrane to reach an electrode, producing a current directly proportional to the oxygen content of the sample. The current produced is then read on a suitably calibrated sensitive meter or recorder and used to trigger the alarm circuit when the set point is reached. Alarm may be actuated on increasing or decreasing oxygen concentration depending upon the application.

Physical description

Both the sample-drawing and the diffusion-detection models provide in the housing or on the front panel: 1) a continuous-reading indicating meter; 2) an alarm circuit with a fully adjustable alarm set point, relays, and terminals for connection to external signals; 3) red and green alarm and pilot lights; 4) power supply; 5) Type K oxygen detection cell; 6) calibration adjustment to permit setting of the instrument against standard air or a known oxygen concentration; 7) terminals for all external connections; and 8) all other required components for complete operation.

In addition to the above, the same drawing models are supplied with a pump for drawing the sample through small diameter tubing to the analyzer and, in the case of multipoint units, a motor driven timer with the appropriate number of solenoid valves to allow scanning of each sample location on a 15 or 30 second per point cycle. The diffusion-sampling models may use the detection cell plugged into the bottom of the cabinet to monitor the surrounding atmosphere, or mounted in a small housing several thousand feet distant, connecting to the analyzer by two wires. For multi-point diffusion-sampling models separate meters, cells, and alarm circuits are provided for each point.

Figure V-37 — Model CDK oxygen alarm.

Model 946 Trace Acid/Base Monitoring System

Beckman Instruments, Inc.
Process Instruments Division
2500 N. Harbor Boulevard
Fullerton, CA 92634

The Beckman Model 946 Trace Acid/Base Monitoring System continuously measures trace acid or base concentrations in a variety of process streams. The background component may be any gas or vaporizable liquid that, when dissolved in demineralized water, does not alter its pH. The Beckman System excels in the following applications which represent only a few of the many possible uses: 1) hydrochloric acid in vinyl chloride monomer product — to provide early warning of hydrochloric acid breakthrough, resulting in product loss by discoloration; 2) hydrochloric acid in catalytic reformer recycle hydrogen — to prevent acid from affecting catalyst activity; 3) trace acids in various hydrocarbon streams — to minimize process equipment corrosion; and 4) trace ammonia leakage — to area-monitor compressor-room atmospheres and all environments where ammonia leakage constitutes a health hazard.

Beckman pH components comprise the heart of the system. A series Three pH Flow Chamber (incorporating a sealed pH preamplifier, electrodes and cable) is integrally installed in the system's NEMA-12 enclosure. An externally mounted Model 960B or 942 pH monitor provides span and indicator scales for 0 to 14 pH units.

Operating principle

The system combines the gas or vaporized liquid sample with a metered flow of demineralized water using precise flow control. Thorough mixing insures that trace quantities of acid or base present in the sample are dissolved in the water. The gas/liquid mixture flows to a separator where the gas phase is exhausted at the top. The liquid phase — maintained at a constant low level — drains out the bottom into a stainless steel pH flow chamber that measures the pH of the water.

With no acid or base present, the demineralized water will have an approximate pH of 6 to 7. With the system accurately controlling the ratio of original sample flow to water flow, the presence of 1.0 $P/10^6$ hydrochloric acid (a strong acid) will depress the approximate pH to 4.5. A 10 $P/10^6$ acid concentration will further depress the approximate pH to 3.5. The Beckman System simply measures these pH shifts and correlates them to ppm to continuously monitor trace quantities of acids or bases in process streams.

The sample handling system employs a vaporizing pressure regulator for liquid samples. The system operates at 10 psig (69kPa) to permit venting the gas, which may be toxic or flammable, to a flare or safe disposal area. Differential pressure regulation precisely controls system flow.

Performance data

Full scale sensitivity: 1 $P/10^6 \pm 0.05$ $P/10^6$, $P/10^6 \pm 0.5$ $P/10^6$, 100 $P/10^6 \pm 5$ $P/10^6$. *Response:* 90% in 3 minutes. *Operating ranges:* selectable span of any units (with the 942) 0–14, (with the 960B). Lower limit continuously from 0–14 pH (pH reading correlated to $P/10^6$ actual). *Sample flow rate:* liquid from 10 to 25 cc/min to vaporizer; gas from 5 to 10 lpm; demineralized water flow rate from 100 to 200 cc/min. Quality of water from 1 to 10 megaohm/cc specific resistance (1 to 0.1 micromhos/cm specific conductivity). *Materials in contact with sample:* stainless steel, glass, Teflon, Viton, PVC. *Sample temperature compensation:* automatic, from 32° to 212°F (0° to 100°C). Steam required for heat to vaporizing pressure regulator when sampling liquids only. Dry nitrogen or air purge gas required only to purge system prior to opening for maintenance, if sample gas is hazardous (e.g., vinyl chloride); also for purging enclosure (60 scfh) (28.3 lpm). *Ambient humidity limits:* up to 99% RH. *Ambient temperature limits:* 32° to 122°F (0° to 50°C).

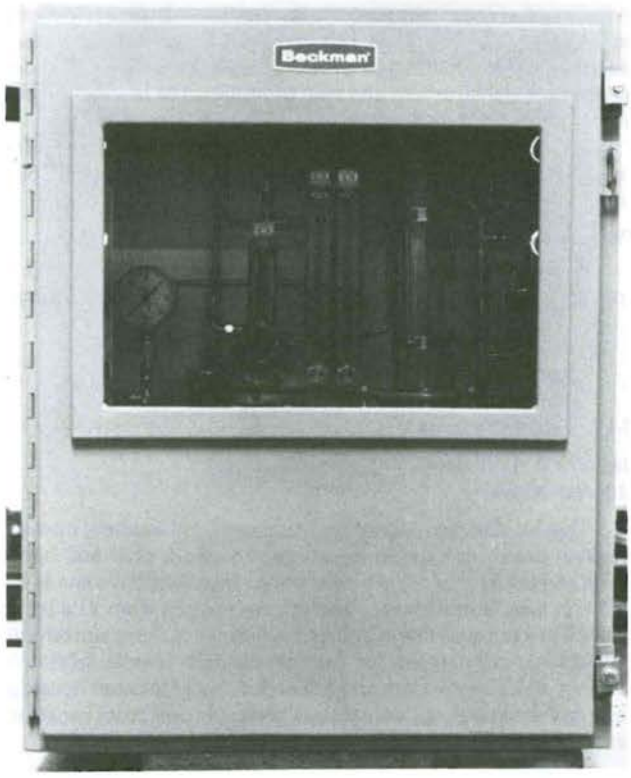


Figure V-38 — Model 946 Trace Acid/Base Monitoring System.

Physical description

System enclosure (NEMA-12) contains all sample handling components and the pH flow assembly (316 S.S.) with sealed preamplifier in dome assembly and 20" of cable to externally located Model 960B or 942 pH Monitor. Additional cable available to 1000' if required. *Power requirements:* 107 to 127 VAC, 50/60 Hz; 214 to 254 VAC, 50/60 Hz. *Size:* 30" × 30" × 12".

Model OM-11EA/OM-11 Oxygen Analyzers

Beckman Instruments, Inc.
Automotive Test Instruments Operations
(address above)

The Beckman Model OM-11EA and OM-11 are designed for monitoring vehicle emissions and other applications requiring precise measurement of rapid changes in the concentration of gaseous oxygen. They are frequently used in emission measurement consoles and other multi-parameter analytical systems.

Operating principle

The analyzers use electro-chemical technology for polargraphic oxygen analysis. The Models OM-11EA/OM-11 utilize a factory-charged, factory-sealed disposable oxygen sensor. The sensor has automatic temperature compensation, at both normal and high temperatures — and throughout ambient temperature fluctuations — the sensor accurately determines the oxygen concentration present in the sample.

Designed principally for engine exhaust analysis, the Model OM-11EA is suited for console mounting. It excels where rapid changes in oxygen concentration must be precisely monitored. For speed, accuracy and analytical stability the Model OM-11EA is excellent.

For applications requiring a remote sensor, the Model OM-11 has a 15-ft interconnection cable which allows the small, compact pick-up head to be remotely located in the most advantageous position.

Analytical data can be continuously read from the 3½" digit front-panel display. A 1 VDC voltage output is continuous on all three ranges.

Performance data, Model OM-11EA

Speed of response: 100 ms for fast mode and 1 sec for slow mode, both typical for 90% response. *Ranges:* 0–5%, 0–10%, 0–25% O_2 (switch-selectable). *Accuracy:* ± 1.0% over 24 full scale. *Zero drift:* ± 0.5% over 24 hours after a four-hour warm-up. *Span drift:* ± 1.0% over 24 hours after a four-hour warm-up. *Noise:* less than 0.2% peak-to-peak. *Linearity:* ± 0.2%. *Readout:* Planar-gas-discharge (PGD) display 3.5" digits. *Outputs:* 10 mV, 100 mV, or 5 VDC; selectable for each range at rear panel terminals. *Power requirements:* 115/230 VAC, 50/60 Hz, 9OW. *Sample flow rate:* 5–10 ft^3/hr (2.36–4.7 lpm). *Sensor control temperature:* 104°F ± 1.8°F (40°C ±1°C). *Ambient temperature limits:* 40°–95°F (4.4° –35°C). *Ambient humidity limits:* 0–95% RH. *Case:* single-unit construction with slide-out chassis.

Performance data, Model OM-11

Speed of response: 100 ms for fast mode and 1 sec for slow mode, typical for 90% response. *Ranges:* 0–5%, 0–10%, 0–25% O_2 (continuous). *Accuracy:* ± 1.0% full scale. *Zero and span drift:* ± 1.0% over 24 hours after a four-hour warm-up. *Noise:* less than 0.2% peak-to-peak. *Linearity:* ± 0.3%. *Readout:* Planar-gas-discharge (PGD) display 3.5" digits. *Outputs:* 1 VDC; continuous outputs on all ranges. *Power requirements:* 115/230 VAC, 50/60 Hz, 50–90W. *Sample flow rate:* 0.047–0.377 ft^3/hr (100–800 ml/min). *Sensor control temperature:* 104°F ± 1.8°F (40°C ± 1°C). *Ambient temperature and humidity limits:* 0–95% RH. *Case:* two-piece construction with separate units for analyzer and pick-up head.

Figure V-39 — Model OM-11EA/OM-11 Oxygen Analyzers.

Ozone Analyzer, Model 950

Beckman Instruments, Inc.
Process Instruments Division
(address above)

The Beckman Ozone Analyzer is designed for continuous monitoring of photochemical oxidants, with a wide selection of full scale ranges for ambient air monitoring with high precision and accuracy.

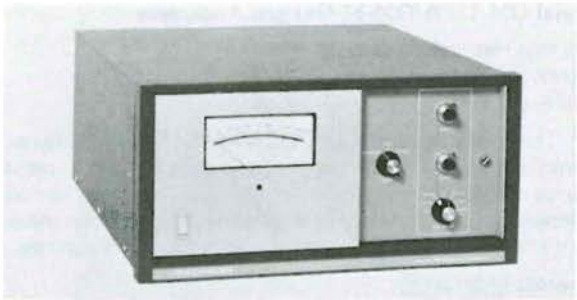


Figure V-40 — Model 950 Ozone Analyzer.

Operating principle

The chemiluminescent method is based on the principle that ozone reacts with ethylene to produce a light emission. The intensity of the light emission, which is proportional to the concentration of ozone (O_3) present in the ambient air sample, is measured by a photomultiplier tube and associated electronics.

Physical description

The primary components of the Model 950 are the electronics section and flow control system. The chemiluminescence reaction is directly proportional to O_3 concentration and provides a signal current in the order of 1×10^{-8} amps/ppm concentration. This current from a photomultiplier tube is measured by a high input impedance integrated circuit MOSFET amplifer. Range selection is determined by a high/low feedback resistor operating in conjunction with output range select relays. The signal is then directed to a second integrated circuit amplifier for additional signal gain. A range switch provides selectable full scale ranges of 0.025, 0.05, 0.1, 0.25, 0.5, 1.0, or 2.5 ppm, while electronic zero and span controls permit calibration adjustment. Selectable recorder outputs of 10 mV, 100 mV, 1 V, and 5 V are available by means of a selector switch.

During operation, ethylene is directed to the detector at a flow rate of 10–20 cc/min. A safety valve (K3) is incorporated which is designed to shut off the ethylene flow in the event of power failure. A three-way valve is designed specifically to direct the ethylene flow to either the flowmeter or bypass it to the detector. This bypass feature prevents long-term polymer contamination and plugging of the flowmeter.

Air samples are introduced at a constant flow rate to the detector by an internal pump and flow control system. A standard for zero calibration is obtained by passing ambient air over a chemical scrubber to remove all traces of ozone. An optional ozone generator is offered which provides a convenient means of providing span checks. The air flow across the ozone generator provides a known level of ozone to the detector, plus the auxiliary flow permits correlations with the wet chemical KI method.

Specifications

Range: 0.025, 0.05, 0.1, 0.25, 0.5, 1.0, and 2.5 ppm. *Sensitivity:* 0.001 ppm on 0.1 range. *Response time:* 90% in 3 seconds. *Zero and span drift:* less than 1% per day. *Precision:* ± 1%. *Operating period:* 7 days or more. *Noise:* 0.5%. *Operating temperature:* 40°–100°F.

NO/NO_x Analyzer, Model 951

Beckman Instruments, Inc.
Process Instruments Division
(address above)

The Beckman Model 951 NO/NO_x Analyzer operates on the chemiluminescent method of detection and is designed specifically for vehicle emissions and stationary (stack) source monitoring applications.

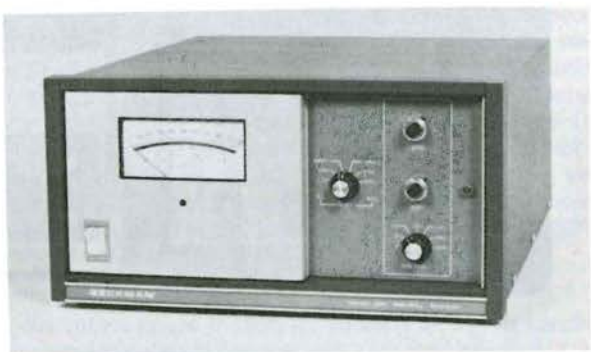


Figure V-41 — Model 951 NO/NO_x Analyzer.

Operating principle

The chemiluminescent method is based upon the principle that nitric oxide (NO) reacts with ozone (O_3) to give nitrogen dioxide (NO_2), oxygen (O_2), and about 10% electronically excited NO_2*. The transition of electronically excited NO_2* to its normal state NO_2 gives a light emission ($h\nu$) between 590–2750 nm, i.e.,

$$NO + O_3 \rightarrow NO_2^* + O_2 + h\nu$$

The intensity of this emission is proportional to the mass flow rate of NO into the reaction chamber. The light emission is measured by means of a photomultiplier tube and associated electronics.

O_3 for the reaction is generated by passing cylinder air or oxygen over an ultraviolet light source. As O_3 and NO mix, the chemiluminescent reaction produces a light emission which is proportional to NO concentration and is measured by the photomultiplier tube.

NO_x analysis ($NO + NO_2$) is obtained by dissociating the NO_2 to NO and then proceeding with the reaction, i.e.,

$$NO_2 \rightarrow NO + O$$

$$NO + O_3 \rightarrow NO_2^* + O_2 + h\nu$$

Physical description

The primary components of the Model 951 are the electronics section and the flow control system.

The chemiluminescence reaction is directly proportional to $NO–NO_x$ concentration and provides a signal current in the order of 3×10^{-10} amps/ppm concentration. This current from a

photomultiplier tube is measured by a high input impedance integrated circuit MOSFET amplifier. Range selection is determined by a high/low feedback resistor operating in conjunction with output range select relays. The signal is then directed to a second integrated circuit amplifier for additional signal gain. A range switch provides selectable full scale ranges of 10, 25, 100, 250, 1000, 2500, or 10,000 ppm, while zero and span controls permit calibration adjustment.

Selectable recorder outputs of 10 mV, 100 mV, 1 V and 5 V are available by means of a selector switch.

Supply air or oxygen is employed for ozone generation by means of a UV lamp. A pressure regulator and restrictor provide a controlled flow rate of ozonized air to the reactor. Pressurized sample is admitted to the reaction chamber under a regulated pressure at a flow rate of 300 cc/min. After reaction of sample with ozonized air, the gases are vented through an O_3 scrubber to prevent emission of excess O_3 into the atmosphere. A back pressure regulator and flow meter determine bypass sample flow from 500 cc to 2.4 lpm. By proper selection of the Mode Switch on the front panel, either NO or NO_x operation may be achieved.

Span gas selection is accomplished by front panel actuation of the Mode Switch to permit introduction of an external calibration gas. Zero gas selection is achieved from the Mode Switch by actuation of a solenoid valve permitting flow of the gas being employed for O_3 generation.

The basic Model 951 is designed to accept positive pressure samples such as would be encountered in an emissions test console. Where ambient pressure samples are to be analyzed, an optional internally mounted pump is available.

Specifications

Sensitivity: 0.1 ppm on 10 ppm range. *Dynamic response* (system electronic plus flow response between zero and span modes of operation): 0 to 90% is within 1 second on 25, 100, 250, 1000, 2500, and 10,000 ppm ranges; 0 to 90% is within 3 seconds for 10 ppm range. *Linearity:* ± 1% FS. *Precision:* ± 0.5% FS. *Detector operation:* atmospheric (no vacuum). *Recorder output:* selectable 10 mV, 100 mV, 1 V, or 5 V. *Ambient temperature:* 40°–100°F (4.4°–37.7°C). *Power:* 107–127 volts, 50/60 Hz, 1000 watts. *Dimensions:* 9" × 7¾" × 22". *Weight:* 76 lbs net; 90 lbs, shipping.

NO, NO_2, NO_x Monitor Model 952

Beckman Instruments, Inc.
Process Instruments Division
(address above)

The Beckman NO, NO_2, NO_x Monitor is used to monitor the ambient atmosphere where the oxides of nitrogen concentration range between 0.1 and 10 ppm.

Operating principle

The chemiluminescent detection principle incorporated in the Model 952 is based upon the reaction of NO with O_3 to produce NO_2, about 10% of which is electronically excited to a higher energy state. Return of the NO_2 molecule to its ground state results in emission of ultraviolet light. This light energy is measured by means of a photomultiplier and electronic circuitry and is directly proportional to the concentration of NO present in the sample.

NO_x is determined by converting the NO_2 to NO, free of interference from other atmospheric compounds, and subsequent determination of the chemiluminescent reaction.

NO_2 is determined by the electronic subtraction of NO from NO_x.

Physical description

The primary components of the Model 952 are the electronics section and flow control system. The electronics section of the Model 952 provides analysis and continuous analog voltage outputs for all three parameters — NO_x, NO, and NO_2. The chemiluminescence reaction is directly proportional to NO concentration and provides a signal current in the order of 1×10^{-9} amps/ppm concentration. An electronic timer provides automatic cycling between NO and NO_x modes and the signal difference is electronically determined to provide a direct NO_2 output. Continuous outputs of 10 mV, 100 mV, 1 V, and 5 V are available for recording, telemetry, etc., of each parameter, i.e., NO, NO_x, and NO_2. Electronics are all solid state with integrated circuits and plug-in circuit boards for easy removal and replacement. Test points provide easy checking of all operations.

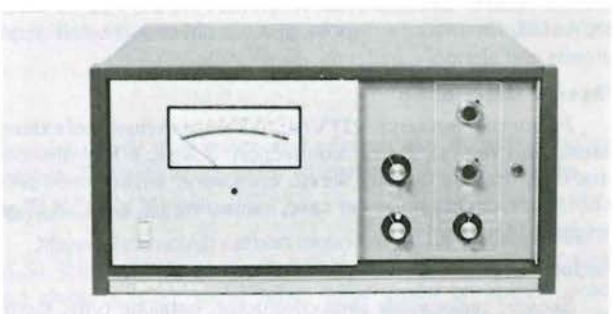


Figure V-42 — Model 952 NO, NO_2, NO_x Monitor.

In the flow control system, ambient air is employed for ozone generation by means of a pump and a UV lamp.

Specifications

Range: 0.25, 0.5, 1.0, 2.5, 5.0, 10.0, and 25 ppm. *Sensitivity:* 0.005 ppm on 0.25 range. *Response time:* 90% in 3 seconds. *Zero and span drift:* less than 1% per day. *Precision:* ± 1%. *Operating period:* 7 days or more. *Noise:* 0.5%. *Operating temperature:* 40°–100°F.

CO-Monitor

Dynamation, Incorporated
168 Enterprise
Ann Arbor, MI 48103

The CO-Monitor Model CO-2300 Carbon Monoxide Monitor/Alarm is a fixed location monitor which will accurately and continuously indicate the level of CO in parts per million (ppm) on its meter. Should the concentration exceed the preset threshold value, the alarm circuit is activated.

Operating principles

The Dynamation catalytic, semiconductor sensor system monitors the air by natural air diffusion and convection. A unit with a single catalytic, semiconductor sensor requires humidity compensation for accurate measurement of carbon monoxide. The Model CO-2300's twin sensor system automatically compensates for humidity changes. Natural air diffusion and automatic humidity compensation eliminates the maintenance that is required in using other CO detection units.

The inexpensive, easily replaceable, catalytic, semiconductor sensors have a life expectancy of up to five years under normal use. Modern, low maintenance solid-state circuitry is employed. An illuminated FAULT/TEST switch indicates if the sensor has become open or disconnected. When the FAULT/TEST switch is depressed, the meter will move upscale checking the electronic circuits and alarms.

Physical description

Power requirements: 117 VAC, 0.2 amp (exclusive of external alarms and relays). *Power connection:* 3 wire, 6 foot line cord provided; may be conduit wired. *Enclosure:* environment-proof NEMA 4; fiberglass-polyester case, measuring 11" × 9½" × 5" and weighing 14 lbs.

Performance data

Sensor: replaceable semi-conductor, catalytic type, factory match pairs. Sensor *purge period:* 1 min nominal. *Sensor stabilization period:* 5 minutes nominal after end of purge period. *Response:* 90% of maximum reading within 20 seconds with 200 ppm CO concentration. *Accuracy:* ± 10% of reading. *Meter scale size:* 3½". *Meter size:* calibrated 0 to 300 ppm. *Alarm:* internally adjustable 10 to 300 ppm CO; factory set at 200 ppm, standard. *Recorder output:* available on terminal strip inside 0–1 mA current recorder standard. *Relay outputs:* 2 amp rated, 117 VAC resistive load; 1 amp rated, DC resistive load; NO, NC, and C contacts available on the terminal strip for alarm and fault signals.

Figure V-43 — Dynamation CO Monitor, Model CO-2300.

Bullard Environmental Instruments

E.D. Bullard Company
2680 Bridgeway
Sausalito, CA 94965

Bullard environmental instruments may be used for detection of carbon monoxide, hydrogen sulfide, combustible gases (% LEL), vinyl chloride, chlorine, and some other toxic gases on special order. Units are available as portable, continuous, or dosimeter models as described below. Continuous models are available for rack-mount, weatherproof, and explosion-proof installations.

Operating principle

The Bullard solid-state electrolytic cell gas sensor consists of several metal and nonmetal oxides from the Transition Elements, Group III and Group IV. In the presence of gases, gas molecules are dissociated into charged ions or complexes by the cell. The ions, or complexes, are collected as an electrical signal and can be used directly to drive a meter or recorder.

Physical description

Portable models are 7¼" × 4¾" × 7⅝" and weigh 5.5 lbs. Power requirements are two "D" size and one 9.6 V Ni-Cad batteries or 115 VAC as continuous. A logarithmic meter and recorder jacks are standard. *Continuous models* are 7¼" × 4½" × 5½" and weigh 4.5 lbs, with power requirements of 115 VAC. Logarithmic meter & recorder standard. The *dosimeter* is 2" × 8½" × 3" and weighs 2.6 lbs. Its power requirements are one 9.6 V Ni-Cad and two 1.3 ½ D size Ni-Cad batteries and battery charger.

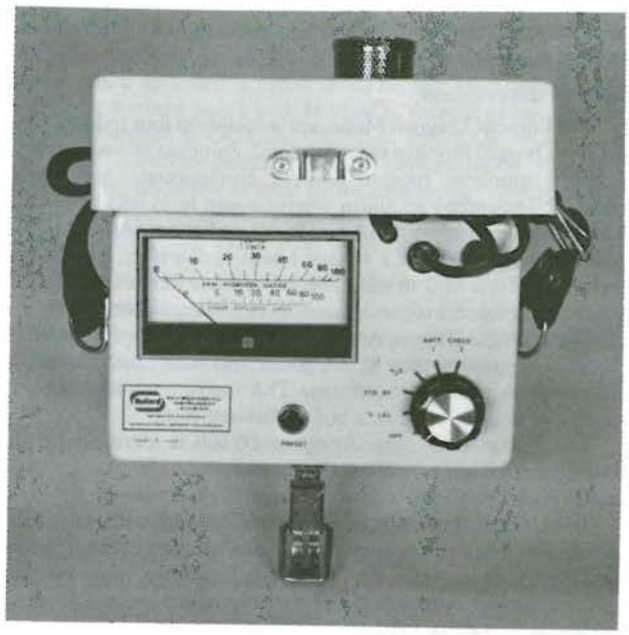


Figure V-45 — Bullard Portable Instrument for H_2S and combustible vapors.

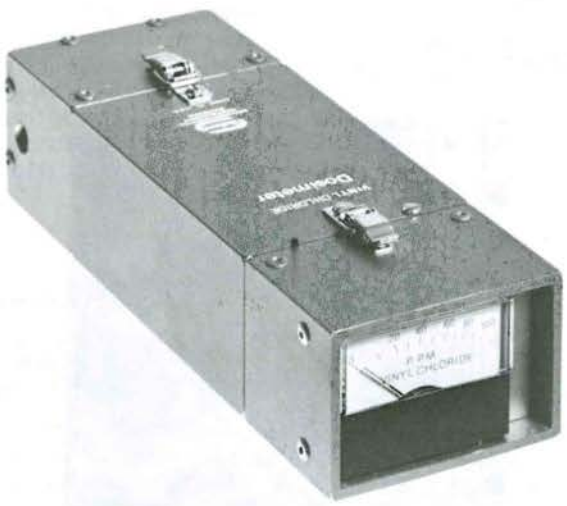


Figure V-44 — Bullard vinyl chloride dosimeter.

Sampling mode is a meter and accumulator for time-weighted average. The sampling rate for all instruments is by diffusion.

Performance data

Material detected: carbon monoxide (CO), hydrogen sulfide (H_2S), Combustible gases (% LEL), vinyl chloride (CH_2:CHCl), and chlorine (Cl_2); some other toxic gases on special order. *Detection limits* (useful range): 0–50 ppm, 0–300 ppm and 0–1000 ppm for the CO models; 0–50 ppm and 0–200 ppm for the H_2S models; 0–100% for LEL%; 1–100 ppm and 0–400 ppm for the CH_2:CHCl models; 0–50 ppm and 0–20 ppm for the Cl_2 models; 0–100 ppm H_2S for 0–100% LEL for the H_2S/%LEL Multigas portable units. *Specificity* (significant interferences: % LEL — n-hexane, acetone, butane, propane, gasoline, acetylene, hydrogen, methanol; CH_2:CHCl — methane and propane, no appreciable interference up to 3% by volume; for CO, H_2S, Cl_2 and other gases, contact E.D. Bullard Company to obtain accurate data. *Response time:* 2 min to 70% of final reading for CO; 40 seconds to 90% of final reading for H_2S; 40 seconds to 90% of final reading for % LEL; 40 second to 80% of final reading for CH_2:CHCl; 40 seconds to 80% of final reading for Cl_2. *Averaging time:* repeatability ± 2% full scale deflection. *Stability:* negligible drift in 30 days. *Precision:* ± 3% full scale for CO; all other ± 2% full scale. *Accuracy:* ± 3% of actual reading.

Edmont Oxygen Analyzer, Model 60-620

Edmont-Wilson
Division of Becton Dickinson & Co.
1300 Walnut Street
Coshocton, OH 43812

OSHA and Bureau of Mines require that the air in confined or enclosed areas be tested for sufficient oxygen (19.5% minimum) before workers are permitted to enter. These areas include open surface tanks, pits, tunnels, wells, shafts, vats, mines, storage tanks, silos, ship's holds, tank trucks and cars, transformers, centrifuges, manholes, digesters, autoclaves, and boilers. Excess oxygen (more than 21%), which can be a fire or explosion hazard, must also be guarded against, particularly during welding, brazing, and cutting operations.

Edmont Oxygen Meters are used to measure residual oxygen in food packaging operations and in petrochemical processing; to monitor inert gas atmospheres used in welding operations and in refrigeration systems; to monitor inert blanketing gases over vats and tanks; to check oxygen levels during catalyst regeneration;

and to monitor combustion efficiency in boilers, annealing furnaces and heat treatment processes.

Physical description

The Edmont Oxygen Meter are available in four models. The Portable Oxygen Monitor 60-625 is small, compact and weighs one pound. It monitors oxygen content continuously, and warns workers by sounding an alarm when oxygen level falls below the 19.5% minimum set by OSHA and Bureau of Mines. Also signals if battery power drops, or if sensor needs recharging. It gives immediate readings of 0 to 25% oxygen without long sampling and dangerous delay. A built-in tester shows battery power level.

The Portable Oxygen Analyzer 60-620 continuously measures 0 to 25% oxygen content in air, gases and liquids without time-consuming sampling procedures. The instrument is compact, weighs one pound, and has a built-in battery tester.

The Portable Oxygen Analyzer 60-600 is identical to the 60–620 except it has a 0–50% scale, sensor probe clip, and carrying handle. A carrying case with shoulder strap is optional.

The Continuous Oxygen Monitor 60-701 has built-in warning light and sound alarm which signal when oxygen content drops below 19.5% or exceeds 22.5%. Sensor response to an oxygen content change is continuous and virtually instantaneous, so there is no dangerous delay between sampling and warning or read-out. An easy-to-read scale indicates oxygen levels up to 50% or 380 mm Hg. The monitor operates on 115 VAC line power, and has an output jack to accommodate any lab recorder accepting 1 volt input across 800 ohms.

Performance data

The Model 600 is 3" × 3" × 5", weighs 1 lb., and has a range of 0–50%. Its power requirements are two 9V transistor radio batteries or 115 VAC. Models 60-620 and 60-625 are the same size and weight as the 60–600, with a range of 0–25%. The Model 60–701 is 4" × 8" × 9", weighs 5.5 lbs, and has a range of 0–50%. Sampling rates are continuous for all models. *Readout mode:* 2½" meter % oxygen. *Interferences:* concentrations higher than 0.25% (2500 ppm) of sulfur dioxide, fluorine, chlorine, bromine, iodine, and the oxides of nitrogen read as oxygen; mercaptans and hydrogen sulfide in concentrations of 1% or more. *Response time:* 90% in 10 seconds. *Stability:* < 1% drift during the first 2 weeks of operation when corrected for atmosphere pressure changes. *Accuracy:* ± 0.2 oxygen in calibration range and temperature. Temperature from 59° to 122°F.

Figure V-46 — Edmont Oxygen Analyzer, Model 60-620

Sulfur Dioxide Sensor-Amplifier/Recorder

Ericson Instruments
P.O. Box 226,
Ossining, NY 10562

The Ericson Sulfur Dioxide Sensor measures SO_2 below the parts per million level and higher concentration. The selective electrode permits direct and immediate reading of SO_2 concentration in gases and solutions, regardless of color and turbidity. Also measures total content of sulfite and hydrogen sulfite in solutions. Areas of application include analysis of SO_2 in air pollution, water pollution, pharmaceutical solutions, beverages, and chemical process streams.

Operating principle

The sensor consists basically of an electrochemical cell which is covered with a membrane having a high permeability for sulfur dioxide. The high selectivity of the sensor for sulfur dioxide results from the selective permeability of the membrane and from the specificity of the electrochemical cell reaction. Sulfur dioxide diffusing through the membrane takes part in an electrochemical reaction, giving rise to an electric current flowing through the sensor in accordance with Faraday's law. Since the rate of sulfur dioxide diffusion through the membrane is directly proportional to its concentration, the sensor current is a direct linear indication of the sulfur dioxide concentration. The sensor current is amplified and displayed on the recorder. The membrane is impermeable for ions and large molecules. The electrochemcial cell does not respond to gases such as O_2, CO_2, CO, NO_2, O_3, or Cl_2.

In liquids, the sensor responds directly to the concentration of dissolved SO_2. For the determination of total dissolved sulfites the pH of the solution has to be taken into account due to

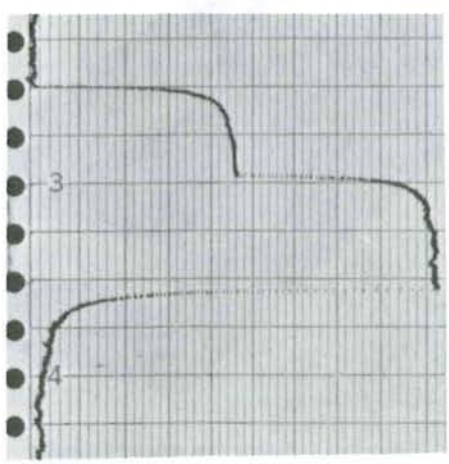


Figure V-47 — Response of SO_2 Sensor to 0.5 ppm/vol and 0.1 ppm/vol SO_2 in air at 22°C.

$$SO_2 + H_2O = H_2SO_3 = H^+ + HSO_3^- = 2H^+ 6 + SO_3$$

At any given pH the amount of free dissolved SO_2 as measured by the sensor is directly proportional to total sulfite concentration. Analysis of total sulfite in a sample of unknown pH consists of mixing the sample with a pH buffer solution to fix the pH value, measuring the free SO_2 concentration with the sensor, and reading total sulfite concentration from calibration curve taken in an identical pH buffer solution.

Physical description

Primary voltage: 115V, 60 Hz, other voltages available. *Chart paper speed:* 1"/hr, other speeds available. *Size:* 7¼" × 5⅝" × 7½". *Chopper lifetime:* 10,000 hours. *Reference cells:* 2 mercury cells to be replace after 1 year. *Offset control:* ± 1% × full scale.

Sensor performance data

Range: in gases 0–1 ppm/vol to 0–5 ppm/vol full scale; in solution 0.05 ppm/weight to 0–2 ppm/weight full scale, higher ranges at higher pH, up to 0–1,000 ppm/weight. *Current output:* directly proportional to SO_2 concentration; in gases at least 10^{-8} amp per ppm/vol SO_2; in aqueous solutions at least 2×10^{-8} amp per ppm/weight SO_2. *Response time:* 90% in 2–3 minutes (see Figure V-47). *Sensitivity:* 0.1 ppm/vol. *Accuracy:* ± 5% of full scale. *Background current:* 1 to 2×10^{-9} amp. *Temperature coefficient:* about 3%/°C. *Temperature range:* 15°–35°C. Unlimited lifetime; electrode needs solution refill every two months. If sensor response drops below specified current level, sensor electrode is regenerated by current pulse in 1 M H_2SO_4. *Interferences:* No measurable response to O_2, CO_2, CO up to 1 atm; O_3, NO_2, Cl_2 give less than 1% of response for equal concentration of SO_2. In solutions no response to ionic or high molecular species. Sensor response is decreased in solutions containing more than 1% (vol) ethyl alcohol. *Cable:* 3 ft coaxial Amphenol 69475.

Amplifier/recorder performance data

Range: 10^{-8} amp to 2×10^{-7} amp, contin. variable. *Accuracy:* ± 2.5% for 0° to 50°C ambient and primary voltage of ± 15% on a.c. primary. *Input resistance:* 10^5 ohms. *Time constant:* 2 seconds.

Personal Oxygen Monitor, Model OX-80

GasTech, Inc.
Johnson Instrument Division
331 Fairchild Drive
Mountain View, CA 94043

The GasTech Model OX-80 Personal Oxygen Monitor is a pocket-sized, light weight instrument designed to continuously monitor oxygen and sound an alarm at a preset level of 19.5%. A push-button activates a digital readout. The top mounted sensor may also be used remotely for tank entry testing.

Operating principle

The OX-80 oxygen sensor is an electrochemical cell in which oxygen produces a chemical reaction directly proportional to the sampled atmosphere. The current produced by this reaction is amplified and used to drive the display and activate the alarm at a preset point. The electrochemical cell is guaranteed for six months of operation before reactivation. Factory reactivation is readily available and carries its own 6 month warranty.

Physical description

External controls: on-off slide switch; finger-activated flush knurled knob calibration adjust; display pushbutton. *Internal controls:* alarm level adjust. *Power source:* Ni-Cad rechargeable batteries possessing a life span of 30 hours continuous operation between charges; low battery alarm. *Dimensions:* 5 9/16" × 3" × 1". *Weight:* 13 oz. *Housing:* enameled aluminum. *Accessories:* 115 or 230 VAC plug-in battery charger, belt clip, and wrist strap standard; 15" and 30" oxygen cell extension cables, lapel-mount repeater buzzer optional.

Performance data

Sampling method: diffusion. *Range:* 0–50% oxygen content. *Readout:* push button digital display readable to nearest 0.1% oxygen. *Alarm:* continuous audible tone, activated when oxygen content falls below alarm level (adjustable, pre-set at 19.5%)

Scen-Trio

Lumidor Safety Products
5364 N.W. 167th St.
Miami, FL 33014

Scen-Trio, a continous gas/oxygen sensing device, guards hazardous gas areas and monitors levels of three different categories of gases; explosives, toxic and oxygen. Both visual and audible alarms are activated when preset threshold levels have been violated.

Physical description

This portable, battery-powered, multi-gas detector/alarm has a rechargeable Ni-Cad battery pack and self-powered oxygen fuel cell. It measures 7¾" × 2⅛" × 5", weighs 3 lbs, and is rated intrinsically safe for Class I Division I Groups A, B, C, D.

Performance data

Scen-Trio operates with reasonable accuracy of alarm settings within temperature range of -5°C to +45°C. Accuracy of oxygen reading is within 0.5% through the temperature range. Humidity range 15% to 100% RH when calibrated in 50% RH atmosphere, and will operate at lower RH (5%–20% RH) with good accuracy if calibrated in a dry atmosphere accordingly. All critical circuit functions are regulated against variations in battery potential providing extremely stable and accurate battery operation.

Rechargeable Carbon Monoxide Meter

Macurco, Inc.
3946 S. Mariposa Street
Englewood, CO 80110

The RCM is a miniature (shirt pocket size) sensitive carbon monoxide (CO) meter, that is powered by Ni-Cad, rechargeable batteries. The RCM may be plugged into 120 VAC power, through the battery charger, and provide a continuous monitor of carbon monoxide, and, when needed, can be unplugged and operated on its batteries for portable measurements.

Operating principle

The CO sensor is a semi-conductor sensor, featuring maintenance free, long life. An electronic meter composed of ten light emitting diodes, displays the 0 to 100 ppm or 0 to 500 ppm range of carbon monoxide.

Physical description

Size: 1¼" × 2¾" × 5" RCM; 4" × 8" × 12" standard package. *Shipping weight:* 16 oz RCM; 3 lbs standard package. *Batteries:* Ni-Cad rechargeable, provide 8 hours of continuous use; charging time, 15 hours.

Performance data

Accuracy: 15% in normal use; 5% after calibration. *Range:* 10 ppm to 500 ppm of CO. *Interferences:* the level of gas to produce a 100 ppm RCM reading is 5000 ppm propane and 20,000 ppm methane.

Mast Portable Ozone and Oxidant Recorders

Mast Development Company
2212 East 12th Street
Davenport, IA 52803

The Model 724-2 Mast Ozone Meter, Model 725-11 Nitrogen Dioxide Meter, and Model 725-21 Microcoulomb Detector are portable non-specific electrochemical instruments which are used for the detection of ozone, nitrogen dioxide, nitric acid vapor, chlorine, iodine, fluorine, and other strong oxidant vapors in low air concentrations.

Operating principle

The micro-coulomb sensor used in all three instruments is illustrated schematically in Figure V-50. Selectivity for specific oxidants is related to the concentration, pH, and composition of the electrolyte used. A chemical solution, containing the proper amounts of sensing reagents, is metered into the sensor by way of the solution supply tube. The solution flows in a thin film down over the electrode support, upon which are wound many turns of a fine wire cathode and two turns of a wire anode, and is deposited in the waste reservoir. The air sample is pumped through the sensor by way of the narrow annulus where it comes into contact with the solution contained on the electrode support, and exits through the air pump. A small potential is applied across the cathode and anode by a battery and the current flow is measured by the microammeter.

Figure V-48 — Mast Model 725-11 Nitrogen Dioxide Meter.

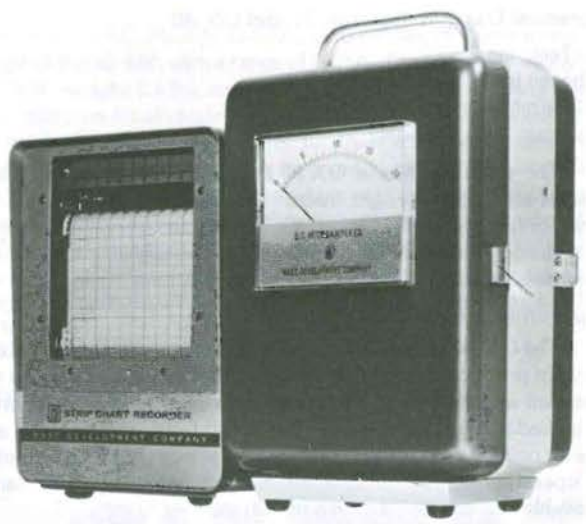


Figure V-49 — Mast Model 725-21 Microcoulomb Recorder, with Model 725-3C strip chart recorder.

In the Model 724-2 Ozone Meter, the sensing of ozone in the air sample is accomplished by the oxidation-reduction of potassium iodide contained in the sensing solution. This reaction takes place on the cathode poriton of the electrode support. In this region, any ozone in the air sample reacts with the sensing solution as follows:

$$O_3 + 2KI + H_2O \rightarrow O_2 + I_2 + 2KOH$$

At the cathode, a thin layer of hydrogen gas is produced by a polarization current:

$$2e + 2H^+ \rightarrow H_2$$

When the voltage is applied to the electrode (about 0.24 volts), the hydrogen layer builds to its maximum and the polarization current ceases to flow.

When free iodine is introduced by the reaction with ozone, it immediately reacts with the H_2 as follows:

$$H_2 + I_2 \rightarrow 2HI$$

The removal of the hydrogen from the cathode allows a repolarization current of two electrons to flow in the external circuit, reestablishing equilibrium. Thus, for each ozone molecule reacting within the sensor, two electrons flow through the external circuit. Hence,

the rate of electron flow or current is directly proportional to mass per unit time of ozone entering the sensor.

High concentrations of sulfur dioxide (SO_2) negatively interfere with ozone determinations, but this interference can be eliminated by using the Model 725-30 SO_2 Filter Kit to trap the SO_2 before it enters the sensor.

The microammeters used on the Model 724-2 Ozone Meter and the Model 725-11 Nitrogen Dioxide Meter are calibrated directly in concentration units. A strip chart recorder replaces the microammeter in the circuit when permanent recordings are needed. Connecting the strip chart recorder to the NO_2 meter has the advantage of extending the operating range. It reads from a low range of 0 to 10 ppm to a range of 0 to 120 ppm per volume, or higher by using an appropriate plug-in range resistor.

Physical description

Models 724-2, 725-11 and 725-21 measure 7½" × 6" × 11½", weigh 10.5 lbs and require 115 volt, 60 Hz, 12 watts. The strip chart recorder Model 725-3C is 8.5" × 8" × 10.6", weighs 14.5 lbs, and requires 115 volt, 60 Hz, 55 watts. The weatherproof case Model 725-4 measures 13" × 7.4" × 17.8" and weighs 21 lbs.

Performance data

Standard range: 0–100 pphm O_3 for Model 724–2 ozone detector; 0–30 ppm NO_2 for Model 725-11 NO_2 meter; 0–20 μamp for Model 725-21 microcoulomb detector, equivalent to 0–1.5 ppm for chlorine. *Sensitivity:* approximately 0.003 ppm for O_3, 0.1 ppm for NO_2, and 0.005 ppm for Cl_2. *Sampling rate:* 140 cc/min. *Rise and fall time:* 1 min. *Operating temperature range:* 32° to 112°F. *Unattended operating time:* 3 days (except 30 days for Model 724-2L large reservoir ozone recorder).

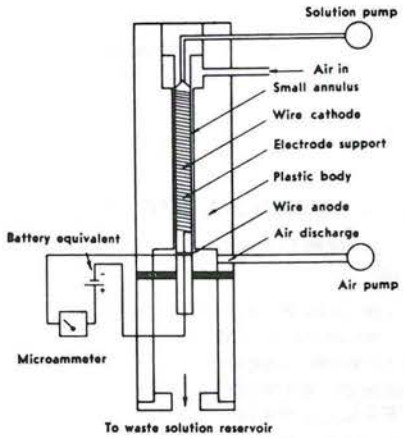


Figure V-50 — Schematic diagram of Microcoulomb sensor cell.

Portable Oxygen Indicator, Models E & S

Mine Safety Appliances Company
600 Penn Center Boulevard
Pittsburgh, PA 15235

The MSA Portable Oxygen Indicator measures oxygen concentration in gaseous mixtures. Model E operates in the range of 0–25% oxygen by volume; Model S has a range of 5–40%. Both models are designed for ambient portable use in the testing of manholes, tunnels, tanks, and other enclosed spaces before entry. They can also provide oxygen measurement for combustion control, flue-gas testing, and similar process uses.

Operating principle

The detection of oxygen by the Portable Oxygen Indicator is based on the principle of a primary galvanic cell. It consists of a negative zinc electrode and a positive carbon electrode in a special electolyte called "Oxylite," which generates electricity in much the same manner as a dry cell batter. With no oxygen present, the carbon electrode is polarized and the flow of current inhibited. In operation, the gas sample flows through the interior of the carbon electrode. A small protion of the gas diffuses through the carbon. Consequently, any oxygen present causes a depolarization which allows current to flow between the electrodes. The amount of current is proportional to the oxygen concentration which is indicated on the meter scale.

Physical description

These battery powered instruments measure 6¾" × 4⅛" × 5¾" and weigh 5.75 lbs. *External accessories:* a line trap assembly is available to prevent liquids from being drawn into the instrument. The trap can also be filled with a Gasorbent to remove acid gases from the sample stream. *Safety provisions:* sampling line may be attached to a solid 4-ft probe rod for additional safety in testing enclosed spaces before entry.

Figure V-51 — MSA Portable Oxygen Indicator.

Performance data

Least detectable quantity: 2%. *Scale readout:* Model E, 0–25% oxygen by volume; Model S, 5–40% oxygen by volume. *Accuracy:* Model E, ± 2% FS or 1/2% oxygen; Model S, ± 5% FS. *Calibration:* may be calibrated in a pollution-free atmosphere at 20.8%; an oxygen-free zero checking unit is available.

Oxygen Indicator Models 245, 245R, and 245RA

Mine Safety Appliances Company
(address above)

MSA Oxygen Indicators are hand-held devices for measuring atmospheric concentrations of oxygen over a range of 0–25%. Model 245 is primarily designed for checking oxygen content in mines. Its sensor cell is contained in the instrument case. Models 245R and 245RA house the sensor cell in a separate plastic holder at the end of a sampling cable. These models find broader application in industrial areas where remote sampling is frequently required.

Operating principle

The Oxygen Indicator detects oxygen by a galvanic sensor cell containing a gold cathode and lead anode in a basic electrolyte. The entire cell is encapsulated in inert plastic; the sensor face is a fluorocarbon polymer. In operation, oxygen diffuses through the cell face to initiate redox reactions which, in turn, generate minute current proportional to the oxygen partial pressure. The signal is amplified through a battery-powered temperature-compensated circuit. The current is converted to a proportional voltage which is displayed on the indicator as a percent of oxygen.

Physical description

All models measure 2" × 2½" × 5". The weight for Models 245, 245R and 245RA are 11 oz, 15 oz, and 19 oz, respectively. *External accessories:* Model 245 — adapter for tube sampling, sampling line (5 ft, with couplings) with other lengths available; Models 245R and 245RA — replacement sensor with 10-ft cable, extension cables, 50-ft lengths. *Probe size:* remote sensors for Models 245R and 245RA — 1 11/16", 1½" depth maximum, minus lead wire. All models operate on a single 2 V alkaline battery. *Safety provisions:* Model 245RA is equipped with audio alarm, factory set to activate when the oxygen concentration falls below 19.5%. (Alarm setpoint is adjustable internally.) Once activated, the alarm will sound continuously for up to 24 hrs until manually deactivated or until the oxygen concentration rises above alarm setpoint.

Figure V-52 — MSA Oxygen Indicator Model 245.

Performance data

Least detectable quantity: 2%. *Scale readout:* 0–25% oxygen by volume. *Sensitivity and accuracy:* ± 1% FS at constant temperature. *Response time:* 90% in less than 20 seconds. All models can be calibrated quickly with uncontaminated fresh air, 20.8% oxygen. Since the response is linear, the instrument can be single-point calibrated with oxygen of any known concentration within 20–25%.

Oxygen Monitor System, Series 540

Mine Safety Appliance Company
(address above)

The MSA Oxygen Monitor System, Series 540, is an instrument package designed to monitor atmospheres for oxygen concentrations in a range of 0–25% by volume. The System is available in three models: the 540, for central monitoring of multiple locations; the 541, for single-location monitoring, and the 542, an explosion-proof system for monitoring a single location.

Operating principle

The Series 540 System operates on the principle of a galvanic sensor cell containing two dissimilar electrodes in a basic electrolyte. The cell is encapsulated in inert plastic; its face is a fluorocarbon polymer. Diffusing though the cell face, oxygen initiates redox reactions which generate a minute current proportional to the oxygen partial pressure. The signal is amplified through a solid-state electronic circuit. The current is converted to a proportional voltage which is displayed on the meter as a percent of oxygen.

Physical description

Dimensions: Model 540, 12" × 9" × 10½" (2-unit housing); Model 541, 6⅛" × 14¾ × 13¼"; Model 542, 6" × 16⅞" × 14¼". *Sensor life:* 180,000 0_2% hr. *Sensor cable requirements:* 4-conductor, 14 ohms closed loop, maximum resistance (16–22 AWG). *External accessories:* diffusion heads including sensors and assemblies. *Power requirements:* 115 V, 80 Va, 50/60 Hz; 11–15 or 19–60 VDC (220 VAC with auxiliary transformer). *Safety provisions:* tamper-resistant controls; malfunction light and relay

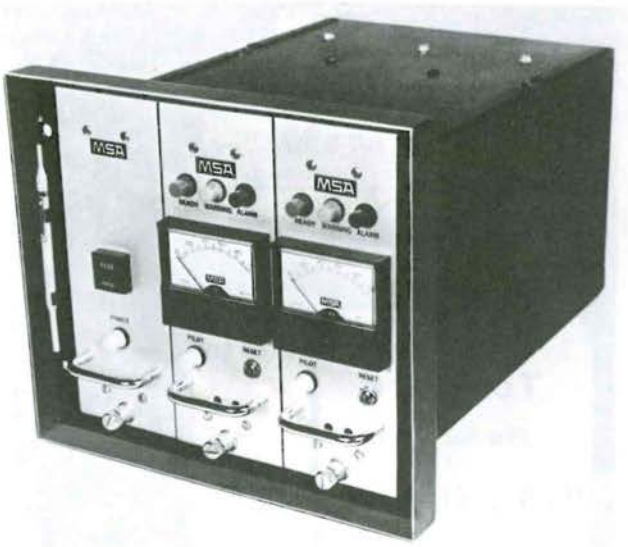


Figure V-53 — MSA Oxygen Monitor, Model 540.

which deactivates in the events of lost power, open sensor, severed or shorted cable; built-in short-circuit protection, warning lights and alarm circuitry; explosion-proof design (Model 542 only).

Performance data

Range: 0–25% oxygen. *Precision:* ± 1%. *Response time:* 90% in 60 sec. *Zero and span drift:* < 1% FS/day.

Toxgard™ Monitor

Mine Safety Appliances Company
(address above)

The MSA Toxgard™ is an area monitoring instrument for measuring hydrogen cyanide, hydrogen sulfide, and chlorine in ranges of 0–50, 0–50 and 0–5 ppm full scale, respectively, or 10, 10 and 2 ppm half scale.

Operating principle

An amperometric-type instrument, the Toxgard™ Monitor contains two electrodes bathed in an electrolyte that flows into a porous glass cell. The center electrode is the reference; the outer electrode measures the gas concentration. As the sample gas diffuses into the cell it contacts the "measuring" electrode and a current is generated proportional to its concentration.

Physical description

Dimensions: 19½" × 9⅞" × 5⅛". *External accessories:* available with a 115 VAC, 50/60 Hz audiovisual alarm.

Performance data

Least detectable quantity: H_2S and HCN, 1 ppm; Cl_2, 0.25 ppm. *Instrument scale characteristics:* 0–10 for Cl_2, 0–50 for H_2S and HCN. *Stability characteristics:* when there are no gases present, a zero shift of less than 1% FS is typical

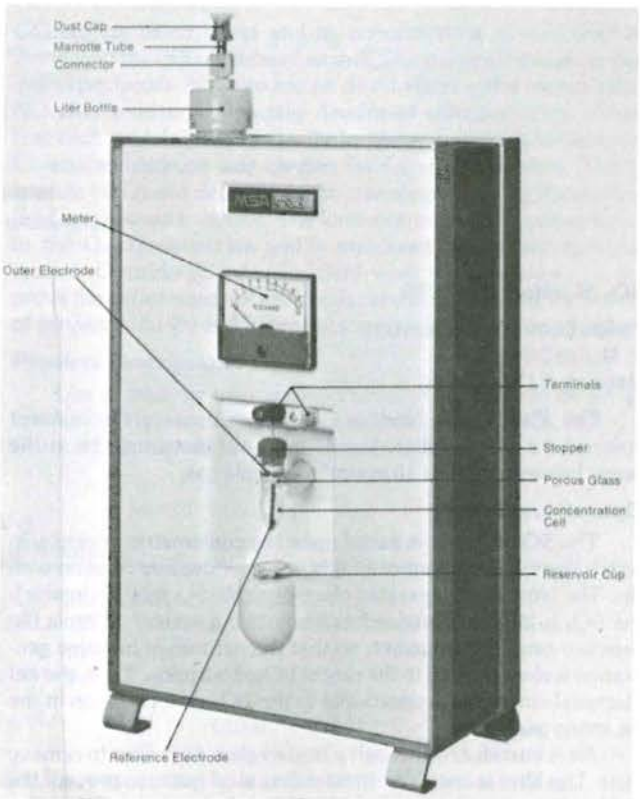


Figure V-54 — MSA Toxgard™

Toxgard™ Indicator, Model C

Mine Safety Appliances Company
(address above)

The MSA Toxgard™ Indicator, Model C, is a continuous instrument for use in the detection of hydrogen sulfide and hydrogen cyanide in a range of 0–50 ppm, or carbon monoxide in a range of 0–100 ppm.

Operating principle

The instrument operates on the principle of an electrochemical polarographic cell that oxidizes the gas of interest in proportion to its partial pressure in the sample atmosphere.

Physical description

Dimensions: 8" × 6" × 3½". *Weight:* 8 lbs. *Power requirement:* 0.2 amps, 120 VAC, 50/60 Hz. *Safety provisions:* tamper-resistant controls; audible and visual alarms.

Performance data

Ranges: 0–50 ppm H_2S or HCN, 0–100 ppm CO full scale. *Precision:* ± 2% FS. *Response time:* 50% in 30 sec, typically 90% in 120 sec. *Span and zero drift:* 1%, 1 day max.

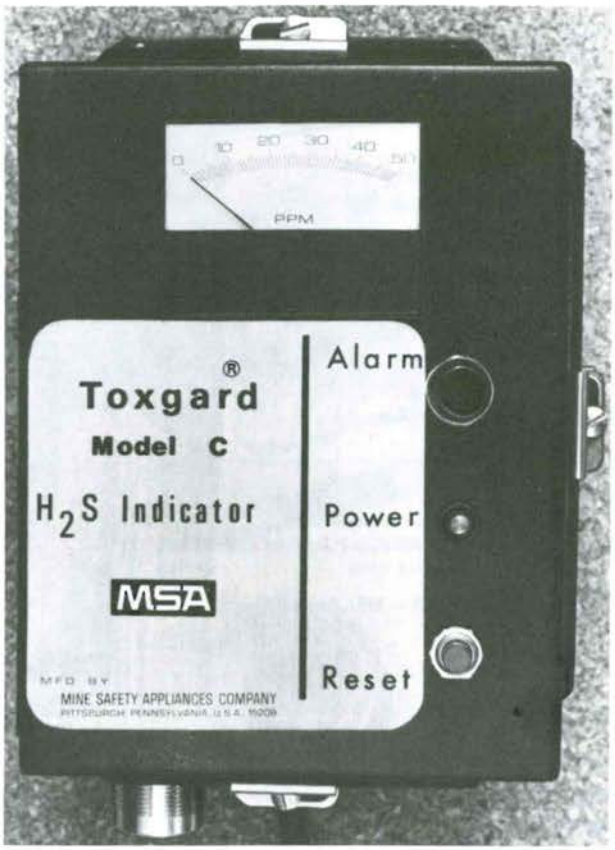


Figure V-55 — MSA Toxgard™ Indicator, Model C.

SO_2 Monitor, PW 9700

Philips Electronic Instruments
85 McKee Drive
Mahwah, NJ 07430

The Philips SO_2 Monitor is used to monitor the ambient atmosphere where sulfur dioxide concentrations may be in the range between 0.3 and 10 mg/m^3 of sample gas.

Operating principle

The SO_2 sampler is based upon the coulometric principle, in which the measurement of SO_2 is accomplished by titration with Br_2. The bromine is generated electrolytically in a solution in which the SO_2 is absorbed. A feedback amplifying system controls the bromine-generating current, so that the net rate of bromine generation is always equal to the rate of SO_2 absorption. Thus, the net electrical current is proportional to the SO_2 concentration in the incoming gas stream.

Air is introduced through a heated glass fiber filter to remove dust. This filter is covered with stainless steel gauze to prevent the intake of large particles or insects. The air is then led to a filter that removes ozone, H_2S and other substances, and then — at a flow rate of about 150 ml/minute — through the measuring cell containing an aqueous solution of KBr, Br_2 and H_2SO_4.

By means of two electrodes, the redox-potential (originating from Br_2) is measured, and this value is compared to a known built-in reference voltage. If the Br_2 concentration is lowered by the reaction with SO_2, the difference between the two voltages is converted into a current through two other electrodes in the measuring cell. This current converts Br^- ions into free bromine, so that the concentration of free Br_2 in the cell is kept constant. The current required to maintain the constant balance is directly proportional to the quantity of SO_2 which is led into the cell. This current determines the output signal, thus giving a measure of the SO_2 concentration in the air.

Physical description

The chemical part is contained in a portable glass-fiber-enforced polyester box. This box stands on the ground or is hung on a wall. In this "chemical" box the highest electrical potential is less than 36 volts, for safety reasons.

The electronics, pump and telemetering system are built in a similar box. The two boxes are interconnected by means of watertight tubes and jacks. The dust filter and the suction lead form a separate flexible unit which can be connected easily to the measuring instrument. *Power supply:* 220–245 V (± 10%), 47–51 Hz. Types for other mains voltages can be delivered (110–135 V, 47–51 Hz; 110–135V, 60 Hz).

Performance data

Response time: approximately 1.5 min (63% of final value); approximately 3 minutes (95% of final value). It is possible to change the time constant to much larger values. It is also possible to integrate the measured values for 1 hour or less. *Accuracy:* overall, absolute; better than 15% of the measuring signal, or better than 0.01 ppm (25 μg/m^3) for SO_2 constant smaller than 0.07 ppm (200 μg/m^3) SO_2 (if we take into account that a zero-current check and a calibration is performed once a day). This accuracy depends

to a large extent on the accuracy of the wet chemical calibration of the SO_2 source (West and Gaeke Method). *Reproducibility:* better than 3% of the measuring signal. *Detection limit:* smaller than 10 $\mu g/m^3$ SO_2 (4 ppb). *Size of zero-current:* same as a measuring signal smaller than 100 $\mu g/m^3$ SO_2. *Drift of the zero signal:* smaller than 25 $\mu g/m^3$ a day, not cumulative. *Influence of 10% main variation:* negligible. *Measuring range:* 3 mg/m^3 SO_2 (1.15 ppm SO_2/m^3 air); other measuring ranges between 0.3 and 10 mg/m^3 can be easily realized. *Output signal (before telemetry):* 0–20 mA, into a resistance of 0–300 ohm. *Climatological influence:* negligible (between -10° and +35°C). *Calibrations and zero point check:* periodically the zero current is checked automatically. Air free from SO_2 passes through the measuring cell for a period of time. Calibration is then performed with the aid of an SO_2 source. This source delivers an exactly known amount of SO_2 which is added to the clean air. Selectivity is defined by,

$$S = (\text{signal 0.5 ppm X/signal 0.5 ppm } SO_2) \times 100\%$$

where: S = interference sensitivity and X = substance (see Table V-4).

The amount of SO_2 coming from the source does not decrease more than 5% over 3 months. For example, 15 min zero current check, 15 min calibration, 12.5 hr measuring. This cycle can be performed automatically or by hand. *Available option:* H_2S Conversion Set PW 9701 removes SO_2, NO_2 and O_3 from sample stream.

TABLE V-4
Interferences

X	S
NO_2	< 5%
O_3	< 1%
H_2S	< 1%
Methyl mercaptans	> 100%*
Ethene	< 2%
Cl_2	< 2%
NO	< 1%
Aldehydes	< 1%
Benzene	< 1%
Chloroform	< 1%
CS_2	< 1%

* The large mercaptan interferences give no practical problem because of the extreme low mean concentration in the air.

Multi-Component Monitoring System For Air Pollution

Philips Electronics Instruments
85 McKee Drive
Mahwah, NJ 07430

This series of instruments allows continuous automatic field monitoring of ambient air quality. The modular set-up provides at the lowest possible cost the flexibility for different monitoring and data processing requirements.

Operating principle

Five of the measuring modules (SO_2, NO_2, NO, CO, H_2S) use the principle of coulometry, as used for the PW 9700. The gas of interest is bubbled through an electrolyte and, as a result, the concentration of one of the components of the electrolyte will change. This is compensated by an electrochemical reaction with a current which is proportional to the concentration of the pollutant. CO has no direct effect and its concentration is measured indirectly by the iodine released when CO is passed through heated iodine pentoxide. NO also has no direct effect and is measured as NO after oxidation. Specially developed selective filters ensure that each module is highly specific for the pollutant it is to measure. Chemiluminescence was chosen for O_3 measurements. This is specific for O_3 and depends on the emission of light by Rhodamine B when exposed to ozone. The luminous intensity is proportional to the O_3 concentration and is measured by a photo-multipler system. Considerable development work was necessary to improve the performance of the Rhodamine B, to eliminate the effects of varying humidity and to produce a reliable calibration standard.

Physical description

Use of modular units allows a measuring station to be set up for monitoring any combination of pollutants, SO_2, NO_2, NO, O_3, CO and H_2S, as well as meteorological variables.

TABLE V-5
Data for Measuring Modules

Modules	SO_2		NO_2		NO		O_3		CO		H_2S	
	ppm	mg/m^3	ppm	mg/m^3	ppm	mg/m^3	ppm	mg/m^3	ppm	mg/m^3	ppm	mg/m^3
Nominal	0.37	1	0.3	0.6	0.3	0.4	0.2	0.4	7	8	0.1	0.1
Measuring	1	3	1	2	1	1.3	0.5	1	20	23	0.3	0.3
Ranges	3.7	10	3	6	3	4			70	80	1	1
			9	18	10	13			(200)	(250)		
Minimum Detectable Concentration	0.005	0.015	0.005	0.01	0.005	0.0065	0.005	0.01	0.1	0.1	0.003	0.005
Maximum zero drift (24 h) non cumulative	0.005	0.015	0.005	0.01	0.005	0.0065	*)	*)	0.2	0.25	0.005	0.005
Time constant (min) 95%	5		5		5		*)		5		5	

*) not applicable

The modules are contained in a standard steel-framed glass reinforced plastic case for wall or panel mounting. As far as possible, the same construction is used throughout the range to simplify servicing.

Up to six measuring modules can be served by one air sampling assembly, and up to three by one power supply/pump module. One telemetering module provides up to 19 channels for control and data transmission.

Performance data

Span drift: < 2% in 24 hours after a stabilization period; for O_3, 5%). *Calibration:* span and zero checks can be performed remotely controlled with built-in standard source and zero filter. *Interference error:* negligible for all interfering gases in the concentrations occuring in the atmosphere. *Climatological influence:* the specifications are given for a temperature range of 0° to 30°C. *Output signal* (before telemetry): 0–20 mA into 0–500 ohm. *Power supply:* 110, 125, 200, 220 or 240V (± 10%), 47–63 Hz. *Power consumption:* 1, 2, 3 modules — 140, 260, 380 VA, respectively. *Weight:* measuring module, 9 kg; supply module, 13 kg. *Maintenance:* 3 months continuous operation without the need for service and/or maintenance. Measuring module data, see Table V-5.

Series 330 Personal Sazfety Oxygen Monitors

Teledyne Analytical Instruments
222 West Mission Drive
San Gabriel, CA 91776

Operating principle

Patented, disposable electrochemical cell which in the presence of oxygen produces an output signal linear with and specific to oxygen.

Physical description

Size: 10¼" × 6" × 3¾". *Weight:* 3.75 pounds; *Power requirements:* 4 "C" batteries. *Readout mode:* integral meter.

Performance data

Detection limits: 0–25% oxygen (up to 100% available). *Specificity:* completely specific to oxygen. *Accuracy:* ± 0.25% oxygen at constant temperature.

Figure V-56 — Teledyne Series 330 Oxygen Monitor.

Portable Gas Monitors, Series 44000

Western Precipitation Division
Joy Manufacturing
P.O. Box 2744, Terminal Annex
Los Angeles, CA 90051

Joy 44000 Series portable gas monitors are used in a broad spectrum of industries to measure ambient air for compliance with OSHA requirements for NO_2, SO_2, H_2S, and CO. Models for stack sampling of SO_2, O_2 and NO_x are also available.

Operating principle

A built-in pump draws a sample through a preconditioner and over an electrochemical sensor. The sensor generates a current proportional to the gas concentration which is amplified by a solid state electronic pack and displayed on a meter. Output jacks for recorder input are provided and an optional dosimeter (for 8-hour OSHA Conformance Checks) is available.

A filter/scrubber cartridge is used to satisfy the requirements for stack gas conditioning. The cartridge is rated at 99.95% removal efficiency for particles of 0.6 μm or larger using the disposable filter tubes. Water condensate is also trapped in the filter cartridge and is easily removed. Interfering gases, if present, are removed in the scrubber portion of the cartridge using the scrubbing solution provided.

Physical description

Dimensions: 11" × 9" × 9". *Weight:* < 10 lbs. *Power requirements:* four 4.5 volts batteries for amplifier; one 1.5 volt Ni-Cad battery for pump.

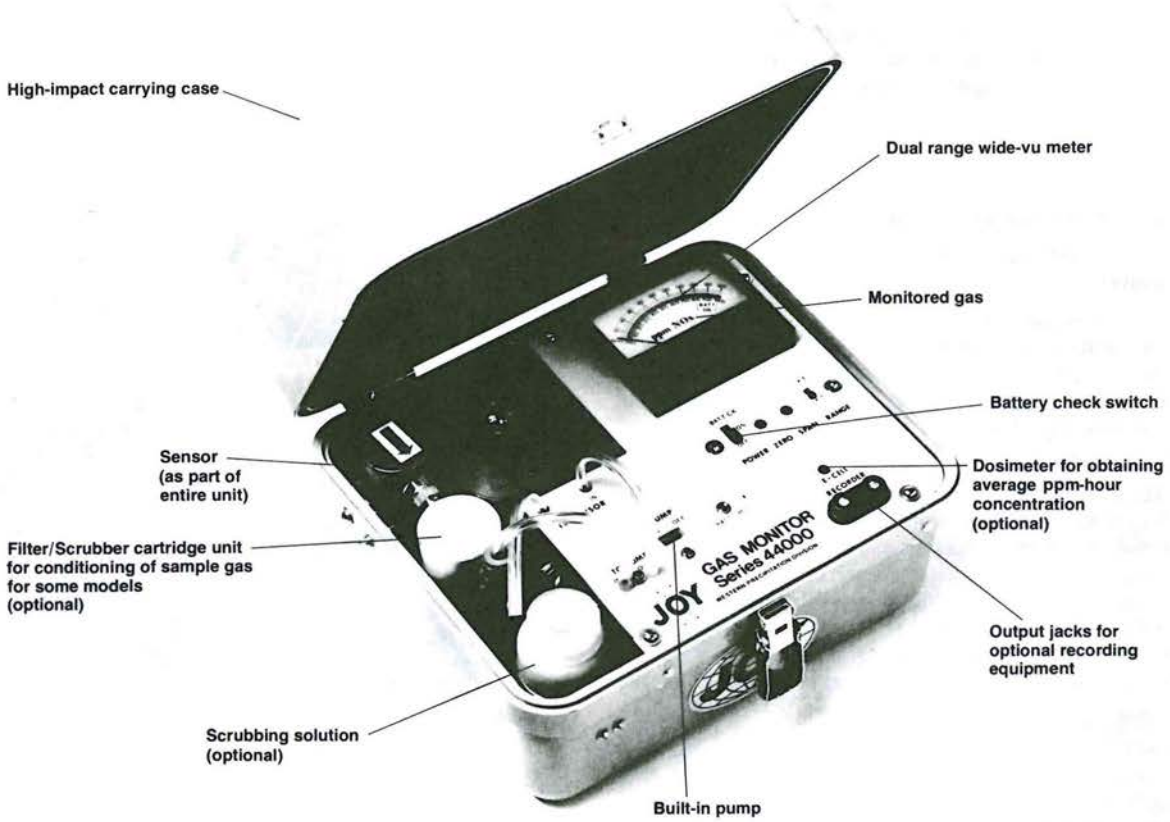


Figure V-57 — Joy Series 44000 Portable Gas Monitor

AID Model 580 amd 585 Portable Organic Vapor Analyzers

Analytical Instrument Development
Route 41 and Newark Road
Avondale, PA 19311

The Model 580 analyzes most organic vapors and a few inorganic vapors in the linear range of 0 to 2000 ppm. The Model 585 operates in the range of 0 to 10,000 ppm. The instruments are intended for use as portable ambient air monitors.

Operating principles

The AID 580 and 585 operate utilizing a photoionization detector. The photoionization detector utilizes a high energy ultraviolet lamp to ionize a sample which is drawn into the instrument. The ionized sample produces an ion current which is proportional to the concentration and is measured with a Pico Am Meter. The ionization is a fundamental process. A photon of light from the UV source energizes an electron of the sample molecule producing an ionized species and a free electron. For this reaction to occur, the photon energy must be equal to or greater than the ionization potential of the sample molecule. In general, the PID will respond to most organic compounds. It is insensitive to methane, ethane and most of the permanent gases.

Physical description

Both models measure 7.6 × 22.8 × 25.4 cm with an operating weight of 3.75 kilograms. The sampling rate is 500 ml/min for the AID 580, and 50 ml/min for the AID 585, and is regulated by a positive displacement pump. No external accessories are required other than a battery charging system. Power required to operate the unit is supplied from a set of internal batteries which can be recharged to provide 8 hours of continuous use. There is no fuel or compressed gases required. Probe size is dependent upon the probe chosen. A variety of probes are available. The AID features an integral audio alarm which can be preset to any level. In addition to the normal liquid crystal display, an optional strip chart recorder may be operated from the recorder terminals provided on the back panel.

Figure V-58 — AID Model 580 Portable Organic Vapor Analyzer.

Performance data

The AID 580 and 585 have a minimum detectable quantity of 0.1 ppm of benzene in an air matrix. The instrument displays information by a linear digital display. The unit is sensitive to 0.1 ppm benzene in air. As with all photoionization detectors, limited specificity is available by changing the energy of the photoionizatin lamp. Both instruments come equipped with a 10.0 eV lamp and an optional 11.8 eV lamp is available. The precision of the instruments is 0.1 ppm benzene with an accuracy of ± 0.1 ppm. Response time for the AID 580 is 2 seconds at 500 ml/min and 5 seconds for the AID 585 at 50 ml/min. A span and zero calibration control is provided on the front panel of the unit.

Model 710 and 712 Portable Total Hydrocarbon Analyzers

Analytical Instrument Development, Inc.
(address above)

The AID 710 is used to monitor total hydrocarbon content in an air stream and may be operated up to 2000 ppm. The AID 712 may be operated up to 20,000 ppm. The AID 710 and 712 are designed as portable ambient monitors for use in the detection of fugitive emissions and other types of leaks.

Operating principle

The AID 710 and 712 detect compounds with the principle of flame ionization of a drawn-in air stream. The AID 710 and 712 flame ionization detector operates when a sample comprised of air and the organic vapors is drawn into the detector with a positive displacement pump. In the detector, the organic components of the sample are ionized in a hydroplane. This ionization creates an electrical current which is measured by an electrometer. After processing, the electrical signal is presented to the digital display.

Physical description

The AID 710 and 712 are comprised of two units; the side pack which measure 10 × 21 × 25 cm and a gun 15 × 16 × 10 cm. The instrument weighs, fully configured, 6.4 kilograms. Samples are drawn in by a positive displacement pump at the rate of 1.5 lpm. The unit requires the availability of an external source of hydrogen to recharge the internal hydrogen supply. After the internal hydrogen tank is depleted, the larger cylinder is used to recharge it. The AID 710 and 712 operate off of an internal battery pack which supplies a minimum of eight hours of power. The batteries may be recharged off a standard line voltage. A variety of pumps are available. The unit is provided with a high level audio alarm and a flame-out indication to determine when the operations are interrupted. An optional recorder may be connected to the instrument through the terminal jacks on the back of the unit.

Figure V-59 — Model 710 Portable Total Hydrocarbon Analyzer.

Performance data

The 710 has a minimum detectable level of 0.1 ppm methane; the 712, 1.0 ppm methane. The instruments display information on a liquid crystal readout in a linear fashion. Sensitivity is 0.1 ppm methane for the 710 and 1.0 ppm methand for the 712. As a Total Hydrocarbon Analyzer, there are no interferences. The response time of the unit is 5 seconds, 90% full scale. A zero and span potentiometer are provided on the front panel of each unit.

Model 910 Organic Vapor Meter

Analytical Instrument Development Inc.
(address above)

The AID 910 Organic Vapor Meter is used to monitor most organic vapors in air; excluding methane, ethane, propane, and few others. The unit operates in a linear range of 0 to 1000 ppm and is designed for stationary montoring of organic vapors.

Operating principle

The AID 910 operates based upon the principle of photoionization. The photoionization detector utilizes a high energy ultraviolet lamp to ionize the sample that is drawn into the instrument. The ionized sample produces an ion current which is proportional to the concentration and is measured with a Pico Am Meter. The photoionization is a fundamental process where a photon of light from the UV source energizes an electron of the sample molecule producing an ionized species and free electron.

Figure V-60 — AID Model 910 Bench Mount Organic Vapor Meter.

Physical description

The AID 910 comes confined in two sizes; a bench-mount unit measuring 23 × 43 × 46 cm, and a unit in 50 × 41 × 28 cm NEMA enclosure. The operating weight for the bench-mount is 26 lbs, for the NEMA enclosure is 31 lbs. The sampling rate is variable up to 4 lpm and is user-adjustable. A positive displacement pump provides the source for the air sampling. No external accessories are required to operate the 910, however, a separate module is available to do multiple-point sampling this unit. A strip chart recorder may be ordered and becomes an integral part of the 910. The unit operates from 115 volts nominally and may be changed as specified by the customer. No fuel or compressed gases are required. The 910 comes equipped with three safety features; an audible alarm, a low-level and a high level alarm.

Performance data

Using a standard 10.0 eV photoionization lamp, the 910 may detect a minimum of 0.1 ppm benzene in an air matrix. The instrument displays all data on a LCD display which is linear. The unit is sensitive to 0.1 ppm benzene. As with any photoionization detector, the specificity is determined by the energy of the ionizing lamp. Normally the 910 has a precision of 0.1 ppm benzene. Response time is dependent upon the variable flow rate and is 2.5 seconds at maximum flow rate. A span and zero calibration adjustments are found on the front panel of the 910.

Model 6710 Analyzer

Beckman Instruments, Inc.
Process Instruments Division
2500 N. Harbor Boulevard
Fullerton, CA 92634

The Model 6710 Analyzer unit contains the chromatographic columns, detector system, sample injection and column switching valves all in a temperature controlled enclosure. The analyzer unit is designed for field location in hazardous areas with the electronics enclosed in an approved explosion-proof housing. Being self-sufficient, the analyzer may function on a "stand alone" basis for direct operation by a computer or Model 6710 Programmer.

Operating principle

The analyzer may be provided with thermal conductivity or flame ionization detectors. Four element thermal conductivity are employed for most applications and provide a wide dynamic range from several hundred parts per million to 100% full scale. The flame ionization detector is specified for trace hydrocarbon analysis.

Field located power supplies and amplifiers, combined with isolated current signal transmission, assume the integrity and accuracy of the detected concentrations. Partial voltage settings use a precision potentiometer with a turn indicator.

The Model 6710 Programmer includes all circuits necessary for measuring the detector signal, automatic control of all time related functions, and data reduction and presentation. Operator controls and indicators permit simple operation and calibration. An integral test meter with selector switch and light emitting diode indicators permit monitoring of system operation and rapid testing of all major circuits for malfunction isolation. The isolated current assures a noise-free unbiased signal which may be compatible with computer input requirements.

Performance data

Ambient temperature limits for the analyzer are -20° to +122°F (-29° to +50°C) and 30° to 100°F (0° to 37.7°C) for the programmer. Power requirements are 107-127 VAC, 50/60 Hz, 750 watts max for the analyzer and 107-127 VAC, 50/60 Hz, 250 watts for the programmer. *Air requirements:* 2-5 scfm at 40 psig (207 kPa). *Carrier gas requirements:* 50 to 100 cc/min normal, varies with application. *Sample flow:* approx. 10 cc/min liquid or 100 cc/min vapor through analyzer (bypass as required). *Operating temperature:* 55° to 225°C as required. *Temperature control:* ± 0.05°C. *Location:* up to 1000 feet (304.8 m) from analyzer max.

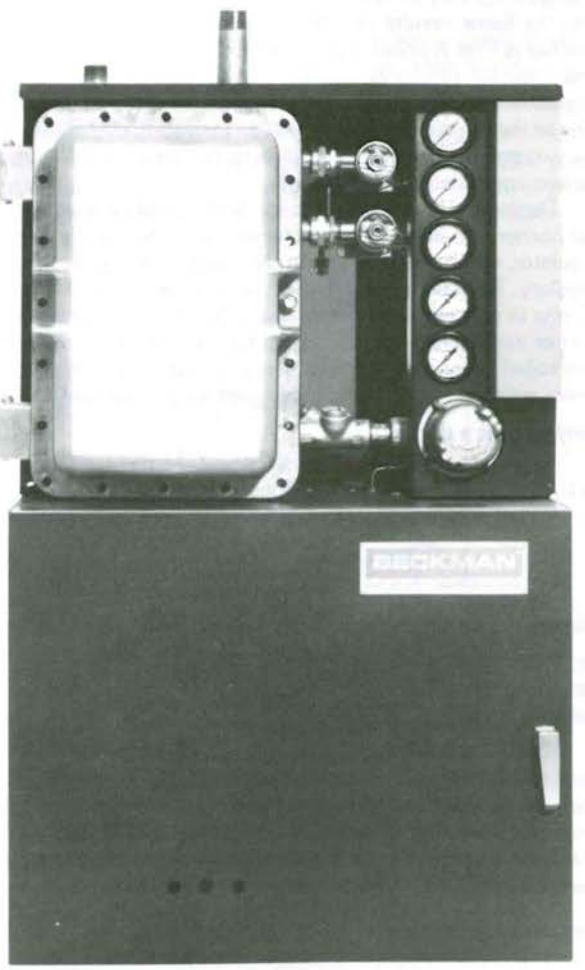


Figure V-61 — The Beckman Model 6710 Analyzer.

Physical description

The analyzer is 38¼" × 22" × 12⅛" and weighs approx. 200 lbs. The programmer is 8" × 19" × 25" and weighs approx. 70 lbs net.

Model 400 Hydrocarbon Analyzer

Beckman Instruments Inc.
Process Instruments Division
(address above)

The Model 400 employs the flame ionization detection method in a field-proven configuration to provide high-level performance in a variety of engine exhaust applications. Its compact, single-unit case is designed for panel, rack, or bench mounting. Case design permits front, top, and rear access to simplify maintenance. All flow controls, plus all related gauges and the burner, are mounted as a compact module. The module can be removed for testing or maintenance via the hinged front panel.

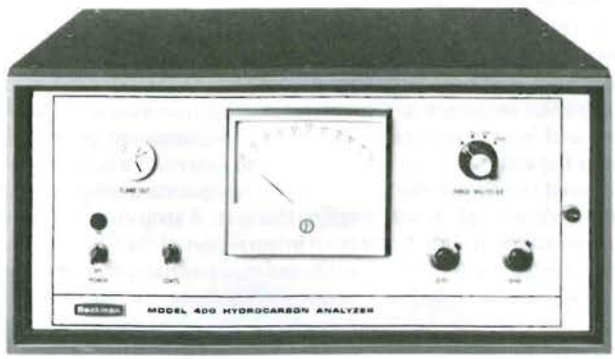


Figure V-62 — Beckman Model 400 Hydrocarbon Analyzer.

Operating principle

The flame ionization detection (FID) method is used to determine the concentration of hydrocarbons present in a gaseous sample. Hydrogen burned in air produces a flame containing a negligible number of ions; introduction of a hydrocarbon sample into the flame results in a complex ionization, creating a large number of ions. A polarizing voltage applied between the burner jet and collector produces an electrostatic field that results in ion migration. Positive ions are attracted to the collector and negative ions to the burner jet, establishing an ionization current between the two points. This current is directly proportional to the hydrocarbon concentration in the flame.

During the operation of the Model 400, sample is admitted to the burner at a precise flow, determined by the sample pressure regulator, which provides a controlled back pressure at the sample capillary. Bypass flow rates may be adjusted from 500 to 3000 cc/min to control system response. Fuel and air flow rates to the burner are determined by regulating the gas pressures against controlled porosity restrictors. The regulators are high precision, direct action units, compactly designed for precise flow control.

Performance data

Sensitivity: 0–4 $P/10^6$ to 10% full scale as CH_4(standard), 0–1 $P/10^6$ to 1% full scale as CH_4 (with pure hydrogen fuel accessory). *Precision:* ± 1% of full scale. *Noise:* < ± 0.5% of full scale. *Zero and span drift:* ± of full scale per 24 hours. *Response time:* 90% of full scale in 0.5 seconds at bypass flow rate of 3000 cc/min. *Ranges:* x1, x10, x100, x1000 standard; x1, x2.5, x10, x25, x100, x250, x1000 optinal with remote range change kit. *Output:* 10 mV, 100 mV, 1 V, or 5 VDC, selectable is standard; 40–20 mA, 10–50 mA DC, optional. *Fuel gas requirement:* hydrocarbon-free air. *Sample requirements:* 500–3000 cc/min at 5–10 psig, input, depending upon desired response time. *Ambient temperature limits:* 32°to 110°F (0 to 43°C). *Ambient humidity limits:* 95% RH. *Safety features:* flame-out indicator, integral flame arrestor, and automatic fuel shut-off.

Physical description

The model 400 measures 18¾" × 8¾" × 15⅝" and weighs 65 lbs.

Model 402 Hydrocarbon Analyzer

Beckman Instruments, Inc.
Automotive Test Instruments Operations
(address above)

The Beckman Model 402 Hydrocarbon Analyzer has been designed for direct analysis of raw exhaust from turbine engines, heavy-duty gasoline and diesel engines, and light-duty diesel engines. Featuring a field-proven circuit design and a rapid-response flow system, the Model 402 accurately measures hydrocarbons over a wide selection of eight full scale ranges.

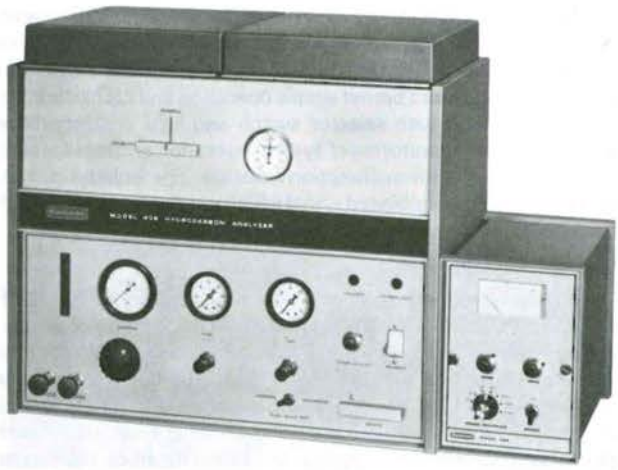


Figure V-63 — Beckman Model 402 Hydrocarbon Analyzer.

Operating principle

The flame ionization detection (FID) method is based on the principle that hydrogen burned in air produces a flame containing a negligible number of ions; introduction of a hydrocarbon sample into the flame creates a large number of ions. A polarizing voltage applied between the burner jet and collector and negative ions to the burner jet, establishing an ionization current between the two points. This current is directly proportional to the hydrocarbon concentration in the flame and is measured by an electrometer amplifier circuit and associated electronics.

During operation of the Model 4302, the sample is admitted to the analyzer at a flow rate of 6 ft^3/hr. The flow rate is controlled by a positive pressure displacement pump. Hydrogen/helium fuel and air flow rate to the burner are determined by regulating the gas pressure against controlled porosity restrictors. The admission of sample, fuel, and air to the burner results in the ionization current as described above.

Performance data

Precision: ± 1% full scale. *Ranges:* x1, x5, x10, x50, x100, x5000 with continuous electronic span adjustment. *Electronic range:* 90% in less than one second (with CH_4 from analyzer input without sample probe). *Sensitivity:* 5 P/10^6 to 1% full scale as CH_4 with H_2/H_2 or H_2/H_c fuel. *Analysis temperature:* 200° to 400°F (93° to 204°C), adjustable. *Ambient temperature limits:* 32° to 110°F (0 to 43°C). *Electronic stability:* ± 1% full scale/24 hours, with less then 10°F (-12.2°C) ambient temperature change. *Ambient humidity limits:* 95% RH. *Power requirements:* 107-127 VAC, 50/60 Hz, 1000 watts maximum; output 10 mV, 100 mV, 1 VDC, option. Temperature controlled probe is available in 10 or 20 feet lengths; teflon surface in contact with sample (proportional temperature controlled and adjusted from 200° to 400°F (93° to 204°C).

Physical description

Model 402 weighs 150 lbs and measures 18⅜" × 27½" × 11½".

Friez® Hydrocarbon Analyzer

The Bendix Corporation
Environmental & Process Instruments Division
12345 Starkey Road,
Largo, FL 33543

The Bendix Friez® Hydrocarbon Analyzer utilizes a hydrogen flame ionization detector (FID) to continuously detect and measure trace contaminants in various atmospheres and in exhausts of internal combustion engines.

Operating principle

Hydrogen burned in air produces an extremely hot, clean, flame. When these gases are of a high purity, relatively few ions are formed. When impurities are introduced into the flame, a short-lived ion cloud is formed. When an electromotive force exists, the ions form a low-current path between the jet and the collector in a suitable burner. The low-current signal can be amplified to deflect a readout meter or a recorder.

Physical description

The Hydrocarbon Analyzer is housed within a cabinet which is suitable for either rack mounting or table top applications.

Specifications

Sensitivity: 0-1 ppm methane (full scale). *Reproductibility:* ± 1% with constant sample. *Ranges:* 0-1 ppm to 0-100,000 ppm methane. *Response time:* < 1 second. *Fuel consumption:* (type A cylinder), air — 2-3 weeks; fuel — 2-3 months; zero gas — 2 months. *Sample flow:* 1.0 ft^3/hr.

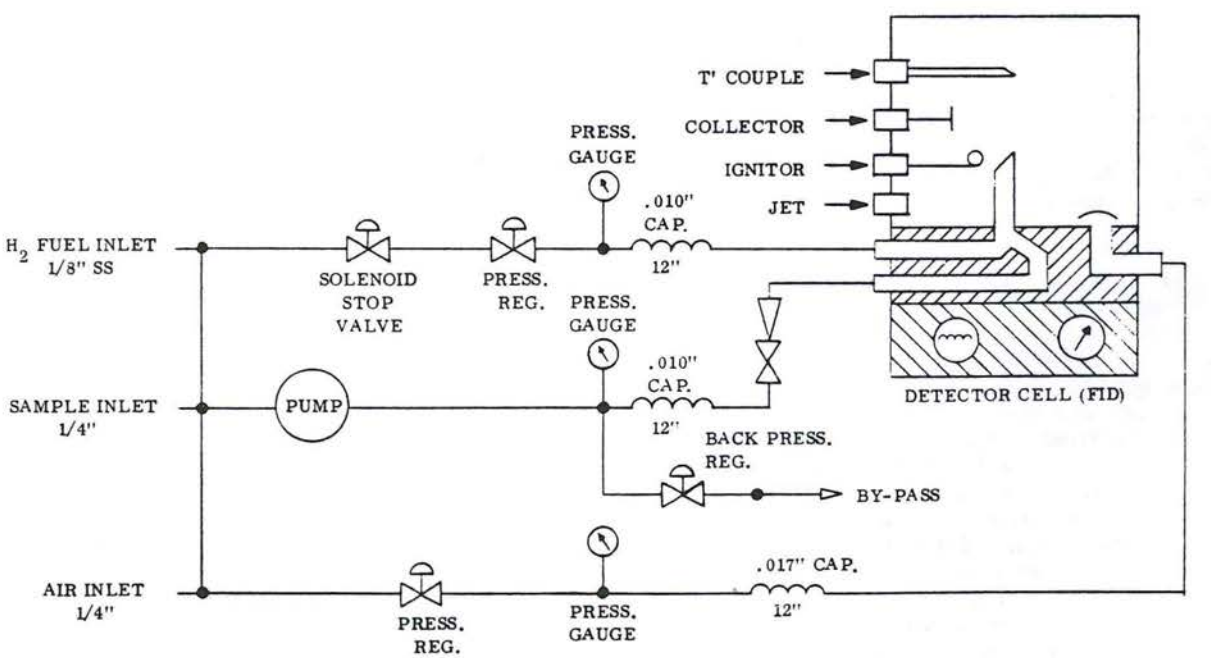


Figure V-64 — Flow Schematic and Flame Ionization Detector of Friez® Hydrocarbon Analyzer.

Organic Vapor Analyzer

Foxboro Company
P.O. Box 5449
South Norwalk, CT 06856

The Organic Vapor Analyzer (OVA) is a highly sensitive instrument designed to measure trace quantities of organic materials in air. It incorporates a hydrogen flame ionization detection system which has similar analytical capabilities to those utilized in gas chromatographs. The flame ionization detector is an almost universal detector for organic compounds with the sensitivity to analyze for them in the parts per million range (v/v) in air in the presence of moisture, nitrogen oxides, carbon monoxide, and carbon dioxide.

The instrument has broad application, since it has a continuous, chemically resistant air sampling system and can be readily calibrated to measure almost all organic vapors. It has a single logarithmically scaled readout from 1 ppm to 100,000 ppm or with lower maximum level, if desired. Designed for use as a portable survey instrument, it can also be readily adapted to fixed remote monitoring or mobile installations.

Figure V-65 — Foxboro Organic Vapor Analyzer.

Operating principle

The instrument includes a detector chamber where the organic vapor being analyzed is introduced into a small hydrogen flame. Air sample is drawn into the instrument at a constant rate of norminally 2 lpm through a chemically resistant line and pump. The oxygen in the air sample is used to support the small hydrogen flame.

Flames characteristically have electrical conductivity due to the presence of electrons and ions generated from the burning fuel. When even trace amounts of organic material enter the hydrogen flame, carbon-containing ions are formed and the electrical conductivity increases significantly. This change in conductivity is measured and the output is directly related to the concentration of organic materials. The exception to this phenomenon is carbon monoxide and carbon dioxide which evidently, due to their structure, do not produce appreciable ions in the detector flame. Thus, other organic materials may be analyzed in the presence of CO and CO_2.

An electric field in the chamber drives the ions to a collecting electrode which causes a current to flow into a preamplifier that is proportional to the ion collection rate. The rate of ion generation is a function of the quantity and structure of the carbon compound present in the sample. The ionization current is samplified in a logarithmic electrometer into a preamplifier, the output of which varies as the logarithm of the input. This logarithmic feature enables measurement and readout of ionization rates over a range of up to five decades (1 to 100,000) without range scaling. The output signal from the preamplifier is fed to the signal conditioning and contol circuits for subsequent readout and alarm signaling.

A fuel handling system including storage tank, valves, regulators and gauges is incorporated to maintain the small hydrogen flame jet in the chamber. The instrument response is read on a hand held meter assembly or can be read out utilizing the external monitor signal. An audible detection alarm is provided which can be preset to any desired level and which has a frequency modulated tone which varies as a function of the signal level. The standard instrument includes an audible flame out alarm, battery test indicator and internal electronic calibration.

Since the response of the instrument is dependent upon the chemical nature of the material being analyzed, it is necessary to calibrate the device with a standard sample of that particular organic vapor. However, the approximate response of the instrument to hydrocarbons or compounds containing halogens, oxygen, or nitrogen can be estimated from the structure of the compounds and utilization of empirical data. The internal electronic reference signals are provided so the operator can readily recheck the instrument response from the point of ion collection to the readout meter.

Physical description

The side pack assembly is 8⅝" × 11⅝" × 4¼", weighs less than 9 lbs, housed in a carrying case constructed of molded high impact plastic complete with a carrying handle and shoulder strap. The probe/readout assembly weighs less than 2 lbs, but size is variable. Standard accessories include instrument carrying and storage case, high pressure fuel filling hose assembly, and AC battery charger.

Performance data

Sensitivity: 1 ppm (methane). *Response time:* < 2 seconds. *Readout:* 250° logarithmic scaled meter, various scales in the range of 1–100,000 ppm; external monitor connector. *Sample flow rate:* nominally 2 lpm. *Fuel supply:* 75 cc tank of pure hydrogen at max, pressure of 2300 psig, fillable while in case. *Primary electrical power:* rechargeable and replaceable battery pack at 12 VDC. *Service life:* hydrogen supply and battery power — 8 hours operating time minimum. The frequency modulated audible alarm can be preset to desired level. Frequency varies as a function of detection level. *Flame-out indication:* audible alarm plus visual meter indication. *Battery test:* battery charge condition indicated on readout meter or battery recharger. *Pickup fixtures:* variety of types for various applications. *Probe:* telescoping adjustment over 8 inches or probe can be completely removed from readout assembly. The umbilical cord is 5 feet long with connectors for electrical cable and sample hose. In-line disposable and permanent particle filters are standard with activated charcoal filter as an option.

Hydrocarbon Gas Analyzer

Meloy Laboratories, Inc.
Instruments & Systems Division
6715 Electronic Drive
Springfield, VA 22151

Operating principle

The HC 500 performs real-time and continuous dry analysis of hydrocarbon gases utilizing the flame ionization detector (FID). Emphasis is focused on stable and reliable performance without a source of clean combustion air required. Thermal control of sample air, hydrogen and exhaust gas is controlled to within ± 1% over 10°to 40°C ambient temperature range. It closely approximates ppm hydrocarbon molecules rather than approximate methane equivalents as provided by FID's operating in the GC mode.

Performance data

Ranges: 0–10 ppm, 0–50 ppm, 0–100 ppm, 0–500 ppm, 0–1000 ppm linear scale. *Minimum detectable sensitivity:* 0.1 ppm CH_4. Noise: ± 0.05 ppm CH_4. *Lag time:* < 15 sec. *Rise and fall time to 90%:* < 30 sec. *Precision and accuracy:* ± 0.1 ppm CH_4. *Zero and span drift:* (S-9) ± 0.2 ppm/day; ± 0.3 ppm/3 days. *Linearity:* ± 0.1 ppm CH_4. *Selectable time constant:* 1 second or 10 seconds. *Operational specifications:* unattended operation (no adjustment of flow or electrical systems) 7 days. *Sample flow rate:* approx. 200 ml/min; hydrogen flow rate, approx. 140 ml/min.

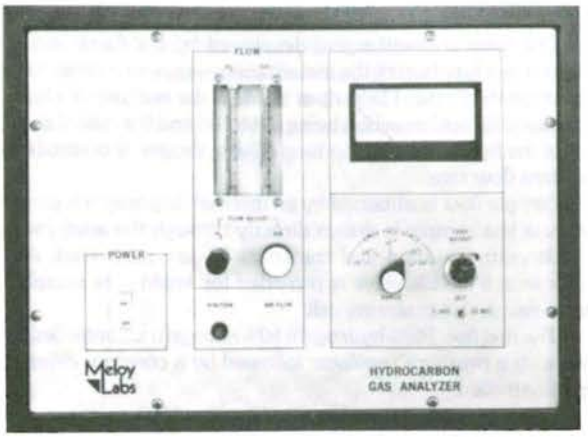


Figure V-66 — Hydrogen Gas Analyzer, HC 500.

Physical description

Power requirements: 115 ± 10 VAC (50/60 Hz) 250 watts. The bench mount instrument is 12¼" × 17" × 20", while the rack mount is 12.¼" × 19" × 20", both weighing 40 lbs. *Sample pump:* internal.

Portable Flame Ionization Meter

Scott Aviation-Davis Instruments
P.O. Box 751
RT 29 North
Charlottesville, VA 22902

The Portable Flame Ionization Meter Model 11-654 is used to detect trace hydrocarbons in air. Applications of the instrument include 1) the measurement of hydrocarbons as atmospheric pollutants; 2) the montoring for fuel leaks in storage areas or during fuel transfer and loading operations; 3) measurement of hydrocarbons in LOX or inert purge gas; 4) the monitoring for toxic concentrations of solvents or process chemicals in manufacturing areas, ventilating systems, or storage areas; or 5) the monitoring of manholes, sewers, and drains for accumulations of toxic or explosive gases.

TABLE V-6
Sensitivity of Model 11-654

Gas	Full Scale Response Range 6 (ppm)	TLV* (ppm)
Methyl ethyl ketone	15	200
Propane	25	—
Methane	20	—
Hexane	15	50
Freon 11	85	1000
Freon 12	35	1000
Octane	15	300
Acetone	25	750
Toluene	10	100
Xylene	15	100
Benzene	5	10
Ethyl alcohol	100	1000
Ethyl acetate	25	400
Methyl alcohol	250	200

*TLV: 1982 ACGIH Threshold Limit Values.

Figure V-67 — Scott Aviation Model 11-654 Portable Flame Ionization Meter.

Operating principle

The basic principle of operation of this detector is ionization of hydrocarbon molecules in a hydrogen flame.

The sample being analyzed is continuously drawn into the detection cell, where it contacts a hydrogen flame. A portion of the carbon compound(s) present in the sample burns in the hydrogen flame producing carbon ions. An electrical potential across the

flame jet and an electrode located above the flame results in an ion current which is measured by an electrometer circuit.

The measurement signal developed by the flame ionization detector is a function of the instantaneous quantity of carbon ions present in the flame. The output signal of the analyzer is a function of the specific hydrocarbon being detected and the rate of combustion of the hydrogen fuel mixture. The hydrogen is controlled to a constant flow rate.

Sample flow is obtained by an internal diaphragm type pump. Because the sample is drawn directly through the analyzing cell, sample contamination and transport lag are minimized. A rotameter with a needle valve is provided for setting the sample flow rate through the analyzing cell.

The fuel flow (40% hydrogen; 60% nitrogen) is controlled in two stages by a pressure regulator followed by a constant differential-type controlled.

Positive sample pressures of up to 3000 psig are readily handled by means of optional pressure regulator accessories.

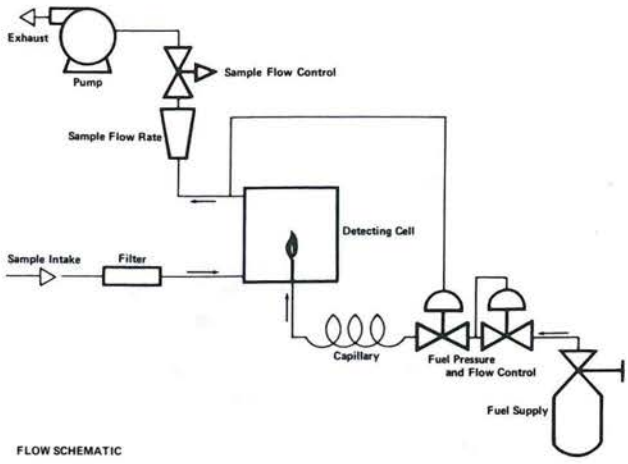


Figure V-68 — Schematic of Davis Flame Ionization Meter.

TABLE V-7
Range Selection of Model 11-654

Range Switch Setting*	Range Factor	Response (to methane) Full Scale ppm
1	1	20,000
2	10	2,000
3	25	800
4	100	200
5	250	80
6	1000	20

*Higher sensitivities available with recorders. A 25 mV recorder will reproduce the indicating meter readings. For higher sensitivities use a narrower span recorder, i.e., a 5 mV recorder will give a full scale sensitivity five times that of the indicator.

Physical description

Size: 10" × 11" × 18". *Weight:* 30 pounds. The fuel supply is a two-cubic foot lecture bottle which is internally mounted but can be replaced without opening the housing.

All controls necessary for operation of the system are mounted on the front panel. Recorder ouput terminals are available on the rear panel as are the fuses, sample inlet and exhaust connections, fuel supply controls, and electrical power input.

Performance data

Sensitivity: < 2 ppm benzene (full scale) when used with 5 mV recorder. *Range:* from parts per million to volume percent. *Speed of response:* varies directly with sample flow rate; 2-3 seconds, exclusive of external sample transport.

Table V-6 lists the sensitivities of Model 11-654, and Table V-7 lists the range selection of Model 11-654.

Hydrocarbon Analyzers, 400 Series

Teledyne Analytical Instruments
333 W. Mission Drive
San Gabriel, CA 91776

The TAI Series 400 flame ionization analyzers are continuous monitoring devices designed to measure trace quantities of total hydrocarbon contaminants in a gaseous atmosphere. The analyzer may be used to 1) detect hydrocarbons and atmospheric pollutants; 2) to monitor for fuel leakage or for toxic solvents; 3) to monitor combustion efficiency by measuring hydrocarbon off gases. In the Series 400 there are three models: 402 for positive pressure sampling; 403 for portable atmospheric sampling; and 404 for portable high temperature sampling.

Operating principle

The detector assembly consists of two parts: an upper and lower section. The lower section is mounted in a heated chamber to produce a flame which has a very low background current. A quartz flame jet is used for stability. The upper portion contains an ion collection system to provide a wide range of linearity. Heating the detector prevents any water formed during combustion from condensing and flooding the flame.

The output of the flame ionization detector is related to the rate input of sample to the flame. Components controlling flow (capillary tubing, needle valves, regulators, etc.) will change the flow characteristics with temperature variations, and current output will be affected. To prevent the analyzer from being temperature-dependent, TAI has contained all sample and auxiliary gas flow hardware in an isothermal chamber. Constant temperature is maintained by a solid-state thermistor regulated proportional temperature controller.

Gas flows are regulated by maintaining a constant pressure across a unique sintered stainless steel restrictor in lieu of using capillary tubing. This eliminates the possibility of plugging. A back pressure regulator maintains a constant input readout with sample pressure fluctuations of over 70 psi. An integral, self-purging manifold for introduction of span, zero and sample gas is provided, allowing all operations to be performed at the front panel of the instrument.

The low volume sample path, in conjunction with a variable sample bypass system provides a fast response to process changes. Only one second is required for 90% response to a change from 10 ppm to 1000 ppm.

Physical description

Contained in a general purpose enclosure suitable for flush panel mounting, the Model 402 is 16" × 17" × 9". An optional recorder readout has power requirements of 50 watts. The Model 403 is offered for stack gas analysis, fuel leakage, and similar

sampling systems with dew points below 125°F. Its dimensions are 18" × 23" × 18". It can be relay rack mounted and suitable for portable use. The vacuum system for drawing sample into system consists of a pump, surge tank, regulator and gauge, shut-off valve and water trap, requiring power of 200 watts. The Model 404 is offered for sampling systems with dew points up to 175°F. It measures 20" × 22" × 18" with power requirements of 350 watts. A 36-inch stainless steel probe with heated sample line supplied.

Performance data

Noise: < ± 0.5% fullscale. *Drift:* < 1% full scale per day. *Range:* triple range attenuator. *Output:* linear signal meter readout provisions for 0–5 mV DC recorder; other outputs available. *Ambient temperature:* 40° to 100°F. *Accuracy:* 1% of full scale range. *Flow rate:* 100 ml to 400 ml/min of sample 40 ml to 50 ml of fuel (200 ft^3 cylinder lasts three months); fuel mixture of 40% hydrogen and 60% nitrogen. *Sensitivity:* as low as 0–2 ppm methane equivalent. *Response time:* a function of the recorder used; flame response is instantaneous. Pressure rating up to 100 psi.

350F Analyzer For CO/CH_4 And Total Hydrocarbons

Tracor, Inc.
Analytical Instruments Division
6500 Tracor Lane
Austin, TX 78721

The Tracor 350F Analyzer combines a gas chromatographic column with a flame ionization detector and can be used to measure concentrations of carbon monoxide, methane, and total hydrocarbons in the range 0.01 to 200 ppm.

Operating principle

Carbon monoxide reacts with hydrogen in the presence of reduced nickel catalyst to quantitatively produce methane. The flame ionization detector is coupled to the reactor for the measurement of the reactant methane. Selectivity is attained by using a pre-column prior to the analytical column, which removes all interferents, passing only CO and CH_4. The analytical column then permits separate identification and quantitation of both the CO and CH_4. Total hydrocarbons can be analyzed by introducing an ambient air sample directly to the flame during each analytical cycle.

Sampling is performed by use of a high velocity, no-contact pump located upstream of the sample loop. Introduction of the sample automatically places the pre-column into its interferent-scrubbing position. Returning the sample valve to its load position causes a reversal of carrier flow through the pre-column, effectively backflushing its contents.

Figure V-69 — Tracor 350F Analyzer for CO, CH_4 and Total Hydrocarbons.

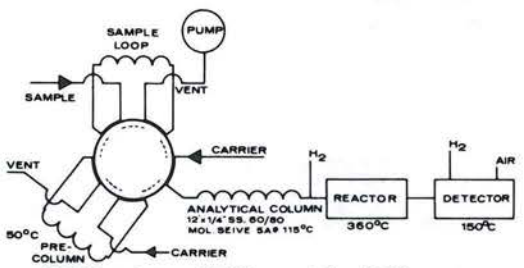


Figure V-70 — Schematic of Tracor 350F for CO and CH_4.

The reactor, where CO to CH_4 conversion occurs, is maintained within 0.05°C by a full proportional temperature controller. A 2-position selector switch takes the unit to either 550°C for preconditioning or 360°C for conversion. The reactor catalyst tube is easily removed for normal, infrequent service.

The flame ionization detector is exceptional in its ability to withstand carrier flows of 200+ cc/min without extinguishing or deteriorating in its response or linearity. Burner gases are maintained with the analyzer's own control system assuring maximum stability. An integral flame-out H_2 cut-off is incorporated.

The analytical column is housed in a heated mandrel oven. Temperature control is within 0.05°C, assuring reproducibility of analytical time. Easy access provides minimum maintenance. A panel-mounted pyrometer with 4-position selector switch enables the operator to monitor temperatures of all analytical parameters; valve oven, column oven, reactor and detector. Fast response thermocouples permit a full temperature/area profile within seconds.

Physical description

The Tracor 350F Analyzer consists of a basic 9" × 19" module containing one heated 10-port valve with integral sample loop/pre-column and actuator with pneumatic control; full proportionally heated flame ionization detector with integral solenoid and manual flame-out H_2 cut-off and manual re-set; mandrel oven with full proportional control containing analytical column; catalytic reactor with 2-heat selection full proportional heater; panel-mounted rotameters for 2 each H_2, 2 each He, and 1 each air flows with H_2 head pressure regulator and independent head pressure gauges; panel-mounted pyrometer with 4-position selector switch; flame ionization detector with electrometer and associated power supplies. Includes both pre-column and analytical column and 3 filter driers.

Model 3020 Air Quality Monitor

Union Carbide Corporation
Instrument Department
Box 372
South Plainfield, NJ 07080

The Union Carbide Model 3020 Air Quality Monitor measures carbon monoxide, methane, and total hydrocarbons in ambient air in ranges of 0–1, 0–10, 0–100 ppm, with accuracy better than 2%. Carbon dioxide, water vapor, other gases, and temperature changes do not affect the precision of the analyzer. The subtraction of methane from total hydrocarbons provides an index of the reactive hydrocarbons.

Operating principle

The Model 3020 analyzer is an automatic gas chromatograph which uses a hydrogen flame ionization detector. With this technique, sensitivities as high as 0–1 ppm full scale are available on all three channels. The three parameters are measured once every five minutes and a calibration check is made automatically once every twenty-four hours.

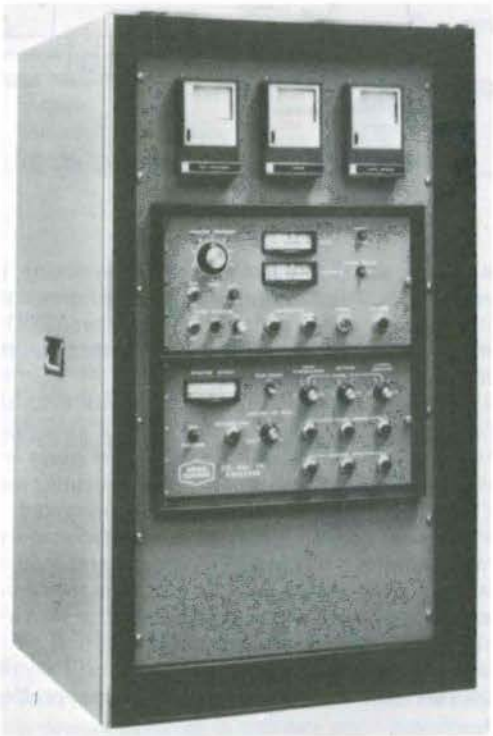


Figure V-71 — Union Carbide Model 3020 Air Quality Monitor.

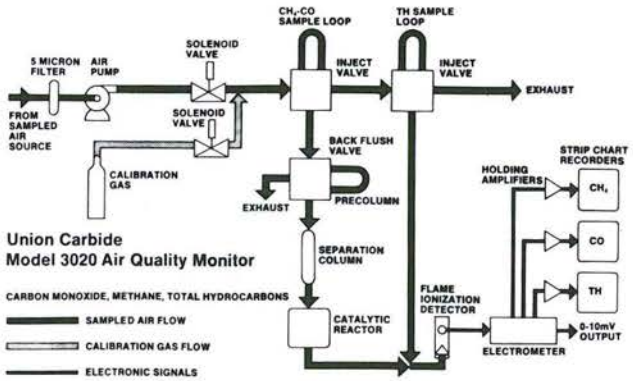


Figure V-72 — Schematic diagram of Model 3020.

Physical description

The standard cabinet is 41" × 23" × 25½". The power requirements are 105–125 volts, 60 Hz, 3.5 amps. Replacement of the 220 ft^3 compressed gas cylinders of hydrogen, air and nitrogen is required monthly.

The Model 3020 is equipped with three 2" strip chart recorders on which the peak values for the three measurements are presented in trend form. These data are simultaneously stored in memory and are available for computer logging as required. Output jacks are also provided so that trend, peak height, or spectrum data may be indicated remotely.

Performance data

Sampling rate: atmospheric air (ft^3/min). *Analyses per hour:* 4, 6, 8, 12, automatic, manual. *Accuracy:* 2% full scale. *Linearity:* 1% full scale all ranges. *Resolution:* 0.1% full scale. *Sensitivity to other gases:* < 5% full scale any range. *Repeatability:* 0.5% full scale. *Drift:* fully compensated in normal operation. *Ambient operation temperature:* 10° to 40°C. *Output signals:* 1) recorder output 0–10 mV, with other levels on request; 2) separate holding amplifier 0–5 volts for each measurement; signal stores and updated at each analysis within 100 milliseconds; output impedance — holding amplifier less than 2000 ohms; recorder 10 ohms. *Calibration:* 1) automatic calibration check from standard gas once each 24-hour period; 2) manual calibration check by toggle switch on instrument panel. Baseline correction is automatic with each analysis.

Titron Beta-Gas Monitors

Johnston Laboratories, Inc.
2301 York Road
Timenium, MD 21030

The Triton Beta-Gas Meters are used to monitor ^{3}H, ^{14}C, ^{133}Xe, ^{85}Kr, ^{41}A, ^{222}Rn, and other radioactive gases around nuclear reactors, accelerators, manufacturing plants, and incinerators burning radioactive wastes.

Operating principle

A positive displacement pump draws the air through a submicron filter, an electrostatic precipitator, and an ionization chamber. Interfering particles, ions and smoke are efficiently removed. The electrical current produced by radioactivity within the ionization chamber is detected and amplified by an electrometer. The output current from the electrometer is connected to a panel meter and recorder jack. Compensation for local ambient gamma flux is provided, as indicated in Figure V-73.

Physical description and specifications

Model 955B measures 19⅝" × 14¾" × 21⅝" and weighs 67 lbs with four 50-liter chambers. Its reproducibility is ± 2%, accuracy is 10% of full scale, and zero drift is < 2%. Power requirement are 115/230V, 50/60 Hz, 100 watts. Ranges measured for tritium are 0–10, 100, 1000, and 10,000 μCi/m.

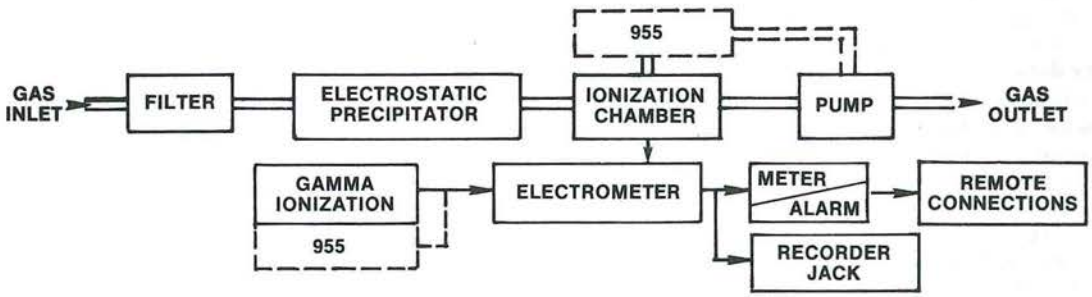


Figure V-73 — Block diagram of Triton Beta-Gas Monitors.

Continuous Monitors For Radioactive Gases

NRC Industries
Division of Nuclear Research Company
125 Titus Avenue
Warrington, PA 18976

The MGP-1A and MGP-2 continuous monitors for radioactive gases are designed for use in reactor operations, radiochemical laboratories, hot cells, fuel reprocessing plants, nuclear test site areas, and other places where the level of the concentration of radioactive gases must be continuously monitored and recorded. These systems will measure radioactive gas activity from the environmental air, through appropriate sampling line connections, from in-duct streams or effluent discharge points.

Operating principle

These two systems are identical except for the type of detector and gas sampler employed. The MGP-1A employs an MG-1A scintillation type gas sampler and an MD-5A gamma scintillation detector, whereas the MGP-2 uses an MD-11 large-area beta-gamma G.M. detector and MG-2 gas sampler. Radioactive gas to be monitored is first passed through an absolute filter assembly with airborne radioactive particulates and then into the appropriate gas sampler. The sample gas enters the gas cell tangentially at one end and traces a cyclonic path to the outlet. This design prevents areas of "dead gas" within the sensing volume.

Physical description

Either unit weighs approximately 950 pounds and is contained within the dimensions of 32.5" × 32.5" × 24.5". The electrical power requirements are 900 watts, single phase, 110/220 VAC, 50–60 Hz.

Figure V-74 — Tracerlab Continuous Radioactive Gas Montor, Model MGP-1A.

TABLE V-8

Activity	Type and Energy (MEV) Gammas	Betas	Half-Life	Minimum Detectable Concentration μc/cc MG-1A*	MG-2A**
O^{19}	1.3(64%) 0.2(96%) 0.1(4%)	4.5(30%) 2.9(70%)	30 Seconds	7×10^{-7}	3.8 x 10-7
A^{41}	1.37(100%)	1.24(100%)	110 Minutes	6.25×10^{-7}	5.5 x 10-7
Br^{82}	γ decay scheme in doubt	0.46(100%)	36 Hours	—	7.6 x 10-7
Kr^{85}	0.54(0.35%)	0.69(100%)	9.4 Years	3.5×10^{-4}	9.6 x 10-7
I^{131}	0.36(87%) 0.64(9%) 0.72(3%)	0.61(87%)	8.1 Days	1.7×10^{-6}	1.3 x 10-6
Xe^{133}	0.08(100%)	0.34(100%)	5.3 Days	4×10^{-6}	2 x 10-6

*With Tracerlab MD-5B Scintillation Detector (250 cpm background, 3" lead shielding).
**With Tracerlab MD-12C Large Area Beta-Gamma G-M Detector (40 cpm background, 2" lead shielding).

Performance data

The sensitivity of the two systems are shown in Table V-8. Specifications for Model MGP-1A are gas sample temperature — 160°; gas pressure — 150 psi maximum (will stand full vacuum); gas connections — 1-inch compression fittings for tubing. Specifications for MGP-2 are gas sample temperature — 200°F, maximum; gas pressure — 5 psi maximum; gas connections — 2⅝" tubes.

Either system can be effectively combined with a continuous particulate monitor for continuous monitoring of stack effluents for both particulates and gas activities. Where maximum radioactive gas activity is desired, a high-pressure version of the MGP-1A is available. This increases the minimum detectable sensitivity by a factor equal to the number of atmospheres of compression. Other variations of the system are available.

A check source and mechanism system is available. This accessory fits onto the gas sampler and demonstrates proper operation of the detector and electronic equipment by providing a positive and reproducible count rate test. The radioactive check source is solenoid operated. The accessory is available as an alpha or beta-gamma source and does not require an AEC license.

In the MCP-2 unit, the detector is mounted centrally in the gas sampler, allowing a 2" annulus for the flow of gas. A disposable polyethylene sleeve 12mg/cm^2 thick is supplied with the detector; it surrounds the detector and may be replaced if the background builds up.

Model 7-C Thermal Conductivity Analyzers

Beckman Instruments, Inc.
Process Instruments Division
2500 N. Harbor Boulevard
Fullerton, CA 92634

The Beckman 7-C Series Analyzers utilize the thermal conductivity principle of measurement to provide reliable and accurate analysis of the concentration of one component in a mixture of gases. Although ideally suited to the analysis of binary gas mixtures, the flexibility of these instruments also allows their application to a wide variety of more complex gas mixtures where the various other gases have a constant ratio or similar thermal conductivities. These analyzers may be used in 1) power generating plants to detect hydrogen in generator cooling systems; 2) ammonia plants to measure hydrogen in nitrogen, ammonia, argon, carbon monoxide or oxygen; 3) petroleum refineries to measure hydrogen in C, through C_6 hydrocarbons; 4) air liquefaction plants to measure argon in oxygen and nitrogen, or measuring oxygen with argon impurities.

Beckman 7-C Series Analyzers are available in standard versions for normal applications or a high-sensitivity configuration for highly surpressed ranges or trace analyses. Panel-mounted or explosion-proof housings for use in Class 1, Group D, Division 1 locations are also available. The instruments provide outputs compatible with all common potentiometric recorders and controllers, local or remote.

Figure V-75 — Beckman Model 7-C Thermal Conductivity Analyzer.

Operating principle

The classic Wheatstone Bridge is the basic measuring device in Beckman Thermal Conductivity Gas Analyzers. Two pair of heating filaments, placed in cavities within a metal block in the thermal conductivity cell, act as two legs of the bridge. A constant voltage DC power supply furnishes current to heat the filaments. One pair of the cell cavities contain a reference gas of known thermal conductivity. The remaining two cavities contain the "sample" gas. Differences in the thermal conductivity of the the reference and sample gases cause an unbalance in the temperature, and therefore current requirements, of the bridge heating filaments. The unbalance, directly proportional to the quantity of the sample gas under analysis, is measured with a meter and/or recorder and calibrated to represent a percent value of the sample gas.

Performance data

Ranges: hydrogen — 0–500 P/10^6 H_2, in air or N_2; 99.5–100% H_2 in N_2; nitrogen —0–5000 P/10^6 N_2 in argon; carbon dioxide — 0–3% CO_2 in air; helium — 0–5000 P/10^6 He in air or N_2; oxygen — 95–100% O_2 in argon; ammonia — 0–15% NH_3 in synthesis gas; argon — 0–5% in air, O_2 or N_2. *Accuracy:* ± 2% of full scale. *Reproducibility:* ± 2% of full scale for a period of 24 hours for most applications. *Cell response time:* 95% of change in 30 seconds at a sample flow rate of 250 cc/min. *Sample flow rate:* nominally 50 to 350 cc/min (3 to 21 in^3/min). *Reference gas flow rate:* 5 to 10 cc/min; at these flow rates a cylinder containing 200 cubic feet of gas will last over a year. Sample pressure is 0 to 50 psig (69 to 345 kPa). An indicating meter is available for most ranges. Meter has four-inch scale with accuracy to 2%. *Ambient temperature limits:* 40° to 100°F (4.4° to 38°C). *Output:* voltage selectable 0–5V, 0–1V, 0–100mV,or 0–10mV DC; also current at 4–20 mA or 10–50 mA.

Physical description

Corrosion resistant cells constructed of 316 stainless steel with Teflon coated filaments for use with corrosive samples are available. Stainless steel cells are standard. Explosion proofing is available in an enclosure for use in Class 1, Group D, Division 1 hazardous locations. *Power requirements:* 115 V, 60 Hz (cps), 150 watts; 220 V available on request. It measures 18⅜" × 15⅜" × 11 1/16".

Analograph & Servocorder

Deutsch Engineering & Testing Services
P.O. Box 389
Monsey, NY 10952

The Analograph uses an air carrier for determinations of hydrogen, helium, oxygen-nitrogen, carbon monoxide, carbon dioxide, methane, ethane, and C_1 to C_{10} hydrocarbons. Helium carrier gas may be used for determinations of chlorinated hydrocarbons, alcohols, aromatics, and C_1 to C_{20}hydrocarbons. The instrument has applications in air pollution analysis, flue gas analysis, utility gas identification, toxic gases, and breath gas analysis.

Operating principle

The Analograph is an improved chromatograph offering sensitivity and accuracy together with ease of operation and minimum maintenance. The Analograph provides regulation for the carrier air, or other carrier gas, to the unique variable sample size gas injection system and liquid injection system. A rapid changeover Dual-Column valving system makes it convenient to change from fixed gas component analysis to vapor analysis. Catalytic combustion and thermal conductivity detection provide sharp peaks via a linear motor drive all-transistor Servocorder made specifically for the Analograph. The top opening all metal case permits access to the columns and all functioning components. The all-transistor feedback power supply provides the required DC power for maximum stability from any 110 VAC supply.

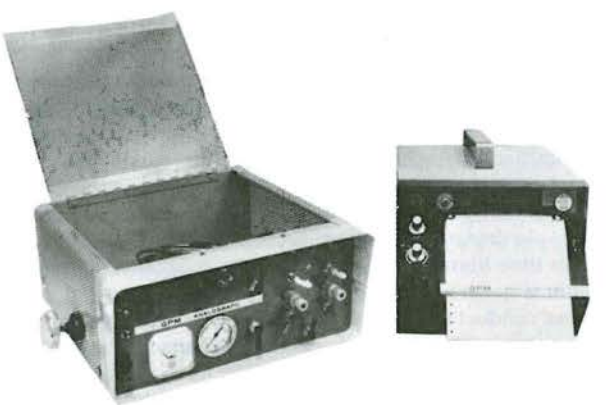


Figure V-76 — Deutsch Analograph and Servocorder.

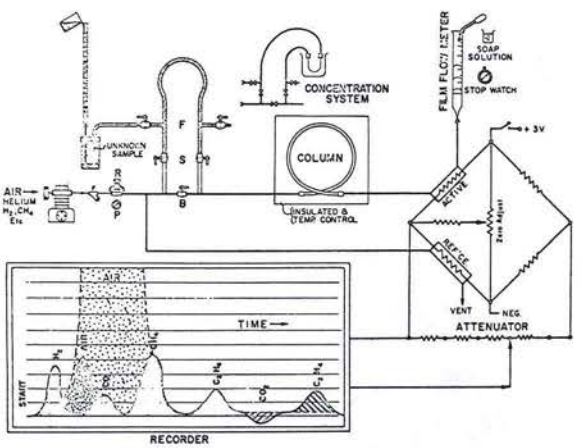


Figure V-77 — Schematic of Chromatograph.

Features of the analograph are improved liquid-gas sample injection, improved catalytic combustion-thermal conductivity detector, improved circuit design with the newest in cordless servorecorders to create a new order-of-magnitude in simplified parts per million gas and vapor analysis.

The fully transistorized Servocorder has full scale response of one-eighth second, zener reference voltage, multi-range switch with an octave span from one millivolt to 1024 millivolt full scale response.

Very low noise-to-signal ratio. Optional dual-column-hot-cold detector in a top opening metal case permits sharp peaks for fixed gases to C_{15} components. Maximum stability from all-transistor feedback power supply.

Analograph description

The standard model measures 7" × 13½" × 14½" and weighs 25 lbs; the oven model is 7" × 13½" × 29", weighing 40 lbs. The

built-in power supply is fully transistorized. The instrument has recorder outlet terminals, fine and coarse zero adjust, bridge voltmeter, and supplied with partition column, carrier gas regulator, flow meter, operating manual, and technical papers complete with built-in thermal conductivity and catalytic combustion detector, 3 sample tubes, zener diode power supply, and silica gel columns. Optional accessories include AC or DC sampling pumps, plastic sampling jars, special columns, and liquid injection syringes.

Servocorder description

A heavy duty continuous writing instrument, the Servocorder is portable in a two-tone black and gray case with carrying handle, weighing 42 lbs. *Range:* 0–1, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024 mV DC special multi-range selector switch (Alternator). *Scale:* 0–100. *Chart:* 26059-x with 0–100 range and 10/50 chart ruling, with a #206 synchronous motor rated for 110 V, 60 cycle providing a speed of ¾ of an inch per minute (chart speed selector optional). *Accuracy:* 0.5% of full scale. *Max. source impedance:* 100,000 ohms. *Zero adjust:* full scale. *Power requirements:* 120 volts plus 10%, 60 cycles less than 60 volt ampere loading. Accessories include one chart, ink cartridges and instruction book.

UNICO Portable Gas Chromatograph

The Bendix Corp.
Environmental & Process Instruments
12345 Starkey Road
Largo, FL 33543

The UNICO PGC, Series 10, is a complete portable gas chromatograph developed for on-the-spot field analysis of trace gases in the parts per million range.

Operating principle

The PGC-10 is a highly sensitive, dual column, thermal conductivity gas chromatograph. Gas and vapor samples are introduced to the instrument by means of a gas-tight syringe or optional micro-volume gas sampling valve. Samples are carried through the columns by the helium carrier gas. The column serves to separate the sample mixture into individual component chemical species. Since components in the sample travel through the column at a rate dependent upon the individual characteristics of the components, each emergent from the end of the column at a different time. As the components emerge, the difference in thermal conductivity between the carrier gas and the carrier/component mixture is detected by a thermistor detector. The difference in elution time from the columns provides qualitative information. Helium is generally used as the carrier gas because of its high thermal conductivity compared to other gases. Changes in carrier gas/component compositions result in a change in the thermistor detector temperature and subsequently, its electrical resistance. The thermistors are connected in a Wheatstone bridge circuit and the degree of bridge unbalance is a measure of the change of sample composition.

TABLE V-9
Gases and Vapor for Which PGC-10 Columns are Available

Gas or Vapor	Lower Detection Limit* per 1.0 ml of Air
Acetone	122 ppm
Ammonia	170 ppm
Argon	36 ppm
Benzene	89 ppm
Butane	44 ppm
Butyl mercaptan	96 pm
Carbon dioxide	40 ppm
Carbon monoxide	22 ppm
Chlorine	20 ppm
Ethane	38 ppm
Ethanol	159 ppm
Ethyl mercaptan	25 ppm
Ethylene	43 ppm
Hydrogen sulfide	20 ppm
Isopropyl alcohol	122 ppm
Methane	13 ppm
Methyl mercaptan	61 ppm
Methyl ethyl ketone	81 ppm
Nitrogen	23 ppm
Nitrogen dioxide	76 ppm
Nitrous oxide	118 ppm
Oxygen	36 ppm
Propane	25 ppm
Propylene	35 ppm
Sulfur dioxide	117 ppm
1,1,1-Trichloroethane, Perchloroethane	25 ppm

*Lower detection limit sensitivity based on 10 to 1 response ratio.

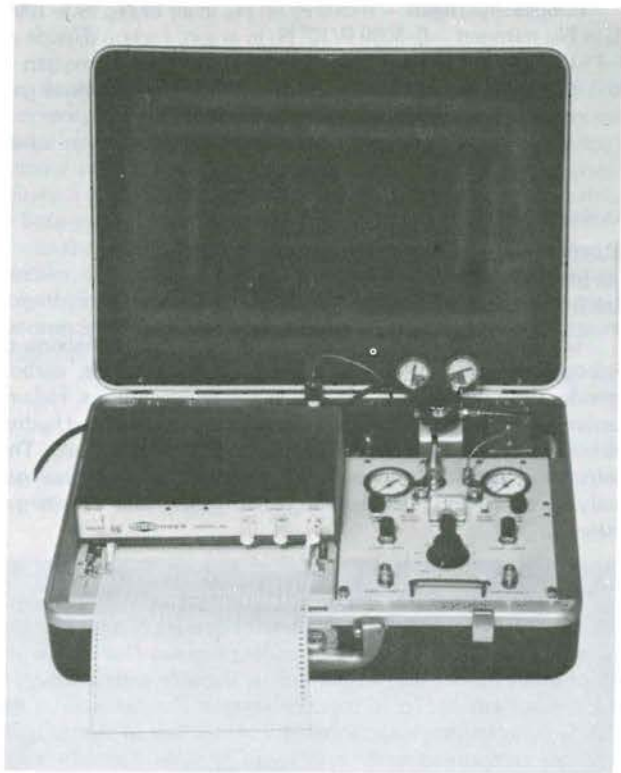


Figure V-78 — UNICO PGC-10 Portable Gas Chromtograph.

Physical description

This instrument is housed in a molded fiberglass case which is 16" × 22" × 7" and weighs 49 lbs. The unit contains its own carrier gas supply, heated columns and detectors, and recorder. The unit operates on a 115 VAC, 60 Hz power source.

The PGC-10 is provided with mounting provisions for a micro-volume sampling valve. The valve is available as an accessary complete with mounting connectors (Cat. No. 3700-20). The unique design of the sampling valves provides the smallest internal volume available and features a kinematic loading principle to achieve leak-tight operation, even at continous elevated temperatures. The small bore, zero dead volume valve produces the sharp peaks required for the analysis of complex samples.

The sampling valve is a two-position valve with two stops at 90°. Two interchangeable loops are connected with Swagelok unions.

The PGC-10 is provided with a recorder, the Unicorder 20. The unit has both left and right hand zero. Response time is less than 0.5 seconds full scale. A range selector switch provides ready selection of any one of the following ranges: 0-1, 0-10, 0-100, and 0-1000 mV. The capillary feed pen has a manual lift and a travelling ink reservoir. The chart width is 7⅞" (200 mm) which provides greater resolution than narrower width charts. The Unicorder has two built-in chart speeds, 1" per minute, and 2" per minute. Other chart speeds are optional.

Performance data

The PGC-10 is capable of qualitative and quantitative determinations of materials that are gases or vapors at 135°C. The ability of gas chromatography to separate mixtures of gases makes the method applicable for the simultaneous determination of several components. A typical chromatogram is shown in Figure V-78. Table V-9 lists the gases and vapors for which column are available. The lower detection limit is also given.

The low volume (58 μL) rapid response, dual micro thermistor detector, standard in the PGC-10, insures the high sensitivity and resolution necessary to provide sharp peaks and separations. Utilizing matched 8-10 K ohm glass-coated thermistors, the detector is free from oxygen burnout associated with filament type thermal conductivity detectors. At temperatures below 100°C, the thermistors are more sensitive than filament type elements.

The detector flow assembly is constructed of 316 stainless steel, has no dead volume, and is virtually free of thermal gradients, providing superior baseline stability. The time constant of the detector head is extremely low — 40 milliseconds at 25 ml/min. The extreme sensitivity of 15×10^3 mv-ml mg^{-1} allows detection of gases and vapors in the ppm range.

A thermostatically controlled heater is available which will maintain the temperature of the columns and detector at approximately 50°C. This eliminates baseline drift arising from column and detector temperature gradients.

An instruction manual is supplied with each instrument, and should be consulted for detailed operating instructions.

Super Sensitive Indicator

Bacharach Instrument Company
625 Alpha Drive
Pittsburgh, PA 15238

Operating principle

Catalytic combustion. Two electrically identical pure platinum elements are incorporated as opposite arms of a precision Wheatstone bridge circuit. One element serves as a reference, the other element exposed to the sample, reacts catalytically in the presence of low concentrations of combustible gas. Oxidation on the surface of the catalyst results in a resistance change. This electrical change in read as a change in combustible condition.

Physical description

Size: 3" × 6" × 7½". *Weight:* 6.75 lbs. *Power requirement:* Ni-Cad rechargeable batteries providing up to 8 hours of continuous operation. *Sampling rate:* approximately 1.0 lpm. Readout mode: meter.

Performance data

Material detected: combustible gases and vapors in air, but is designed for methane detection. *Detection ranges:* 0-1000 ppm, 0-100% LEL. *Specificity:* generally specific to combustible gases and vapors in air. *Response time:* initial response within 1 to 2 seconds of exposure. Its stability is in keeping with battery operated instruments of this general design. *Repeatability:* short term, ± 5% (under similar conditions).

Figure V-79 — Super Sensitive Indicator.

TLV Sniffer

Bacharach Instrument Co.
(address above)

Operating principle

This instrument operates on the principle of catalytic combustion (a process of oxidizing a combustible gas/air mixture on the surface of a heated catlaytic bead element). As oxidation takes place on the surface of the element, the heat of that element increases and thus its electrical resistance changes. This change in electrical characteristic is interpreted by the electronics as a change in the sampled condition. Through refinements in operation, this instrument is capable of detection changes as small as two or three parts per million.

Physical description

Size: 228 mm × 95 mm × 168 mm. *Weight:* 5 lbs with Ni-Cad batteries. *Power requirements:* battery or line powered (eight hours continuous operation with six, size D, Ni-Cad batteries or approximately three hours with six, size D, carbon-zinc batteries. *Sampling rate:* 1.65 lpm, nominal. *Readout mode:* meter, audible alarm, earphone output, recorder output.

Applications and performance

Materials sampled: combustible vapors in air with detection ranges of 0–100 ppm, 0–1000 ppm, 0–10000 ppm. *Specificity:* generally specific to combustible gases and vapors in air. *Response time:* initial response within one to two seconds of exposure. Its stability is in keeping with instruments of similar sensitivity and construction. *Repeatability:* short term, ± 5% (under similar conditions).

Figure V-80 — J-W TLV Sniffer.

Gastron Combustible Gas Detectors

Bacharach Instrument Company
(address above)

The Gastron is a portable instrument used to detect and locate combustible gas leaks. This device will detect hydrocarbon concentrations from 50 ppm to 20% gas/air mixtures. The Model 310 is identical to the Model 282 except that it provides an additional feature, i.e., hydrogen detection. The 310 will detect hydrogen concentrations from 50 ppm to 5% gas/air mixtures.

A multi-position selector switch provides operational mode selection. The Model 282 provides an ON position, a battery check position, and a system OFF position. The Model 310 provides, in addition to the above an H_2 position. In the ON mode, both the 282 and the 310 detect combined hydrocarbons and hydrogen. The Model 310, when used in the H_2 mode, detects only hydrogen.

Operating principle

A continuous sample of air is drawn through a sensing element where controlled catalytic combustion occurs, causing a signal to be generated which feeds both a visual and an audio indicating circuit. When gas is detected, an audio signal is momentarily interrupted and a visual indication is presented on a visual readout meter.

Physical description

The Gastron contains a pump, detector element, filters, control circuit, audio circuit, indicator, switch and zero-adjust. A quick-disconnect cable leads to a battery pack. A carrying strap for the Gastron is provided to allow the operator to free both hands.

The lightweight battery pack is designed to conveniently slip on the operator's belt. It contains a Ni-Cad rechargeable battery with integral charger and cable. The battery cable can be connected to any 115 VAC source for overnight charging.

The probe consists of several sections of tubing tightly connected and sealed against leakage. The end of the probe is closed

Figure V-81 — Bacharach Model 282 Gastron Combustible Gas Detector.

Figure V-82 — Carrying Case for Model 282.

and the lower section contains numerous small holes to minimize pickup of dust and moisture. The probe contains a humidity controlling filter. *Operating ranges:* combustible gases —Search mode, 0 to 500 ppm; Midrange mode, 0 to 2.5%; Coarse mode, 0 to 25%; hydrogen only — search, 0 to 250 ppm, midrange 0 to 0.5%, coarse, 0 to 5%. *Battery type:* rechargeable 5 V (nominal) Ni-Cad, 4 ampere hours capacity, providing 10 hrs continuous operation. *Recharge time:* 14 hrs. *Charger input voltage:* 115 V, 60 Hz. *Filters:* humidifier — commercial fiber; dust — fiberglass. Detector weight is 2 lbs, battery in case is 2.25 lbs.

Performance data

Sensitivity: better than 50 ppm for combustible gases; better than 10 ppm for hydrogen. *Response time:* < 2 seconds. *Warm-up time:* 2 minutes. *Water vapor discrimination:* dry filter, 100 to 1; west filter, 1000 to 1. *Dust discrimination:* filters down to 1.0 μm. *Temperature:* operating -30° to +130°F; storage -60°to +150°F. *Drift rate:* 100% of scale/hr in "Search" range (approx.). *Detector cell life:* 40 hours (normal operation) average.

Ultra I and Ultra II

Bacharach Instrument Company
(address above)

The Ultra I measures the degree of flammability of any combustible gas or vapor mixture in air. The Ultra II is a dual-scale instrument which indicates both percent LEL and the actual quantity of combustible gas in the sample.

Operating principle

Ultra I and Ultra II measure the flammability of gas in the LEL range using the catalytic combustion principle. Each instrument has two scales: 0 to 20% LEL and 0 to 100% LEL. When concentration exceeds 20% LEL, the indicator switches automatically from the lower to the upper scale. The Ultra II also can switch to a thermal conductivity circuit to indicate the actual quantity of combustible gas in the sample.

Phyical description

Ultra I an Ultra II measure 8½" × 2¾" × 5¾" and are housed in ABS plastic cases. Both use methane as its calibration gas, have span and zero adjustments through holes in lower housing, are powered by 4 "D" size batteries and have temperature ranges from -10°C to +50°C (limited by battery specifications). Without batteries, the Ultra I weighs 3 lbs, while the Ultra II weighs 3.5 lbs.

Performance data

Scale range: 0 to 20, 0 to 100 LEL for the Ultra I; 0 to 20, 0 to 100 LEL and in percent 0 to 20, 0 to 100 gas for the Ultra II. The Ultra I has one catalytic and one reference sensor. The Ultra II has one catalytic, one thermal, and two reference sensors.

Carbon Monoxide Detection System

Devco Engineering, Inc.
Control Systems Division
36 Pier Lane West
Fairfield, NJ 07006

The Devco Engineering Carbon Monoxide Detection System is used to detect the presence of CO in parking garages, vehicle tunnels, steel mills, industrial plants and warehouses, and in air pollution monitoring.

Operating principle

Devco Series 1000 Carbon Monoxide Detection Systems utilize the "Heat of Reaction" method for the measurement of carbon monoxide in air. A schematic of the flow system is shown in Figure V-83.

The sample is drawn by a suction pump through a series of filters and scrubbers ahead of the analysis cell. The filters remove airborne solid particles and a chemical scrubber removes hydrocarbons and deleterious gases and vapors.

Control of the sample flow rate is by means of a dial type flow meter calibrated directly in liters per minute. The temperature of the sample is stabilized as it enters the analysis cell. The sample then passes through a heated chamber containing a catalyst bed which promotes the oxidation of carbon monoxide. Heat generated by this reaction is proportional to the concentration of carbon monoxide in the air sample. The heat of reaction is measured by means of thermocouples, and the output is amplified to provide a control signal for the measurement and alarm circuits. A solid state time proportioning temperature controller maintains the constant temperature within the analysis cell and cell chamber.

Designed for "Fail Safe" operation, all Series 1000 instruments also include a "Trouble Alarm" relay circuit. This relay, controlled by instrument failure alarm circuits, illuminates a blue "Trouble" light and provides for external or remote alarm actuation on sample flow failure or low analysis cell temeperature.

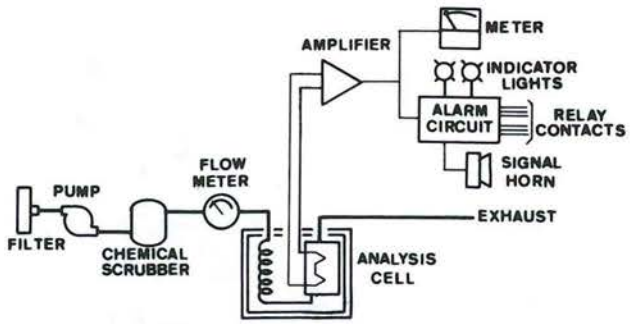


Figure V-83 — Schematic of the Devco Series 1000 Carbon Monoxide Detection System.

Physical description

Operating voltage: 115 VAC, 60 Hz or 220 VAC, 60 Hz as specified.

Performance data

Zero drift: $< \pm 2\%$ with voltage fluctuations of $\pm 15\%$. *Range:* 0 to 500 ppm CO in air typical. *Repeatability:* error $< \pm 2\%$ of full scale reading. *Response to reading:* thirty seconds. *Error:* none due to hydrogen or hydrocarbon gases. *Catalyst life:* one to two years average. *Calibration drift:* due to relative humidity, error $<$ 2% of full scale reading for relative humidity 50% $\pm$ 20%.

Combustible Gas/Vapor Detection System

Devco Engineering, Inc.
(address above)

Devco Engineering Series 5000 Combustible Gas and Vapor Detection Systems are designed to continuously monitor any sample area, and to signal the presence of combustible gas or vapor in concentrations below the lower explosive limit (LEL).

Operating principle

A component schematic for the Series 5000 Combustible Gas/Vapor Detection System is shown in Figure V-84. This system employs a pair of catalytic hot wire elements forming two legs of a balanced Wheatstone bridge. When the active element is exposed to a combustible gas-air mixture, catalytic combustion occurs on the surface of the active element. The increase in temperature of the active element, due to the combustion on its surface, causes an increase in the resistance of the element which results in unbalance of the Wheatstone bridge. This unbalance results in an electrical signal from the bridge proportional to the amount of combustible gas or vapor present in the air sample.

As the combustion on the surface of the active element is aided by catalytic action, combustion occurs with a mixture which is below the LEL. Therefore, a meter or millivolt recorder connected to the output of the Wheatstone bridge may be calibrated to read in terms of 0 to 100% of the LEL of the gas or vapor to be detected. In the case of hydrogen, for example, this means that the meter full-scale reading would be equivalent to 4.1% of hydrogen in air.

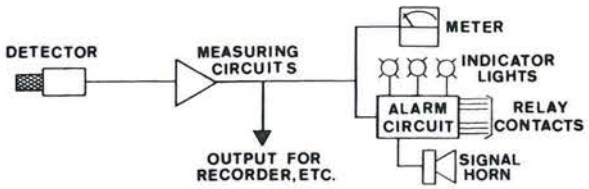


Figure V-84 — Schematic of components in the Series 5000 Combustible Gas/Vapor Detector System.

Physical description

Packaging of the system is based on the modular construction method which permits any combination of standard basic module sections to form a fully engineered system tailored to the requirements of a given application.

Single point or multiple point units are available, for either continuous monitoring of each sample area or for sequential sampling via a single detection system.

The measuring cell may be located within the control unit, requiring only a ¼" o.d. tube connection into the sample area, or may be located directly in the sample area for maximum speed of response. Two types of remote detector heads are available. The "Diffusion Detector Head" samples by means of diffusion and convection of the combustion gas in air. The "Continuous Flow Detector Head" makes use of a highly reliable suction pump to maintain a continuous flow of the sample through the analysis cell.

Performance data

Range: 0–100% LEL standard; other ranges available. *Accuracy:* better than 3% of full scale reading. *Speed of response:* < 1.0 second. *Sensitivity:* hydrogen or any combustible gas in air mixture including methane. Excellent zero stability over 30-day period. Analog signal output for recorders, controllers or digital display. Solid-state single and dual alarm circuits available with S.P.D.T. relay contact output. *Ambient temperature limits:* instrument, 35° to 135°F; detector head, to 200°F standard; to 250°F for high temp. head.

Dynamation LCD Combo

Dynamation, Incorporated
168 Enterprise
Ann Arbor, MI 48103

The LCD Combo may be used to measure the level of combustible gas and oxygen deficiency on its digital meter and it may be used continuously to monitor an area for worker protection. Small, compact, and belt worn, the LCD Combo can travel with the worker and warn of pockets of gas that might be missed by aspiration at the entrance of a confined space.

Operating principle

The unit utilizes catalytic hot wire sensors for detection of combustible gas and a chemical cell for oxygen detection. The twin combustible sensors are electrically connected in a bridge configuration to compensate for temperature, humidity and electronic changes. The sensors output is linear from 0 to 100% LEL.

The chemical electrolytic cell measures the oxygen level and has up to 18 months of life before replacement. The oxygen cell is temperature compensated with a thermistor that is imbedded inside the sensor. The cell can be easily changed and operated from 15° to 120°F.

Physical description

Enclosure is constructed of anodized aluminum with leatherette carrying case. The instrument is powered by 5 self contained rechargeable C size batteries which provide a continuous operation cycle up to 9 hours. Battery recharge time is 14 to 16 hours for full charge (2 hours charge for 1 hour of operation). Battery charger requirements are 110 volts, 0.5 amp. *Dimensions:* 7" × 4" × 3". *Weight:* 3 lbs.

Performance data

Sensors: combustible — matched pair platium oxidation catalytic; oxygen — chemical cell. *Response time:* combustible gas — 90% of max reading within 5 sec. with 20% LEL methane; oxygen — 90% of max reading within 30 sec. *Typical gases detected:* combustible gas (natural gas, methane, butane, propane and other types of combustible hydrocarbons) and oxygen (oxygen level). *Warm up time:* 3 sec for combustible gas; 10 sec for oxygen.

Figure V-85 — Dynamation LCD Combo

Respiratory Air Line CO Monitor/Alarm

Dynamation, Incorporated,
(address above)

The Model ABL-50 is a low cost carbon monoxide monitor/alarm specifically designed for respiratory air line breathing applications. It will continuously indicate the level of CO in ppm on its built-in meter, and activate external alarms if the concentration exceeds the preset alarm threshold.

Operating principle

The Model ABL-50 is connected to a tee fitting in the air line which bleeds off a small, continuous sample of air flowing between the compressor and the user. This sample is filtered for particulate matter and then passes through an oil coalescer which removes any oil mist present. It then passes through the pressure regulator where its output pressure is adjusted to about 10 psig. Next the sample passes through ⅛" o.d. capillary tube into the flowmeter where the flow rate is set to about 0.5 ft^3/hr. The flowmeter also indicates that air is actually passing over the sensor. When the air supply has less than 50% relative humidity, an optional Humidifier No. 2610-001 should be used at the inlet side to insure accurate reading.

No ON/OFF switch is provided to prevent accidental shutdown. Instead, the Model ABL-50 is activated immediately and operates continuously when connected to a 110 VAC or 12 VDC power source. Only a 10 minute automatic purge cycle occurs before actual operation, to clean and stablize the sensor. At the end of this cycle the Model ABL-50 is completely operational. The automatic purge cycle repeats if power is lost and re-applied; or may also be activated by an internal purge button. When in the purge mode, the external alarm circuit is disabled eliminating annoyance from the horn during the unit's warm-up.

Physical description

Enclosure: polyester fiberglass NEMA 4 with cover latch. *Air connection:* ⅛" NPT inlet. *Power requirements:* 110 VAC, 1 amp, or 12 VDC. *Power connection:* line cord provided; may be conduit wired. *Dimensions:* 13" × 14" × 5½". *Weight:* 16 lbs.

Performance data

Sensor: replaceable solid-state catalytic semi-conductor. *Controls:* calibration and alarm threshold internal. *Meter size:* 2½". *Meter scale:* 2 to 50 ppm range standard. *Response:* 90% of maximum reading within 2 minutes with 20 ppm CO concentration; faster at higher concentrations. *Accuracy:* better than ± 10% of full scale after 24 hour operation. *Alarm adjustment range:* 2 ppm to 50 ppm CO. *Recorder output:* available on terminal strip inside for 0–1 mA current recorder. *Relay outputs:* 2 amp rated normally-open and normally-closed contacts available. *Interferences:* other types of organic vapors will be detected if present in high concentrations or at their TLV. *Sensor purge period:* 1 minute nominal. *Sensor stabilization period:* 10 minutes nominal.

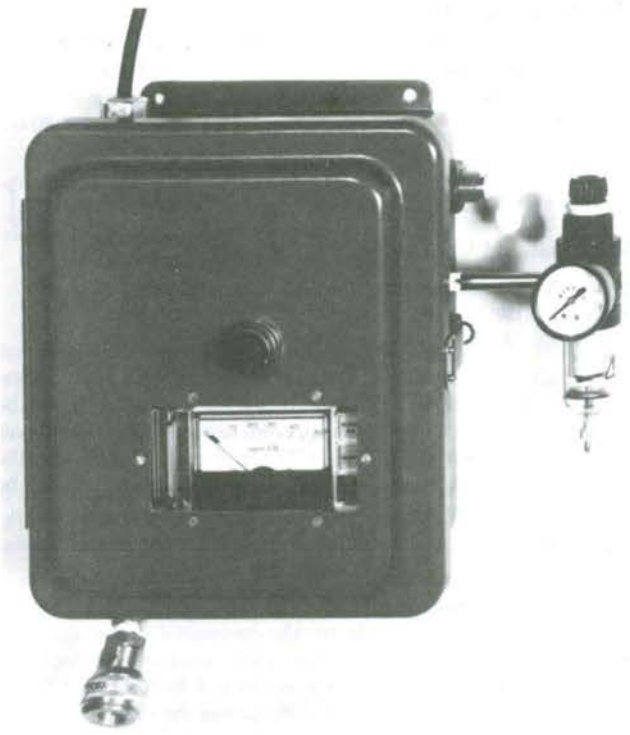


Figure V-86 — Dynamation Respiratory Air Line CO Monitor/Alarm, Model ABL-50.

Combustible Gas/Vapor Detectors

ERDCO Engineering Corporation
P.O. Box 1310
Evanston, IL 60204

The ERDCO Engineering Corporation line of TOX-EX portable combustion gas/vapor indicators are used as safety checks for the presence of combustible gases or vapors. They are used for plant and personnel safety when inspecting, cleaning or repairing tanks, manholes, ships' holds, and for sewage treatment plants. They are widely used in utilities, refinery, laboratories, and combustible storage areas. The respective models available consist of Model 03HCS, 05HCS, 06HCS, and 07HCS.

Operating principle

TOX-EX gas/vapor indicators operate on the basic principle of the catalytic reaction of flammable gases and vapors on an electrically heated platinum filament. When a flammable gas or vapor comes in contact with the platinum filament, it is oxidized, releasing heat and thereby increasing the temperature of the filament. The filament is one leg of a Wheatstone bridge circuit. As it is heated its resistance increases, thereby unbalancing the bridge. Since the amount of unbalance is in direct proportion to the volume percent of gas in the air sample, the meter indicates directly the percent of combustibles preset.

Operating procedures in all portable models are similar. The sample is diffused directly into the sensing head or infused by means of a non-restricting orifice-free, sampling hose. Operating voltages are set to "V" on the scale for general use and to "M" for methane. This automatically checks battery voltage.

Physical description

Model 03HCS: Overall size is 8" × 1¾" × 3", weighing 1.75 lbs. It is powered by two "D", carbon-zinc, alkaline or Ni-Cad rechargeable batteries. *Model 05HCS:* Overall size is 9" × 2¾" × 3½, weighing 2.5 lbs. It has an audible alarm with a fully adjustable set point in addition to the meter indicator supplied as standard on all models. This instrument is powered by 2 "D" size alkaline batteries; 2 Ever Ready #228 for alarm. *Model 06HCS:* Overall size is 5⅞" × 6¼" × 3½" and weighs 4 lbs. It is powered by 8 "D" size carbon zinc batteries. The meter is illuminated and recessed with additional shatter-resistant protective meter window. Standardly supplied with 5-ft sampling hose. *Model 07HCS:* Overall size is 9" × 2¾" × 3". Separate batteries power the audible alarm and instrument to lengthen operational life. It is also available with a power line cord for 110 VAC, 60 Hz operation.

Accessories available for most models include hose sampling attachment with 5-ft hose or additional lengths optional; 30-inch semi-rigid nylon tubing probe; rechargeable Ni-Cad batteries; 110 V, 60 Hz, or 220 V, 50 Hz battery charger; calibrator; adapter and tank with 25% lower explosive limit (LEL) methane.

Performance data

All models have a response time of less than 3 seconds using 25 feet of sample hose; approximately 5 seconds with 50 feet of hose. All models differentiate methane from petroleum vapor electrically, without adding an absorption filter. In addition, the filament in each model is designed to prevent burnout even when repeatedly exposed to high gas. It is also highly resistant to mechanical shock.

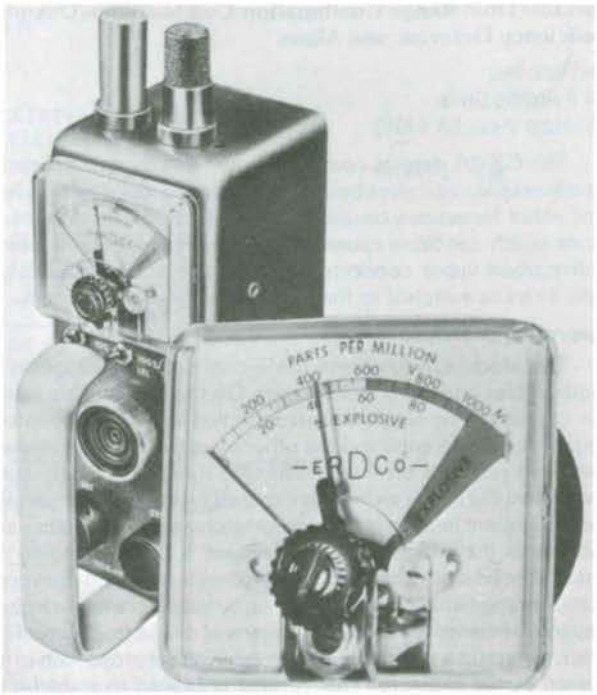


Figure V-87 — ERDCO Portable Gas/Vapor Detector, Model 07HCS.

Model O3HCS: Designed for continuous monitoring or hose sampling. Meter scale calibration is 0–100% of the lower explosive limit and is intrinsically safe for Class I, Groups B, C and D.

Model 05HCS: Capable of continous diffusion monitoring and hose sampling. As sensitive scale from 0–10% of LEL, explosive scale for 0–100% of the LEL. In addition to the visual meter, there is an audible alarm contained within the unit. This model is intrinsically safe for Class I, Groups B, C and D.

Model 06HCS: This model is designed for hose sampling and has an explosive scale reading of 0–100% of the LEL.

Model 07HCS: This model may be used for continuous monitoring or hose sampling. It has a dual meter reading of 0–1000 ppm or 0–100% of LEL. designed into the model is an auto-alarm.

Portable Dual Range Combination Combustibles/Oxygen Deficiency Detector and Alarm

GasTech, Inc.
331 Fairchild Drive
Mountain View, CA 94043

The GX-3A detects combustible gas and oxygen deficiency simultaneously, and gives both an audible and a visual alarm whenever either hazardous condition is encountered. Alarm lights indicate which condition caused the alarm. For indication of toxic hydrocarbon vapor concentrations, or detection of a small gas leak, it can be switched to the sensitive range of 0–1000 ppm.

Operating principle

The Model GX-3A alarm has a dual detection capability in combustibles and oxygen deficiency. On the combustible side, a pair of resistive sensing elements form two legs of a Wheatstone bridge, one a reference and the other an active catalytic element with fixed resistors on the remaining two legs. Oxidation takes place when the active element is exposed to combustible gas, and the consequent heating of the element increases its resistance and unbalances the bridge with a subsequent % LEL reading on the meter. A solid-state amplified circuit permits a second ppm combustibles range which can be turned on by means of a toggle switch. Oxygen deficiency is detected by means of an electrochemical cell which generates a positive ionic current in direct proportion to the oxygen partial pressure. This current is applied to a solid-state amplifier which transmits the signal to the meter to give a readout. The sample is drawn into the instrument by means of an integral pump and continuous operation of up to 6 hours is assured by the use of Ni-Cad rechargeable batteries. Solid-state alarm circuits for oxygen and for combustibles actuate independent alarm lights and a common audible signal which continues until manually reset.

Physical description

The GX-3A is 11" × 7" × 5½" and weighs 12 lbs. The sampling rate is continuous for up to 6 hours without recharging, or for spot checks as required. The readout is on a panel meter. *Scale:* 0–100% LEL, 0–1000 ppm for combustibles; 0–25% for oxygen. The instrument is powered by 6 "D" size Ni-Cad rechargeable batteries, 4.09 AH.

Performance data

Combustible detection limits in the LEL range, read up to the lower flammable limit of most combustible gases. Standard calibration based on methane. In the ppm range, calibrated to read directly in ppm of a specific hydrocarbon vapor, normally calibrated on toluene. Calibration curves can be supplied for interpreting readings of other vapors of interest. Detection limits for oxygen are direct readings from 0 to 25% oxygen. Alarm can be set at OSHA limit of 19.5%. The response time is within 3 seconds when using standard sampling hose. Its stability is ± 2% full scale per 4-hr period; precison is ± % full scale; and accuracy is ± 5% full scale, combustibles, for gas on which concentration is based and ± 0.25 oxygen.

Figure V-88 — GasTech Gas Detector/Alarm, Model GX-3A.

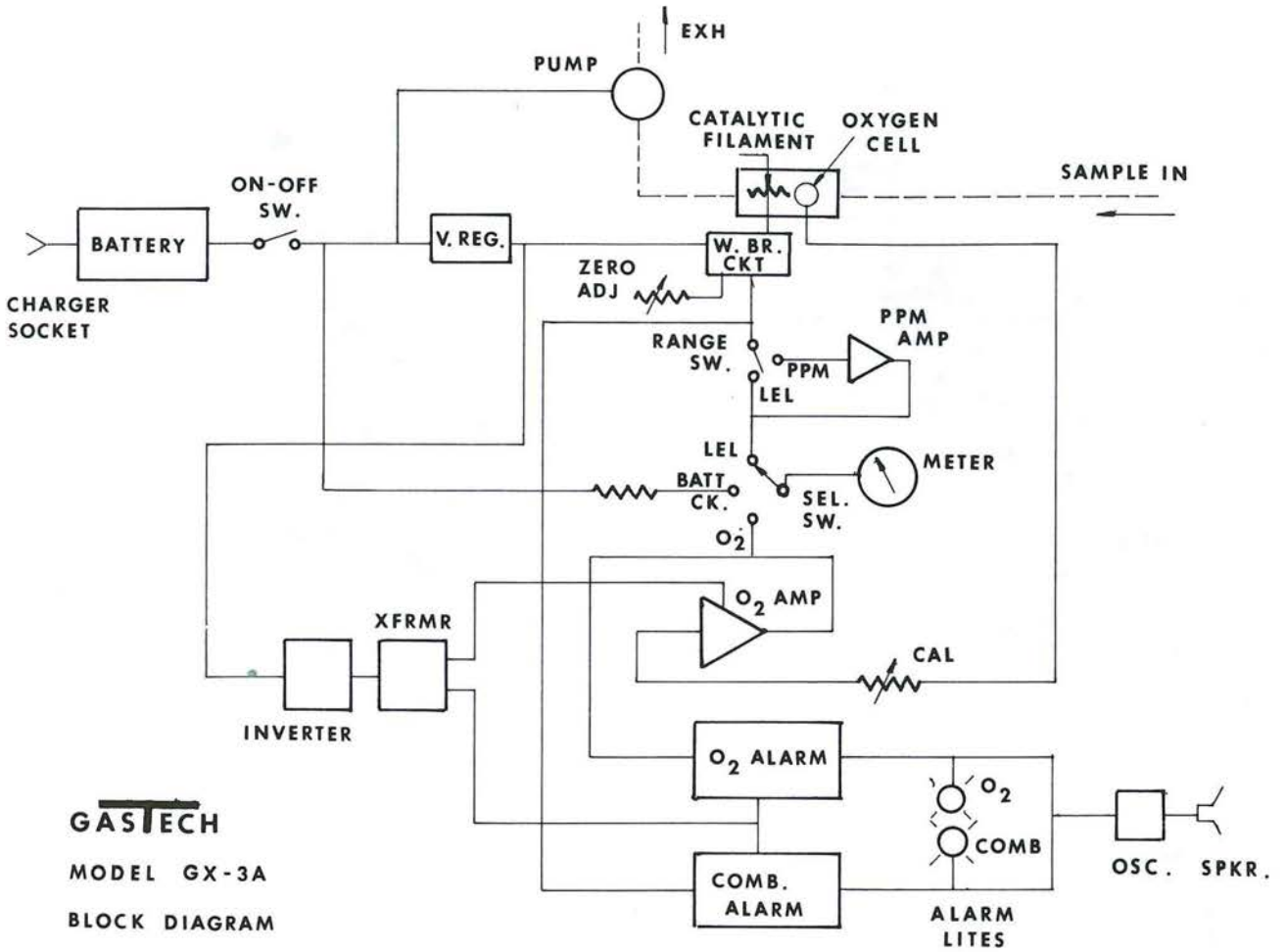


Figure V-89 — Block diagram for Model GX-3A.

Combustible Gas Monitor and Detector

General Monitors, Inc.
3019 Enterprise Street
Costa Mesa, CA 92626

The General Monitors, Inc. Model 170 Combustible Gas Detector is a small, lightweight instrument that detects all hydrocarbon gases, including methane, in addition to alcohols, ketones, ethers, etc. It can be used individually or as a multi-channel system.

Discrete channels are provided for each detection point, providing maximum safety protection. Each channel includes a control unit with individual controls, indicators, power supply, and alarm circuitry, and is supplied with a detector probe with appropriate sensing.

The Model 1100E combustible gas moitor serves as a personal gas alarm system for anyone who must work underground or in potentially explosive atmospheres. It can be employed as a temporary fixed system or for gas leak searching. Extension probes for inserting the diffusion sensor into tanks or through manhole covers are provided.

Operating principle

The operation is based upon a proprietary version of the diffusion catalytic principle. The sensing element consists of two platinum wires connected as two arms of a Wheatstone bridge. Each of these wires is covered with a ceramic bead impregnated with a special catalytic chemical. One of these beads is made inert and serves as a reference element. The other bead, when exposed to a compustible gas, is heated slightly, increasing the resistance of the platinum wire. An important distinction between the General Monitors sensors and other types of catalytic detectors is that the platinum does not serve as the catalyst, but only as a temperature sensor. This allows low temperature operation of the sensing element so that the platinum is not oxidized, resulting in longer life and stability of the element.

The signal from the sensing element is amplified for display on a meter, recorder output, and alarm relays.

Physical description

Model 170 is 4.12" × 2.12" × 8", weighs 3 lbs, and requires 115 VAC, 60 Hz, 5 watts to operate. Model 110E is 4" × 6" × 1.88" to 2.88" deep, weighs 2.5 lbs, and requires 2.5 VDC from two "D" cell rechargeable batteries. Battery life is 8 hours continuous operation. Recharge time is 12 hours at 117 VAC.

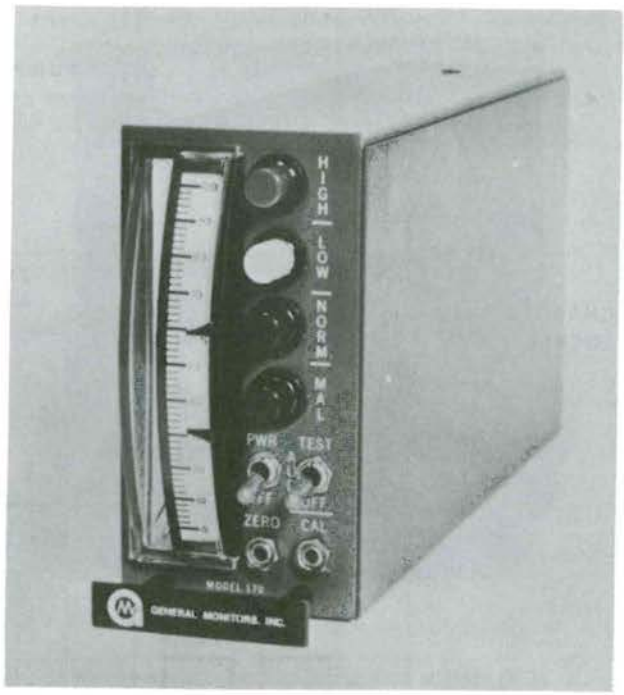


Figure V-90 — General Monitors Combustible Gas Detector, Model 170.

Performance data

Generally, the detection limits are 0 to 100% LEL. Elements are available for specific detection of hydrogen. In general, other elements are not specific, but will have varing responses to different combustible gases. Response time is 1 to 2 seconds. Stability varies with the application, but generally, recalibration should be performed every one or two months. Precision and accuracy is generally within 5%, although in specific applications, higher accuracies can sometimes be attained.

Hydrogen Sulfide Monitor

General Monitors, Inc.
(address above)

This monitor is designed to protect personnel who may be exposed to deadly hydrogen sulfide gas, using a technique which combines electronics and chemistry. The system is simple to use, requiring only periodic checks. The sensor is H_2S specific. Less than 1.0 ppm change in meter reading will result should other gases be combined in the measurement with H_2S. Two alarm levels are provided that can be set and changed easily in the field. No sampling tubes are used. The sensor is a continuous diffusion type.

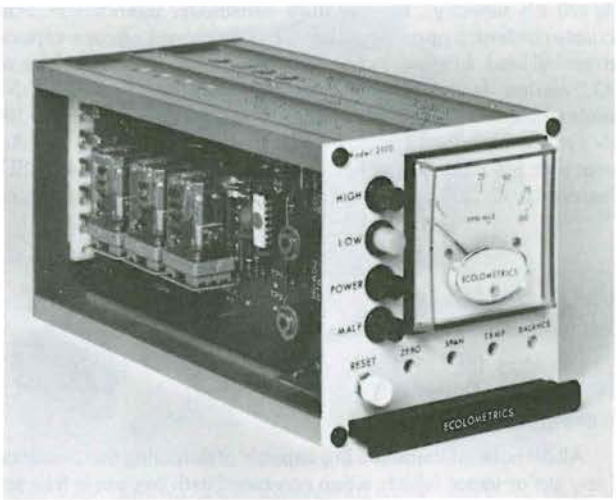


Figure V-91 — General Monitors Hydrogen Sulfide Monitor, Model 2100.

Operating principle

A heater is used to develop the operating temperature of the semiconductor sensing element. When exposed to H_2S, the sensing element electrical resistance characteristics are changed, thus altering the current flowing through it. This change in sensor current produces a signal proportional to the amount of H_2S present. The signal is amplified and displayed on a meter calibrated 10 to 100 ppm.

Description and performance data

The Model 2100 is an all-solid state controller. It is a single-channel device, packaged in a small (4" × 4" × 8") housing and weighing only 4 lbs. Three printed circuit boards contain all the electronics and alarm relays. *Temperature range:* 0° to 150°F. *Power:* 150/130 V or 220/240 V, 50–60 Hz, 10 watts. *Repeatability:* 5% of reading.

Combustibles Analyzer, Model 647

Hays-Republic Divison
Milton Roy Company
4333 S. Ohio Street
Michigan City, IN 46360

The Hays-Republic Model 647 Heavy-duty Industrial Combustibles Analyzer effectively monitors combustibles levels in the flue gases. Combined with accurate oxygen analysis, monitoring of combustibles can provide an extremely high degree of burner efficiency not possible through oxygen analysis alone.

In addition to its broad application potential on all types of industrial and institutional combustion processes, the Hays-Republic Model 647 is equally well suited to 1) coating ovens and dyers; 2) controlled-atmosphere furnaces; 3) crude oil handling facilities; 4) distilling operations; 5) engine test cells; 6) electrolytic generators; 7) explosives and fumigant manufacturing; and 8) sewage treatment plants.

Figure V-92 — Hays-Republic Model 647 Combustibles Analyzer.

Operating principle

The Model 647 Combustibles Analyzer operates on the principle of catalytic combustion, utilizing a balanced Wheatstone bridge circuit. Combustible gases contacting the element increase the element temperature changing its electrical resistance. This resistance change produces an electrical signal proportional to the amount of combustible gases present in the stream. The electrical signal is then amplified to actuate the indicating meter and alarm circuits, and provide 0–100 millivolt analog output.

The gas detector sensor produces a resistance change proportional to the percent of combustibles present. The sensor consists of two flame arrestors, five (5) layers of fine mesh, woven, monel wire and a porous metal cup, for a double margin of ignition safety. The sensor is further protected by a unique, selective, molecular barrier which reduces catalytic poisoning from tetraethyl lead and silicone compounds. The rugged construction and high stability of the sensor minimize sampling system requirements.

Physical description

Dimensions: 9¾" wide × 12 9/16" high × 8⅞" deep.

Performance data

Detector materials: sintered bronze, polypropylene. *Pressure range:* ± 50" H_2O max. *Flow rate:* 0–45 SCFH. *Flow sensitivity:* <

2%/120 FS velocity. *Temperature sensitivity:* 0.007%/1°F. *Particulate content:* 5 ppm maximum. *Contaminants:* silicone vapors, tetraethyl lead. *Integral indications:* meter for % combustibles or LEL; alarms, failure, and pilot lights. *Ranges and scales:* 0–5% combustibles, 0–10% combustibles, 0–100% LEL. Output: 0–100 mV for any standard range. *Load impedence:* minimum 1K. *Accuracy:* ± 5% FSD. *Repeatibility:* 1% FSD. *Linearity:* ± 4% FSD. *Hysteresis:* < 1% FSD. *Zero drift:* 1% FSD/30 days maximum. *Speed of response:* 90% in 10 seconds. *Adjustments:* zero, gain, detector voltage, test range, output tracking, and alarm set points. *Alarm outputs:* isolated NO and NC contacts for warning, alarm, failure. *Alarm reset:* integral or remote. *Fail safe features:* failures alarm indicating open, short, or low voltage at detector, negative zero drift in excess of 10% FSD, loss of power. *Power requirements:* 115/230 VAC, 50/60 HZ or 12 VDC 10 watts. *Temperature range:* minimum 32°F maximum 150°F.

Combustible Gas Detectors

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

All of these instruments are capable of detecting the presence of any gas or vapor which, when combined with oxygen in free air, presents a potential hazard due to explosion. Typical examples of such materials are methane, ethane, propane, and other volatile hydrocarbons; methanol, ethanol, and other volatile alcohols; all volatile aldehydes and ketones, hydrogen; carbon monoxide; etc.

Operating principle

All of these instruments use the hot wire plantinum element for detection. A current is applied to the element for detection. A current is applied to the element which burns the contaminant gas on the wire surface without a flame. The heat generated changes the resistance value of the wire element which is part of a bridge circuit. This resistance produces an accurate meter reading proportional to the quantity of explosive gas present. Indication on all meters is calibrated in percent of the LEL.

All of these instruments are equipped with a buzzer connected to a separate meter with a second set of contacts to operate any alarm system external to the instrument itself. This circuit is adjustable to cover the entire range of the instrument so that the warning will sound at any pre-selected value of the LEL.

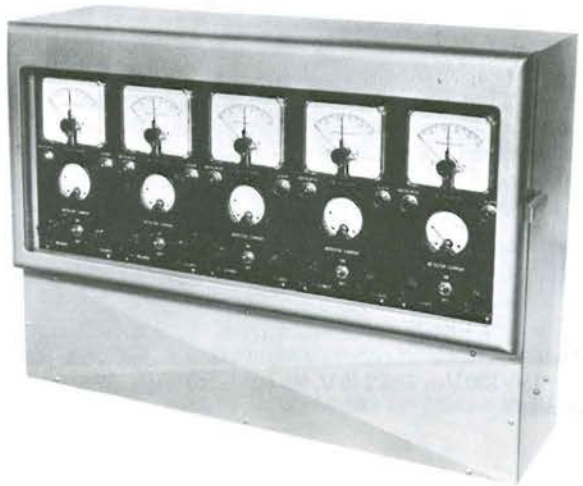


Figure V-94 — Atlas Multitector Model 520.

Figure V-93 — Atlas Duotector Model 510.

Physical description

Model 510: Portable type in aluminum case 5" × 7" × 8" in size, weighing 12 lbs including solid electrolyte Ni-Cad batteries and built-in charger. May also be operated on 110 VAC. Its probe on 6-foot cable. *Model 520:* A multi-unit instrument composed of 2 to 6 channels, each similar in operation to the Model 510 above. Either rack or panel type mountings.

Houston Atlas explosion proof inflammable gas detector head can be installed in plant location requiring Class I Group C and D installations. This detector head measures inflammable gases below the explosive level. It is cable connected to the Houston Atlas Model 510 or Model 520 which may be mounted in a safe area up to 1500 feet from the detector head. Response time is one minute for full scale deflection.

Performance data

Indication on all meters is calibrated in percent of the Lower Explosive Limit. Since each unit can be calibrated for any individual gas or vapor, no concern need be given as to this limit. However, should absolute values be desired, it is a simple matter to refer to the reference chart provided.

The sensing element is housed in a probe and safety shielded by a Monel metal screen. Up to 100 feet of extension cable may be used with this probe. Range: 0 to 100% of LEL of any gas-air mixture. *Response:* full scale in 4 seconds. *Accuracy:* ± 5% of full scale.

Portable Combustible Gas and Oxygen Alarm, Models 260, and 100

Mine Safety Appliances Company
600 Penn Center Boulevard
Pittsburgh, PA 15235

The Portable Combustible Gas and Oxygen Alarm, Model 260, is a dual-purpose instrument designed to monitor areas for combustible gases and/or oxygen deficiency. It measures combustible gases in a range of 0 to 100% LEL; oxygen in the range of 0 to 25% by volume. Although primarily a portable instrument, Model 260 may be used as a semicontinuous monitor in areas where an audible/visual alarm is required. The Model 100 contains the combustible gas monitor only.

Figure V-95 — MSA Portable Combustible Gas and Oxygen Alarm, Model 260.

Operating principle

The combustible gas portion of the instrument operates by the Wheatstone bridge principle. One arm of the bridge is a catalytically activated Pelement™ filament. When the gas sample passes across the filament, combustibles are burned, raising the temperature of the filament, increasing its resistance, and unbalancing the bridge. The imbalance is proportional to the concentration of combustibles and is indicated on the meter in percent of LEL.

The oxygen portion of the instrument operates by means of a galvanic sensor cell. The cell contains two dissimilar electrodes in a basic electrolyte. The cell in encapsulated in inert plastic; the sensor face is a fluorocarbon polymer. In operation, oxygen diffuses through the cell face, initiating redox reactions which, in turn, generate a minute current proportional to the oxygen partial pressure. The signal is amplified through a battery-powered, temperature compensated circuit. The current is converted to a proportional voltage which is displayed on the meter as a percent of oxygen.

Physical description

Its dimensions are 7" × 10" × 3¾", weighs approximately 7 lbs, and samples at a rate of 1.6 lpm. The instrument is equipped with a carrying handle which can be locked in any position through a 260° arc to provide a base when used for semi-continuous monitoring. A shoulder/waist harness is available as an optional accessory. Other accessories include standard MSA probe rods and tubes, and sampling lines, when used for remote sampling. It is powered by an integral, rechargeable 2.4 V battery pack. The combustible gas alarm is factory set to trigger at 50% LEL and the oxygen alarm at 19.5% oxygen. Both alarm points are field adjustable.

Performance data

Silanes, silicones, silicates, other compounds containing silicon, and leaded gasoline vapors may seriously impair instrument response. Consequently, the instrument should be checked frequently when the presence of these compounds is suspected in the atmosphere. An inhibitor filter should be used to nullify the effect of leaded gasoline vapors. *Response:* 90% in < 20 sec. *Accuracy:* ± 5% of full scale for combustible and ± 2% for oxygen. A combustible gas "zero" calibration knob and oxygen calibration knob are mounted on the instrument face. Combustible portion of the instrument may be field-calibrated using 0.6% propane-in-air.

Explosimeter® Combustible Gas Indicator, Model 2A

Mine Safety Appliance Company
(address above)

The MSA Explosimeter®, Model 2A, measures combustible gases and vapors in concentrations up to 100% of LEL.

Figure V-96 — MSA Explosimeter® Combustible Gas Indicator, Model 2A

Operating principle

The instrument operates by the catalytic action of a heated platinum filament in contact with combustible gases. The filament is heated to operating temperature by passage of an electric current. As the sample is drawn through the instrument by the aspirator bulb, it passes through the filter, inlet flashback arrestor, coming into contact with the filament. Combustion on the filament surface raises the temperature in proportion to the quantity of combustibles in the sample. A Wheatstone bridge circuit, incorporating the filament as one arm, measures the change in electrical resistance due to the temperature increase. This change indicates the percentage of combustibles present in the sample.

Physical description

Size and weight: 3⅜" × 5⅜" × 5½"; 4 lb, complete with carrying straps and batteries. *External accessories:* sampling line for remote testing, available in length multiples of 5 ft; hollow 3 ft

rigid probe tube for sampling from bar holes or manholes; solid 4 ft probe rod for use in testing tanks that may contain liquids; charcoal filter in external cartridge holder for use as aid in distinguishing between gases and condensable vapors in sample. *Power requirements:* instrument powered by 6 standard D dry cells.

Performance data

Least detectable quantity: 2% LEL. *Scale range:* 0–100% LEL. *Accuracy:* ± 5% of full scale. *Response time:* 10–15 seconds. Model 2A is factory-calibrated on pentane in air. Pentane calibration is used because it is representative of petroleum vapors and, when testing may be other combustible gases, generally results in readings that are on the high or safe side.

Combustible Gas Detection System, Series 510

Mine Safety Appliances Company
(address above)

The MSA Combustible Gas Detection System, Series 510, is an instrument package specifically designed to continuously monitor an atmosphere for flammable gases and vapors. The System is available in three models: 510, for central monitoring of multiple locations; 511, for single-location monitoring; and 512, and explosion-proof system for monitoring a single location.

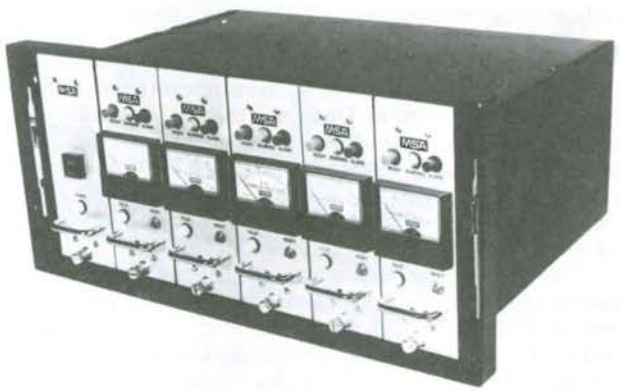


Figure V-97 — MSA Combustible Gas Detection System, Series 510.

Operating principle

The Series 510 System operates on the principle of catalytic combustion. An air sample passes over the catalytic Pelement™ detector in the sensor and the combustible gases in the sample are burned catalytically. This raises the temperature of the detector and, consequently, its electrical resistance. The increase in resistance produces an output voltage proportional to the combustible gas concentration. This output voltage is transmitted to the control module and translated into an analog readout of percent LEL.

Physical description

Dimensions: Model 510 — 12" × 9" × 10½" (2-unit housing); Model 511 — 6⅛" × 14¾" × 13¼"; Model 512 — 6" × 16⅞" × 14¼". *Sensor life:* three years expected. *Sensor cable requirements:* 3 or 4 conductor, 14 ohms closed loop, maximum resistance. *External accessories:* diffusion head including sensor and assemblies. *Power requirements:* 105, 115, 230 V; 50/60 Hz; 11–15 or 19–60 VDC standby. *Safety provisions:* tamper-resistant controls; malfunction light and relay which deactivates in the event of lost power, open sensor, severed or shorted cable; built-in short-circuit protection; built-in warning lights and alarm circuitry; explosion-proof design (Model 512 only).

Performance data

Range: 0–100% LEL. *Accuracy:* ± 2% with control unit and sensor 0° to 130°F; ± 4% with sensor -40°F to -18°F and +130°F to 200°F. *Response time:* typically less than 5 sec to alarm at a present level of 40% with an input of 50% LEL. *Zero drift:* ± 0.5% FS/week.

Spotter™ LEL Combustible Gas Detector, Model QII

Mine Safety Appliances Company
(address above)

The Spotter™ LEL Combustible Gas Detector, Model QII, is designed for ambient portable use in the measurement of combustible gases and vapors. The instrument indicates the concentration of combustibles as a percentage of their Lower Explosive Limit.

Operating principle

The Spotter operates on the Wheatstone bridge principle. A catalytically treated Pelement™ detector forms one half of the bridge. As sample gas diffuses onto the Pelement filament it burns, increasing the temperature of the Pelement, creating a proportional change in resistance and thereby unbalancing the bridge. The result of this imbalance is measured on the digital display, which is calibrated to show the resistance change as a percentage of the LEL of pentane.

Physical description

Size and weight: 5¾" × 2⅝" × 1½"; 9.5 oz. *Power:* rechargeable 2.4 V Ni-Cad battery supplies approximately 175 readings on a single charge. *External accessories:* instrument come supplied with soft leather carrying case; single-unit and ten-unit battery chargers are also available. *Safety provisions:* out-of-range LED lights when combustible gas exceeds instrument range.

Performance range

Least detectable quantity: 0.1% LEL. *Range:* 0–99%. *Accuracy:* ± 5% FS. *Response time:* 90% within. *Calibration:* factory calibrated on pentane-in-air.

Figure V-98 — MSA Spotter™ LEL Combustible Gas Detector, Model QII, with carrying pouch.

Gascope® Combustible Gas Indicator, Models 60 and 62

Mine Safety Appliances Company
(address above)

MSA Combustible Gas Indicators are portable instruments for use in detecting, measuring and pinpointing leaks of combustible gases or vapors. Model 60 is calibrated on methane-in-air by volume in a low range of 0–5% and a high range of 0–100%. Model 62 is calibrated on pentane-in-air in a low range of 0–100% LEL, and a high range of 0–100% by volume.

Operating principle

MSA Combustible Gas Indicators use two different types of filaments: a catalytic combustion filament for low range operations and a thermal conductivity filament for high range.

Concentrations on the low ranges are measured by the hot-wire, Wheatstone bridge method. The filament is one arm of the bridge. When the gas sample passes across the filament, combustibles are burned, raising the temperature of the filament, increasing its resistance, unbalancing the bridge. The imbalance is proportional to the concentration of combustibles and is indicated on the low range of the meter.

For measuring in or above the explosive range, a thermal-conductivity filament is used; the selector switch substitutes it in the bridge network. Combustibles in the sample cool this filament, decreasing its resistance, and unbalancing the bridge. The imbalance, proportional to gas concentration, is measured by the meter and read as percent-by-volume.

Physical description

Size and weight: 6½" × 7¼" × 4"; 5 lb 2 oz. *Sampling rate:* 1.5 lpm. The Gascope may be used with MSA 3-ft probe tubes and rods, and with standard MSA sampling lines. An external cartridge holder to hold charcoal cartridges attaches to sample line connection of the instrument. For easy mounting on the outside of the instrument case, a line trap assembly is also available. Gascope

Figure V-99 — MSA Gascope Combustible Gas Indicator, Models 60 and 62.

indicators can operate continuously for over 8 hrs on a set of 8 zinc carbon batteries. Instruments are automatically turned off when the hinged case lid is closed.

Performance data

Ranges: Model 60 — 0-5% by volume, 0-100% by volume; Model 62 — 0-100% LEL, 0-100% by volume. Silanes, silicones, silicates, and other compounds containing silicon in the tested atmosphere may seriously impair response of the instruments. Some of these materials rapidly "poision" the catalytic combustion filament so that it will not function properly. When there is a suspicion that such materials are in the automosphere being tested, the instrument must be checked frequently (at least after each 5 tests). Leaded gasoline vapors can also poison the catalytic combustion filament of the Gascope instrument; an inhibitor filter should be used to nullify this effect. *Accuracy:* 15% of full scale. Patent constant voltage power supply to filaments assures essentially no zero drift. *Calibration:* separate adjustment knobs for each measuring circuit of the changings of zero settings. The Model 60 instruments may be field-calibrated using 2% or 2.5% methane-in-air while the Model 62 can be checked with 0.75% pentane-in-air.

UNICO Guardian Combustible Gas Detector/Alarm

The Bendix Corp.
Environmental & Process Instruments Division
12345 Starkey Road
Largo, FL 33543

The UNICO Guardian Combustible Gas Detector/Alarm is used to detect the presence of explosive or combustible gases or vapors in confined ambient work atmospheres such as tunnels, wells, mines, pipelines, sewers, tanks, chemical reaction vessels, and other locations where fire and explosion hazards may be encountered.

Operating principle

The instrument employs the principle of controlled catalytic oxidation on the surface of an electrically heated filament. A specially coated platinum filament is used which is operated below the normal ignition temperature of the contaminant. This filament provides large electrical resistance changes from small temperature changes. When the sample contains a combustible gas, the unbalance of a Wheatstone bridge is detected and produces a distinct audible alarm.

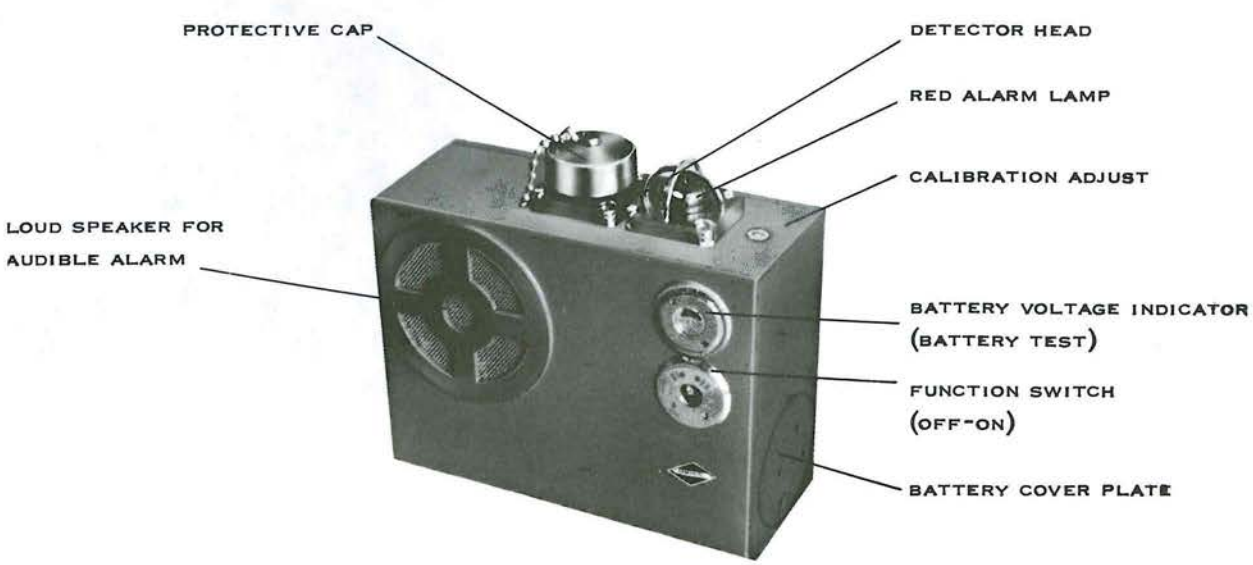
Physical description

The solid state circuitry consists of 13 transistors and one tunnel diode. It is powered by a 2.5 volt rechargeable nickel-cadmium battery which will operate the alarm for eight hours when fully charged. Current limiting resistors are incorporated into the Guardian battery so that in the event of accidental short circuits,

TABLE V-10
Response of the UNICO Guardian to Various Gases and Vapors

Gas or Vapor	LEL*	Approximate Alarm Conc.
Methane	5.3%	1.5%
Propane	2.2%	0.6%
Hydrogen	4.0%	1.1%
Ethylene	3.1%	0.9%
Gasoline vapor	1.4%	0.35%
Methyl alcohol (Methanol)	7.3%	2.0%

* The lower explosive limit representing the minimum concentrations in air, which are capable of burning or exploding, as described in *Limits of Flammability of Gases and Vapors*, U.S. Bureau of Mines Bulletin No. 503, 1952, by H.F. Coward and G.W. Jones.



neither the battery not its components can overheat and create danger of fire or explosion. The battery is rechargeable in 14 hours at a charging rate of 300 milliamps. *Size and weight:* 4¼" × 5¾" × 2¼"; 3.25 lbs.

Performance data

The UNICO Guardian is factory calibrated to produce a distinct continuous audible alarm and red lamp when approximately 1/3 LEL (Lower Explosive Limit) of methane is reached. The alarm concentrations of the Unico Guardian for typical flammable gases or vapors are shown in Table V-10.

Methanometer

National Mine Service Company
4900/600 Grant Street
Pittsburgh, PA 15219

The G-2000 Methanometer is a pocket sized, hand held instrument for measuring the concentration of methane in air.

Operating principle

The G-2000 is a diffusion type methanometer. Gas is admitted to the sensor through two screened ports in the top of the instrument. A light emitting diode chain is activated by holding a pushbutton on the side of the case. An additional LED on the front of the instrument gives a constant indication of battery condition while the instrument is in use.

Physical description

The G-2000 is housed in a rugged stainless steel case measuring only 2⅛" × 3¾" × 1⅜" and weighing only 11.5 oz. It is powered by a rechargeable 3.6 volt Ni-Cad battery. *MSHA certification:* 8C-43.

Performance data

Display: light emitting diode chain (0–2% CH_4) with underrange and overrange indicators. *Detector:* catalytic bead on platinum wire. *Charging:* 50 mA constant current. Approximately 300 readings with fully charged battery.

Vapotesters

Scott Aviation-Davis Instruments
P.O. Box 751
RT 29 North
Charlottesville, VA 22902

These instruments are used in general industrial hygiene surveys and safety inspections to determine the presence or absence of combustible gas or vapors in confined spaces, storage areas, work spaces, etc.

Operating principle

The measurement of combustible gases and vapors by the use of portable and continuous indicators is based on the principle of catalytic combustion of these vapors. When a combustible gas or vapor is passed over a catalytic filament, it burns. The filament is usually a platinum wire, 0.003 to 0.010 inch in diameter, heated to a red glow. Two identical filaments are used in a bridge circuit. One of these filaments, known as the "reference filament", is sealed in air in a separate well of the same chamber as the "active" or exposed filament. Two fixed resistors are used as the other legs of the bridge, connected together by a variable resistor. The bridge is balanced with both the filaments in air by adjusting the variable resistor or zero control, until the galvanometer or meter reads "Zero."

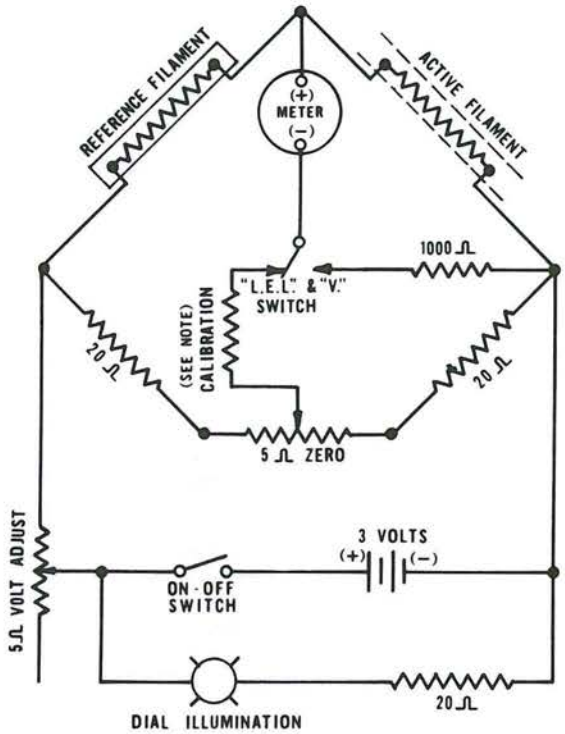
Figure V-101 — D-11 Vapotester No. 11-325.

A mixture of gases, such as propane and air, may be either flammable or not, according to the concentration of propane in air. The explosive range includes all concentrations of a mixture of flammable vapor or gas in air (usually expressed in percent by volume) in which a flash will occur or a flame will travel if the mixture is ignited. The lowest percent at which this occurs is the LEL, and the highest percentage is the Upper Explosive Limit (UEL). If such a mixture is confined and ignited, an explosion results. The LEL of propane in air is 2.3% and the UEL is 7.35. Mixtures above 7.3% are too rich to support combustion, and those less than 2.3% are too lean. Since air is the diluent and is readily obtainable, all concentrations above 2.3% are dangerous; therefore, the portable indicator is usually calibrated from zero to the LEL of some specific gas or vapor. The LEL is considered 100% and points below this level are considered as percent of the LEL.

Many common flammable liquids and gases have very wide explosive ranges. That of carbon disulfide is 1% to 50%, and hydrogen 4.1% to 74.2% which shows that only very lean or unusually rich mixtures of these materials in air are free from an explosion hazard. Since the concentration of combustibles may be above the LEL, it is necessary that the flashback arrestor will prevent the propagation of flame to the point of origin of the sample. This flame arrestor operates on the principle of the flame safety lamp.

Figure V-102 — D-16 Vapotester No. 11-660.

Figure V-103 — D-2 Vapotester No. 11-410.



NOTE:

CODE	CALIBRATION RESISTOR
11-325	FIXED FOR HEXANE CALIBRATION
11-326	FIXED FOR VARIOUS SPECIAL CALIBRATIONS
11-327	VARIABLE FOR FIELD CALIBRATION

Figure V-104 — D-11 Vapotester schematic.

Physical description

The components are housed in a die cast aluminum case and plastic battery holder. Power is supplied by 8 flashlight type "D" cells contained in the instrument. Battery life is approximately 8 hours, continuous duty, An aspirator bulb furnishes the suction necessary for sampling. *Size and weight:* 6" × 5¾" × 3½"; 4 lbs.

The Model D-11 Vapotester No. 11-325 is a two filament instrument designed for general use, suitable for detecting the presence of any combustible gas or vapor in air. Meter scale range 0–100% of LEL of hexane in air. Because two identical filaments (one active, one reference) are set up in the bridge circuit, this instrument provides outstanding zero stability, even as the battery voltage decreases. Since separate zero and voltage rheostats are provided, the bridge voltage can be periodically checked and adjusted during long tests, without disturbing instrument zero. The user can calibrate the instrument for any combustible gas or vapor.

The Model D-2 Vapotester No. 11-410 is a single filament, single control instrument designed for general use for detecting the presence of any combustible gas or vapor in air. Meter scale range 0–100% of LEL of hexane in air. One control knob permits adjustment of meter pointer to zero, and simultaneously sets correct operating voltage across the bridge. Ideal for spot testing, and short duration tests.

The D-16 Vapotester No. 11-660 is a two filament, two range instrument designed to detect combustible gases or vapors in the ppm range, in addition to the zero to LEL. Meter scale ranges 0–10% LEL of hexane in air. Many different calibration curves are available for interpreting readings of various combustibles in terms of ppm.

Combustible Gas Alarm Systems

Scott Aviation-Davis Instrument,
(address above)

The 3800 Series Combustible Gas Alarm System is suitable for monitoring process work, utility areas, industrial sewers, and storage areas where an explosive condition may arise through combustible gas accumulation.

Operating principle

The 3800 Series Diffusion Sensor detects 0 to 100% lower explosive limit of combustible gases and vapors in a silicone-free atmosphere. The sensor consists of a pair of catalytic filaments which oxidizes (burns) the combustible gas at concentrations lower than usually required for combustion. The Scott Davis patented sensor employs inner and outer stainless steel sintered metal flame arrestors. A 1/8" NPT tappered opening in the base of the outer arrestor allows for remote calibration of inaccessible sensors.

Perferred installations utilize one sensor per module for distances up to 2,000 feet. Alternate installations utilizing two sensors per module are limited to total distances for both sensors of 1000 feet.

Physical description

3800 A Series modules are 3½" high and mount directly into a 19-inch relay rack or cabinet. *3800 B Series* modules are 3" wide, 7" high and require mounting in a 5 unit module rack, which in turn mounts directly into a 19-inch relay rack or cabinet. *3800 S Series* modules include a single unit panel mounting adaptor and molded bezeled frame. Overall dimensions are approximately 5¾" wide × 8⅞" high.

Performance data

Measurement range: 0–100% LEL most combustible gases. *Speed of response:* 1 second for 1 RC (hydrogen). *Zero drift:* ± 3% in 30 days of constant ambient conditions. *Repeatibility:* ± 1% full scale. *Sensor temperature limit:* 0° to 250°F. *Module temperature limit:* 32°to 150°F. *Power required:* 117 VAC ± 3%, 60 H_2 standard, 50 Hz optional, constant voltage optional transformer available. *Alarm setting:* adjustable from 5–95% LEL.

Hydrogen Sulfide Monitor Model 10HS

Sierra Monitor Corporation
1031D East Duane Aveune
Sunnyvale, CA 94086

Using a solid state sensor, the sierra Model 10HS monitor continuously measures the concentration of hydrogen sulfide in the ambient air.

Operating principle

Incorporated in the Model 10HS is an H_2S sensor, an electronic circuit, microprocessor, concentration display, operating controls, audible alarm, and rechargeable battery or AC power supply. The miniaturized circuit changes the analogue electrical output of the H_2S sensing element to a digital signal that is processed by the microprocessor, so that by changing a selector switch concentrations can be displayed on the light-emitting diode display: present concentration, time-weighted average value for exposure on a single shift, or maximum concentration value sensed during a work period.

Physical description

Size and weight: 7.5" × x 3.9" × 1.9" (19 mm × 99 mm × 48 mm); 1.5 lbs. *Accessories supplied:* battery charger/power supply 110 or 220 volts AC; ear phone for high noise area; instruction manual; instrument case. *Battery:* Ni-Cad rechargeable battery pack which gives 8–10 hour operation per charge/750 overnight charges. Device and alarm are intrinsically safe for use in hazardous locations.

Performance data

Range: 0 to 50 ppm. *Operating temperature range:* -20° to +40°C. *Response time:* 80% of full scale in 2 minutes. *Zero drift:* < 3% of full scale in 8 hours. *Warm-up time:* < 5 minutes. *Operating controls:* ON-OFF switch; display concentration switches for 1) present concentration sensed, 2) time-weighted average value for exposure, 3) maximum concentration value sensed, 3) time unit has been in operation, 4) test for checking operation function and audible alarm, 5) zero screw is adjusted to display zero present concentration in fresh air (interior adjustment), 6) calibrate screw is adjusted to display 25 ppm present concentration (interior adjustment) when exposed to 25 ppm calibration gas. Alarm levels are factory preset for ceiling concentration level of 20 ppm, time-weighted average value alarm at 10 ppm, evacuation alarm at 50 ppm, and when battery condition is low.

Model 102 Combustible Gas Analyzer

Teledyne Analytical Instruments
333 W. Mission Drive
San Gabriel, CA 91776

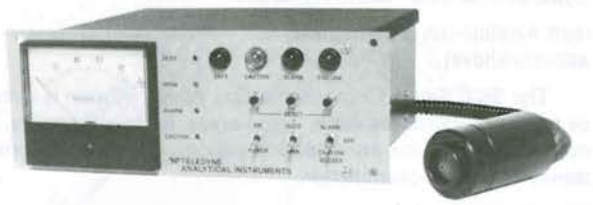


Figure V-105 — Teledyne Model 102 Combustible Gas Analyzer.

Operating principle

Catalytic bead sensor. Combustible gases present in the air burn in the presence of oxygen, producing a signal proportional to the concentration of the combustible gases.

Physical description

Size and weight: 3½" × 9½" × 7"; about 7 lbs. *Power requirements:* 115 V, 60 Hz. *Sample rate:* diffusion when placed in air. *Readout mode:* integral meter with recorder output signal.

Performance data

Detection limits: 100% of LEL of most combustible gases. *Specificity:* must be calibrated in "equivalent" of a designated combustible gas. *Response time:* 90% of full scale in < 20 seconds. *Accuracy:* meter ± 0.5% of full scale.

CEA 555 Continuous Colorimetric Analyzer

CEA Instruments, Inc.
15 Charles Street
Westwood, NJ 07675

The CEA 555 is a portable ambient air monitor that can be used for the continuous colorimetric analysis of SO_2, NO_2, NO_x, NH_3, Cl_2; TDI, HCN, HCHO, acrylonitrile, bromide, fluorine, hydrazine, hydrogen chloride, hydrogen sulfide, or total oxidants.

Figure V-106 — CEA 555 Continuous Colorimetric Analyzer.

Operating principle

The CEA 555 contains a rechargeable DC power source and a constant-volume adjustable air pump. An air sample is continuously drawn into the unit and scrubbed with an absorbing reagent which removes a trace pollutant from the air stream and transfers it into the liquid reagent system.

The subsequent color formation is read by a colorimeter and displayed on a built-in meter or on the optional digital readout shown in Figure V-106. A recorder output is also provided.

Physical description

Size and weight: 12" × 20" × 5½"; 25 lbs. *Power requirements:* 12 VDC unregulated, 310 mA, 4 watts (external 10.2 VDC minimum) 120 VAC, 60 Hz, 35 watts (maximum). *Operating period:* 20 hours, fully charged internal batteries. *Signal output:* 0–1.0 V at 0–2.0 mA.

Performance data (for SO_2)

Operating range: 0–0.25 ppm full scale, adjustable up to 0–10 ppm. *Reproducibility:* 1%. *Calibration:* < 1% drift/72 hours. *Minimum detectable concentration:* 0.025 ppm. *Sensitivity:* 1% of full scale. *Non linearity:* < 2%. *Zero and span drive:* < 2%/72 hr. *Air flow dirft:* < 1%/72 hours. *Noise:* 0.75% of full scale. *Lag time:* 4 minutes. *Rise time to 90%:* 4 minutes. *Fall time 90%:* 2.5 minutes. *Temperature range:* 40° to 120°F. *Temperature drift:* laboratory conditions ± 5°F, ± 1%; 60°–80°F, ± 2%; 60°–120° F, ± 4%; 40°–120°F, ± 8%. *Relative humidity range:* 5–95%. *Reagent requirements:* SO_2 — 3.4 L/week modified West and Gaeke; 3.4 L/week demineralized water; NO_2 — 3.4 L/week modified Saltzman (Lyshkow).

Open Cell NDIR Gas Detector, Model 5600

Astro Safety Products Division
P.O. Box 58159
Houston, TX 77058

The Model 5600 is designed for fix station monitoring of combustible gases in chemical plants, ships, well logging, refineries, drying ovens, drilling platforms, sewage digesters, mines, and tunnels.

Operating principle

Infrared energy from the IR source passes alternatively through two narrow band interference filters and the sample gas, then is reflected back by a spherical mirror to the solid state detector. The sample filter wavelength is selected for line spectra absorbed by gases analyzed. The "Zero" or reference filter is chosen for non-absorbance characteristics of moisture and all gases present. Synchronous detection, dual wavelength ratioing, and processing of reference and sample signals are then performed to eliminate drift associated with alternate IR detectors. The Model 5600 has compensating circuitry for IR source and detector aging and dirt accumulation on the windows. It employs automatic gain control in the detection process and has a "dirty window" alarm with relay output that activates when insufficient energy reaches the detector. The system verifies "Zero" once each second providing an active detection device. Fail-safe operation and system status are automatic.

Physical description

Size and weight: 7.2" × 7.2" × 6.5"; 12 lbs. *Power:* 110/220 V, 50/60 HZ, 12 watts (24 VDC back-up capability). *Output:* 0–1 VDC or 0–10 VDC or 4–20 mA DC, fault alarm (relay); two independent settable alarms.

Performance data

Range: 0–100% LEL. *Response time:* 8 seconds. *Repeatability:* ± 3%. *Zero and span drift:* ± 2% (non-accumulative).

Models 864/865 Non-Dispersive Infrared Analyzers

Beckman Instruments, Inc.
Automotive Test Instruments Operations
2500 N. Harbor Boulevard
Fullerton, CA 92634

The Beckman Models 864/865 Non-Dispersive Infrared (NDIR) Analyzers are designed for precise determination of a given chemical component concentration in vehicle emissions. The Models 864/865 offer high sensitivity and maximum analytical stability for the following applications: 1) vehicle emissions — assembly line testing, determining catalytic converter effectiveness, measuring engine combustion efficiency; 2) automotive research and development — fuel economy studies, engine development, basic combustion research, component performance testing, continuous dilute monitoring, exhaust gas recirculation (EGR) testing; and 3) automotive certification testing — CVS bag analysis.

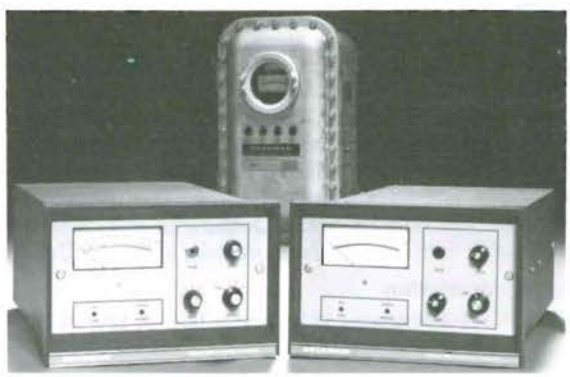


Figure V-107 — Beckman Non-dispersive Infrared Analyzers; left: Model 864; right: Model 865.

Operating principle

The Models 864/865 produce infrared radiation from two separate energy sources. Once produced, this radiation passes through a chopper which interrupts it 10 times/second, and then passes through optics selected to eliminate interference from other infrared absorbing components. The infrared beams pass through two cells; one a reference cell containing a non-absorbing background gas, the other a sample cell containing a continuous flowing sample.

During operation, a portion of the infrared radiation is absorbed by the component of interest in the sample cell. The detector converts this difference in energy between sample and reference cell to a capacitance change. This capacitance change, equivalent to component concentration, is amplified and indicated on a meter, and, if desired, transmitted to a data acquisition device and/or controller.

Performance data

Precision: 1% of full scale. *Noise:* 1% of full scale. *Zero and span drift:* 1% of full scale per 24 hours. *Response time (electronic):* variable, 90% in 0.5 sec. to 26 sec (15 field-selectable speeds). *Maximum sensitivity:* 1000 P/10^6 full scale CO for Model 864 and 100 P/10^6 full scale CO for Model 865; 500 P/10^6 full scale CO for both models. *Sample cell length:* 0.157", (4 mm), 0.25" (6.4 mm), 0.5" (12.7 mm), 5" (127 mm), 13.5" (34.3 cm), 15" (38.1 cm). *Sample flow rate:* nominal 500–1000 cc/min. *Sample pressure:* 15 psig. *Maximum, ambient temperature range:* 30° to 120°F (–1° to +49°C). Output (field selectable): 0–10 mV, 0–100 mV, 0–1 V, 0–5 VDC. Non-linear output standard; plug-in linear output optional.

Physical description

Model 864 is 8 11/16" × 13⅛" × 22⅜" and weighs 50 lbs. Model 865 is 8 11/16" × 13⅛" × 27⅜" and weighs 61 lbs.

Model 866 Ambient CO Monitoring System

Beckman Instruments, Inc.
Process Instruments Division
(address above)

The Model 866 is designated as a reference method for ambient monitoring. Also, Model 867 is available for CO in vehicle exhaust monitoring and CVS bag analysis applications.

The Model 866 monitoring system combines the Model 865-17 NDIR analyzer, the Automatic Zero/Span Module, a Beckman-developed Automatic Flowing Reference Panel, and a Pump/Sample Handling Module into a compact self-contained system. The Model 866 represents a new generation of ambient CO monitoring systems, designed to eliminate routine calibration cycles and provide weeks of maintenance-free operation, even while operating under stringent EPA performance requirements.

Operating principle

Model 866 utilizes non-dispersive infrared radiation absorption. The infrared beam passes through two cells: one reference cell containing a non-absorbing background gas. The other cell containing a continuous flowing sample.

Performance data

Range: 0–50 P/10^6 CO. *Noise:* < 0.2 P/10^6. *Total interference equivalent:* less the 1.5 P/10^6 per EPA specifications. *Zero drift:* ± 0.5 P/10^6 per 12 and 24 hours. *Span drift:* ± 1% per 24 hours. *Electronic response time:* 0.5 to 26 sec, field selectable; EPA designated at 13 seconds. *Precision:* 0.2 P/10^6. *Ambient temperature limits:* 32°F to 120°F (0°C to 50°C); EPA designated at 68°F to 86°F (20°C to 30°C). *Power requirements:* 115 ± volts rms, 50/60 Hz ± 0.3 Hz, 500 watts maximum. *Outputs:* 10 mV, 100 mV, 1 V, 5 VDC available from auto zero/span module; 4–20 mA DC optional.

Physical description

The Model 866 weighs 57 lbs and is 18⅜" × 12¼" × 25⅞".

Figure V-108 — Beckman Model 866 Ambient CO Monitoring System.

Friez® Carbon Monoxide Analyzer

The Bendix Corporation
Enviromental & Process Instrument Division
12345 Starkey Road,
Largo, FL 33543

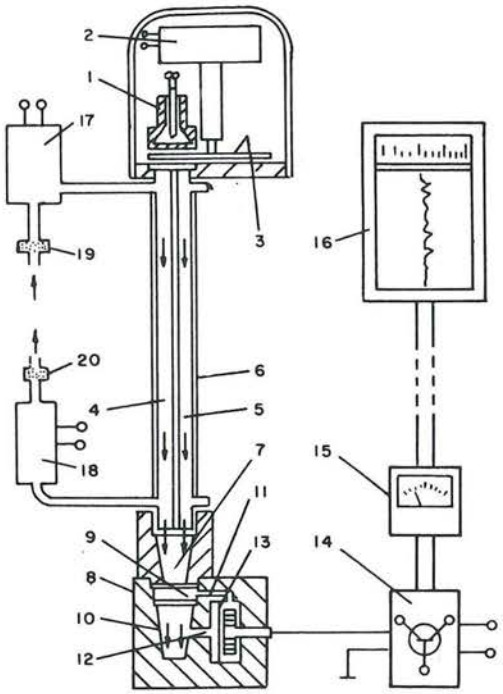
The Bendix Friez® Carbon Monoxide Analyzer is used for both ambient air and auto exhaust emission monitoring. The UNOR principle of infrared detection insures a minimum interference from other contaminants such as water vapor and carbon dioxide.

Operating principle

As depicted in Figure V-110, the infrared radiation from the radiation source (1) is divided by a rotating chopper (3), driven by the synchronous motor (2) into two equally intense portions modulated in phase-reversal, which alternately pass through the sample cell (4) and the reference cell (5) of the analysis chamber (6). Both radiation portions pass through the beam combiner (7) and enter the double-layer detection chamber (8), which contains the gas component to be measured. The two layers (9) and (10) of the detector chamber are arranged in series in the single ray path and are connected through channels (11) and (12) with the diaphragm (13) of the measuring capacitator (microphone).

The spectra of absorption of the gases is a band comprised by a number of absorption lines. In the shorter front layer (9) of the detector, absorption of the radiation that takes place primarily in the center of the absorption band (E_1), while the radiation in the outer edges of the band is absorbed in the longer rear layer (10) of the detector (E_2). The radiation energies absorbed, heat the gas in these layers so that the resulting gas pressure applied to the diaphragm of the microphone increases. The gas concentration of the two layers and the geometry are so adapted that the pressure pulses on both sides of the diaphragm will almost cancel each other

Figure V-109 — Bendix Friez® Carbon Monoxide Analyzer.



1 Radiation source
2 Synchronous motor
3 Rotating chopper
4 Sample cell
5 Reference cell
6 Analysis chamber
7 Beam combiner
8 Detection chamber
9 Front measuring chamber
10 Rear measuring chamber
11 Connecting channel
12 Connecting channel
13 Diaphragm of capacitor
14 Measuring amplifier
15 Output meter
16 Recorder
17 Gas pump
18 Automatic interference indicator
19 Safety filter in the gas inlet
20 Safety filter in the gas outlet

Figure V-110 — Schematic diagram of UNOR gas analyzer.

in the zero condition ($E_1 = E_2$), even if the reference cell should be obscured. If the radiation in the sample cell (4) passes through a gas mixture containing the component to be measured, some of the specific radiating energy is absorbed in this vessel. As this reduction of radiation takes place mainly in the center of the absorption band, it effects primarily the front layer (9) of the detector. The measurement of the desired component is thus proportional to the capacitance change of the microphone, caused by the resulting change in pressure as the gas is heated due to radiation absorption of the measured component. Deflection of the diaphragm results in a change of electrical capacitance. This change in capacitance is converted by an amplifier (14) into a proportional DC signal which is indicated on the instrument (15).

This measurement technique assures a stable zero without drift and with good selectivity. The percent physical design and geometry of the detection chamber assures a minimum of cross sensitivity to possible interfering compounds. This technique is analogous to the use of a prism or grating monochromator to selectively utilize a specific wavelength of radiation for the measurement. In this case the detection chamber is designed such that only a discrete wavelength band is effective in the measurement, resulting in the high selectivity and ease of calibration.

Physical description

The Carbon Monoxide Analyzer is housed within a cabinet which is suitable for either rack mounting or table top applications.

Specifications

Sample flow: 1 ft^3/hr. *Recorder output:* 0–10V (full scale), with a "live" zero signal. *Sensitivity:* 0–100 ppm CO (full scale). *Zero stability:* ± 1% of full scale. *Response time:* 3 seconds. *Power requirement:* 115 VAC, 60 Hz, 20 watts. *Accuracy:* ± 1% of full scale.

SC/LC Infrared Gas Analyzer

Calibrated Instruments, Inc.
731 Saw Mill Road
Ardsley, NY 15020

Hilger I.R.D., Ltd.
98 St. Pancras Way
Camden Road
London, England

The SC/LC Infrared Gas Analyzer measures and provides a direct reading of the amount of concentration of a specific heteroatomic gas in a mixture in stream of mixed gases. Most heteroatomic gases can be measured by the Gas Analyzer with the exception of water vapor and carbon dioxide. This instrument finds use in the measurement of toxic concentrations of CO in the atmosphere, in exhaust gases in internal combustion engines, and measurement of flue gases. It is also used in determination of gas distribution in model furnaces, study of airflow and ventilation systems, and determining gas-to-air ratios. As a leak detector, it may be located for measuring leaks in sealed compartments and components, in pressured electrical equipment, in refrigeration systems, and in water mains.

Operating principle

A schematic of the Infrared Gas Analyzer is shown in Figure V-112. Radiation from the nickel-chromium wire sources is chopped at 7 Hz by the rotating vane and projected in a double beam through the analysis tubes to detector.

Radiation is absorbed in the sample tube in proportion to the concentration in the measured gas, but it passes unattenuated through the reference tube and the detector reacts to the different levels of radiation received. The compartment facing the reference tube receives the greater amount of radiation, causing its gas to

TABLE V-11
Minimum and Maximum Full Scale Range for Typical Gases at Ambient Temperature and Pressures for Standard SC/LC

Gas	Min. ppm (v.v.)	Max. % (v.v.)
CO	500	50
N_2O	100	20
NO	500	50
NO_2	500	50
CH_4	500	100
SO_2	500	50
C_2H_2	1000	50

expand and move the diaphragm separating the compartments. The diaphragm acts as a plate of one of the capacitors in a capacitance bridge circuit to which radio frequencies are fed. In its quiescent state the bridge is balanced but the movement of the diaphragm unbalances it, and the resultant output is amplified and fed to the meter or external recorder output.

To overcome the effects on the sensitivity of the instrument caused by changes in ambient temperature and pressure and variations in source emittance, sample tube reflectance and window tube transmission, it is recommended that the scale length and zero setting of the analyzer be checked each day. This check is accomplished by applying known concentrations of gas mixtures for checking the scale length and the zero setting can be checked with a stream free from the gas being measured.

Physical description

Size and weight: 20¼" × 18" × 10½"; 56 lbs. *Power requirement:* 190–260 V, 50 Hz, or 95–130 V, 50 VA or 100 VA with sampling pump. *Ambient temperature:* 0° to 40°C. *Pressure:* normal atmospheric pressure. *Bell volume:* depends on range of concentration; the volume for the most sensitive instrument is 150 cc approximate. *Sample volume:* depends on range of concentration; on the most sensitive instrument a minimum volume of 250 cc is required to insure that the sample cell is adequately flushed. Outfits other than those fitted with two or three section sample tubes, can be adapted for continuous analysis of a stream at flow rates up to 2 lpm by the addition of an internal sampling pump and a panel mounted filter, throttle and flow indicator.

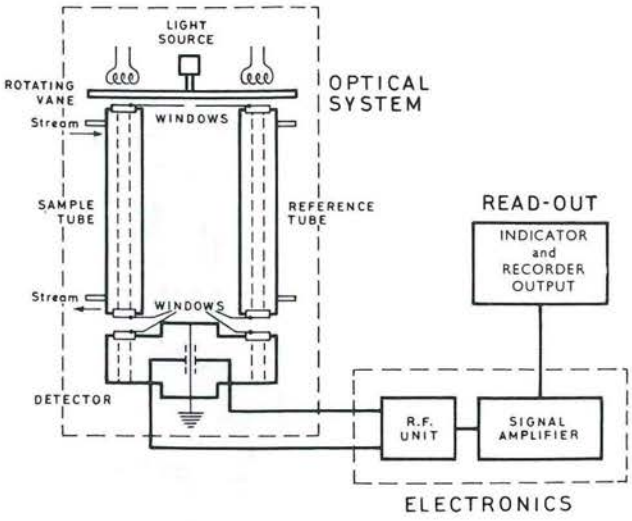


Figure V-112 — Schematic of Infrared Gas Analyzer.

Figure V-111 — Infrared Gas Analyzer SC/LC.

The analysis tubes are of brass with highly polished gold-plated interiors. The length and volume capacity of tubes and sections depends on the range of gas being measured. The detector is designed on the luft principle and constructed of aluminum alloy with highly polished interior surfaces; thermostatically controlled is required; indicator is a 5" direct reading meter.

Performance data

Gas measured: most heteroatomic gases, except CO_2 and H_2O — typical gases given in Table V-11. *Concentration range:* up to six ranges available using optical and electrical methods. *Flow rate:* up to 2 lpm. *Calibration accuracy:* ± 2% of full scale reading. *Discrimination:* 1% of full scale reading. *Modulation:* 7 Hz nominal. *Standard output:* 50–550 mA through loads up to 200 or 1500 ohms. *Standard response:* on the order of 15 seconds depending on flow rate and range.

Riken RI-550A

CEA Instruments, Inc.
15 Charles Street
Westwood, NJ 07675

The Riken Infrared Gas Analyzer Model RI-550A is a single gas, compact, lightweight, nondispersive infrared analyzer designed to measure carbon monoxide, carbon dioxide, methane, ethylene, ethane, propane, or butane levels.

Operating principle

This instrument operates on the nondispersive infrared (NDIR) absorption principle. The gas stream to be analyzed is drawn into the unit through a sampling probe and sampling line by means of an internal vacuum pump. The sample gas passes through an optical system and the concentration of the constituent to be measured is read out directly on a meter. A recorder output is also provided.

Physical description

Power supply: 115, 220 or 240 VAC ± 10%, 50 or 60 Hz ± 1 Hz (specify). *Power consumption:* < 60 watts. *Size and weight:* 7⅞" × 8⅔" × 12⅔; 21 lbs.

Performance data

Response time: < 10 seconds to 90% response. *Zero and span drive:* < ± 2%/8 hr of full scale. *Accuracy:* within ± 2% of full scale. *Minimum detection:* 1% of full scale. *Sample flow rate:* 6 lpm, normal, variable. Calibration is by internal span gas canister and/or built-in mechanical reference filter. *Ambient temperature range:* 32°–104°F (0°–40°C). *Ambient humidity range:* 0–90% RH. *Warm-up time:* 30 minutes after power switch ON (usable after 3 minutes). *Recorder output:* 0–10 mV DC (internal resistance 100 ohms).

Figure V-113 — Riken Infrared Gas Analyzer, Model RI-550A.

Miran Gas Analyzers

Foxboro Company
P.O. Box 5449
South Norwalk, CT 06856

Any gas which absorbs infrared radiation in wavelengths between 2.5 and 14.5 μm can be detected. The useful range depends on properties of the gas but in general, ranges are available to measure from less than a ppm to the low percent level. Table V-12 lists gases which have been frequently analyzed with the Miran Analyzer, as well as the minimum detectable concentration and wavelength for each gas.

From the table it can be seen that it is possible to selectivity analyze several gases even when present in the same atmosphere. However, when several gases are present, gas spectra should be consulted to determine the best choice of analytical conditions. Unlike many other gas analysis methods, infrared has a fail-safe feature in that even in completely unknown atmospheres a measurement for a specific gas can never be too low.

Operating principle

The Miran Gas Analyzers are unique instruments for the measurement of a wide variety of gases and vapors. The Miran Analyzers can be detect and measure most any gas having absorption bands in the infrared region of the spectrum. Because of the ability to vary the optical path of the gas cell and expanded absorbance ranges, most gases can be measured over a sensitivity range of less than 1.0 ppm up to several percent.

The Miran Gas Analyzers have been constructed to withstand field conditions. The instruments are primarily used with a wavelength set for a characteristic absorption band. Ambient air is continuously sampled and either absorbance or percent transmittance (%) measured. The Miran-I Variable Filter Gas Analyzer can be used to scan through the infrared spectrum as well.

TABLE V-12
Selectivity of the Miran Analyzer

Material	Minimum Detectable Concentration in ppm	Wave length μm
Ammonia	0.2	10.3
2-Butaone (MEK)	0.08	8.5
Carbon disulfide	0.5	4.54
Carbon dioxide	0.05	4.25
Carbon monoxide	0.2	4.7
Carbon tetrachloride	0.06	12.6
Chloroform	0.06	13.0
Dimethylflormanide	0.1	9.2
Ethylene oxide	0.9	11.8
Halothane	0.05	8.4
Methylene chloride	0.2	13.3
Nitrous oxide (N_2O)	0.2	7.8
Styrene	0.4	11.0
Sulfur dioxide	0.5	8.6
Toluene	0.5	13.7
Trichloroethylene	0.2	10.6
Vinyl chloride	0.7	10.9

A new lighter weight, lower cost analyzer (Miran-101) reading directly in concentration complements the Miran-I Variable Filter Gas Analyzer and is used when a limited number of vapors are to be analyzed. The Miran-II Gas Analyzers are designed for continuous monitoring applications in field installations.

Physical description

Miran-I Variable Filter Gas Analyzer. Size and weight — 70 cm × 28 cm × 18 cm, 25 lbs; power requirements — 25 watts (115 or 230 VAC) (12 VDC with inverter); sampling rate — 28 lpm; readout mode — full scale ranges 0–0.025, 0–0.1, 0–0.25, 0–1; absorbance units — 0–100% transmittance. *Miran 101 Specific Vapor Analyzer.* Size and weight — 47 cm × 14 cm × 15 cm, 14 lbs; powered by a self-contained rechargeable battery; sampling rate — approximately 15 lpm (cell volume, 2.25 liters); readout mode — direct reading in concentrations.

Performance data

Response and averaging time: < one minute. *Stability:* drift < 0.004 absorbance units at 23.25°C, 3.5 m. *Precision:* better than 2%. Accuracy is as good as the precision, provided a sufficiently accurate calibration method is used.

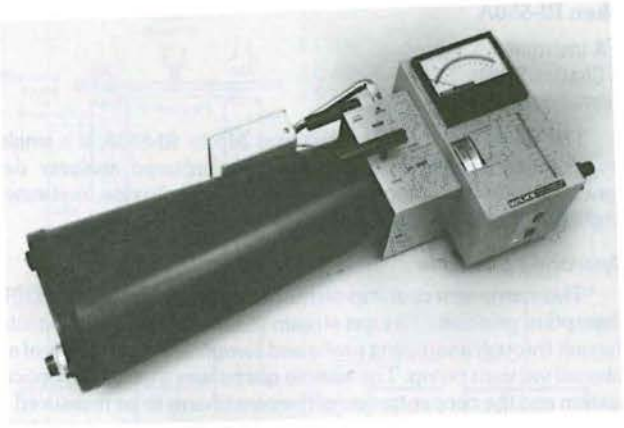


Figure V-114 — Miran I Variable Filter Gas Analyzer.

IR-702 Infrared Analyzer

Infrared Industries, Inc.
Western Division, Instrumentation Group
P.O. Box 989
Santa Barbara, CA 93102

The Infrared Analyzer has the capability of detection of two gases simultaneously. Its internal standardization eliminates need for span gases, and solid-state circuitry allow fast response with low vibration sensitivity.

Operating principle

In general, the system compares the optical (infrared) transmittance of two identical optical paths. One optical path passes through the sample of unknown gas, the other optical path passes through the reference path. The difference in optical transmittance between these paths then is a measure of the optical absorption. These variations in transmittance are sensed by a photon detector. The signal from the detector is processed and used to drive the output meter as a direct measure of the concentration of the unknown gas.

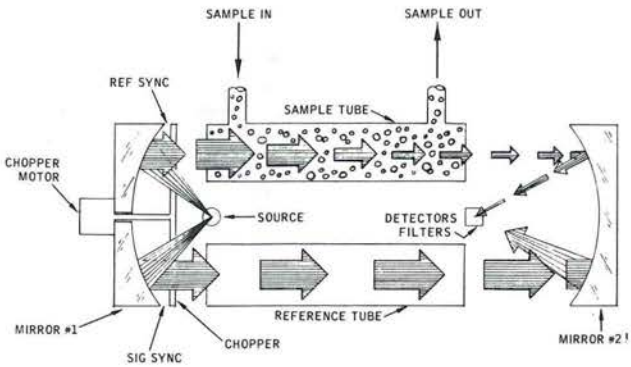


Figure V-116 — IR-702 detector diagram.

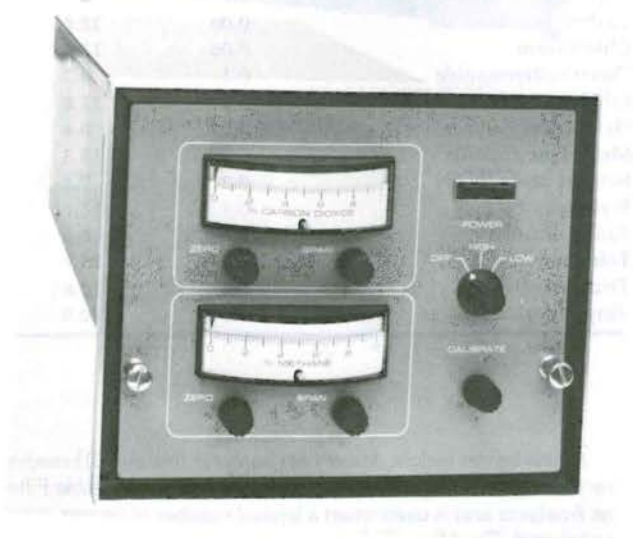


Figure V-115 — Infrared Industries Model IR-702 Infrared Analyzer.

The infrared source is operating at a temperature of about 1500°F where it emits infrared radiant energy optimized for the spectral bands of interest and long life. The emitted energy is directed to a concave front surface mirror. The infrared source surface being at the focal plane of the mirror, the reflected energy is effectively collimated where rays leaving the mirror surface are essentially parallel.

The reflected or collimated radiant energy forms two identical infrared beams. These beams of radiant energy are chopped by the coaxial chopper or beam interrupter to effect an alternate ON-OFF sequencing of each beam. The beams then pass through two parallel tubes which are rigidly mounted to the optical bench. One of these tubes contains the sample or unknown gas, the other tube, the reference tube, contains ambient air at ambient conditions. The length of the gas tube has been selected based on the intensity of the absorption bands and the calibration of the instrument.

The radiant beams after passing through the two tubes are reflected and imaged by a second mirror onto a photon detector after first passing through an optical filter. The optical filter represents the precise "window" of the absorption band for the specific gases of interest.

Performance data

Speed of response: 90% of reading in 1 sec. *Accuracy:* (specification dependent upon certified calibrations gas) ± 1% of

full scale. *Noise level:* < 1% of full scale. *Zero and span drift:* < 1%/24 hr. *Temperature range:* 32° to 120°F. *Detector type:* solid-state (PbSe). *Power consumption:* 70 watts. *Line voltage:* 90–130 V at 60 Hz. *Output:* 1–100 mV or 0–1 V. *Warm-up time:* 15 min. The sampling system is constructed of 316 stainless steel, windows of silicon, and tubing of Teflon. *Calibration:* internal optical attenuator.

IR-711 Portable Hydrocarbon Analyzer

Infrared Industries, Inc.
(address above)

The IR-711 Portable Hydrocarbon Analyzer is used for the instantaneous detection and measurement of % LEL and health hazards of the alkane family of hydrocarbons in and around fuel tanks and other enclosures. Because of its unique design, the IR-711 is particularly successful in the monitoring of JP-5 and other kerosene type fuels.

Operating principle

This instrument is a nondispersive infrared (NDIR) analyzer for continuously monitoring the concentration of a specific gas in a gas sample stream. Each analyzer is designed for optimum performance for the selected gas and concentration range. All units are fully linearized with either analog or digital readouts. Standard recorder outputs (0–100 mV) are provided.

The analyzer features a single infrared energy source which eliminates the complex alignment problems associated with dual infrared energy sources found in some NDIR analyzers. Dual beam optical systems minimize drift effects due to changes in ambient temperature, spectral emission of the source and power line variations. Reflective coatings are not required on the inside of the sample or reference cells reducing maintenance, cleaning and replacement costs.

Physical description

See Figure V-117. Total weight is 9 lbs.

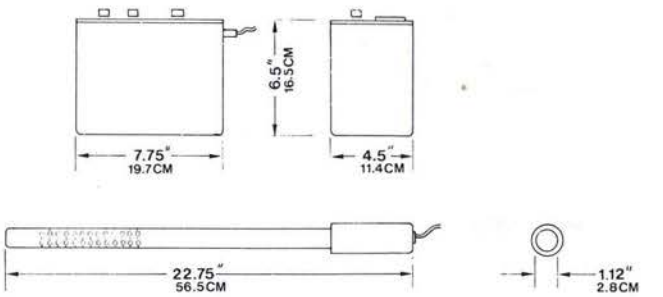


Figure V-117 — Diagram of the IR-711 Portable Hydrocarbon Analyzer

Performance data

Ranges: high, 0–100% LEL; low, 0–1000 ppm JP-5. *Calibration gas:* propane. *Accuracy:* 5%. *Resolution:* high range, 2.5% LEL; low range, 25 ppm JP-5. *Drift:* 1 hr — high range, < 2.5% LEL; low range, < 25 ppm; 8 hr — high range, < 5% LEL; low range, < 50 ppm. *Warm-up time:* 5 minutes. *Precision of span temperature compensation* (0°to 50°C): 2%. *Response time for temperature compensation:* 2 min.

Lira Model 202 Nondispersive Infrared Analyzer

Mine Safety Appliances Company
600 Penn Center Boulevard
Pittsburgh, PA 15235

The Lira Model 202 Nondispersive Infrared Analyzer is a highly selective instrument designed for fixed station use in the detection of any component of interest that absorbs infrared energy, including methane, ethyl chloride, ethylene chloride, ethyl and methyl alcohol, fluorinated hydrocarbons, carbon monoxide, carbon dioxide, sulfur dioxide, and others.

Operating principle

The instrument operates on the nondispersive infrared (NDIR) absorption principle. As infrared radiation is beamed through a sample cell, it is absorbed (and reduced) by the component of interest. Consequently, the amount of radiation reaching the sealed-in gas of the instrument detector is unequal to the amount reaching the gas from a parallel reference cell. When the twin beams are alternated by a chopper, the detector gas expands or contracts in response, varying the condenser microphone of the detector and producing an electrical signal proportional to the difference in emergent radiation. This signal is then amplified and fed to the meter, indicating the concentration of the component of interest.

Figure V-118 — MSA Lira NDIR Analyzer, Model 202.

Physical description

Models 202 and 202FR (general purpose design) measure 19" × 13" × 12½" and weigh 76 lbs. Model 202X (Class I, Groups B, C, D, Divison 1 design) is 20⅜" × 18" × 14" and weighs 135 lbs. Model

202S (general purpose long cell design) is 37½" × 12" × 9" and weighs 60 lbs. Model 202SX (Class I, Groups B, C, D, Division 1 design) measures 39½" × 14½" × 12⅜", weighing 90 pounds. The sample cells are of an aluminum block contruction with stainless steel insert, internally gold plated; length up to 8" standard; up to 20" with the high sensitivity option. The windows are of sapphire, quartz, calcium fluoride, barium fluoride, etc. and the tubing is flexible and corrosion resistant; solid type available. *Inlet-outlet:* ⅛" NPT. *External accessories:* explosion-proof or nonexplosion-proof design; optional recorder. *Power:* 500 VA, 115 VAC, 60 Hz; 50 Hz designs also available.

Performance data

Least detectable quantity, sensitivity, and specificity are application dependent. *Precision and accuracy:* ± 1% FS. *Response time:* Model 202, 90% in 5 sec; Model 202FR, 90% in 0.4–1.5 sec (field adjustable); 4-position switch. *Zero and span drift:* < 1% FS/day. Calibration curve is determined and provided for each instrument. Calibration is accomplished by using known gas on liquid samples for zero and span at instrument. *Span check:* precision resistor in source circuit simulates gas presence in Lira cell, actuated by push-button on front panel

Lira Model 3000 Nondispersive Infrared Analyzer

Mine Safety Appliances Company
(address above)

The Lira Model 3000 Nondispersive Infrared Analyzer is a selective, stable, and economical instrument designed for fixed station use in the detection of any gas or vapor that absorbs infrared energy, including carbon monoxide, halogenated hydrocarbons, carbon dioxide, and most hydrocarbons.

Operating principle

The instrument operates on the nondispersive infrared (NDIR) absorption principle. As infrared radiation is beamed through a sample cell, it is absorbed (and reduced) by the component of interest. Consequently, the amount of radiation reaching the sealed-in gas of the instrument detector is unequal to the amount reaching the gas from a parallel reference cell. When the twin beams are alternated by a chopper, the detector gas expands or contracts in response, varying the condenser microphone of the detector and producing an electrical signal proportional to the difference in radiation. This signal is then amplified and fed to the meter, indicating the concentration of the component of interest.

Physical description

The Lira Model 3000 weighs 44 lbs and measures 21⅜" × 9⅜" × 6¾". Its sample cells and windows are application dependent. Inlet, outlet, and purge fittings are ⅛" NPT and the tubing is made of nylon. *Power:* as shipped, 60 VA, 120 V, 60 Hz; 50 Hz designs; also available, 100 VA, 120 VAC, 60 Hz; field selectable 50 or 60 Hz; 105, 120 or 220 VAC.

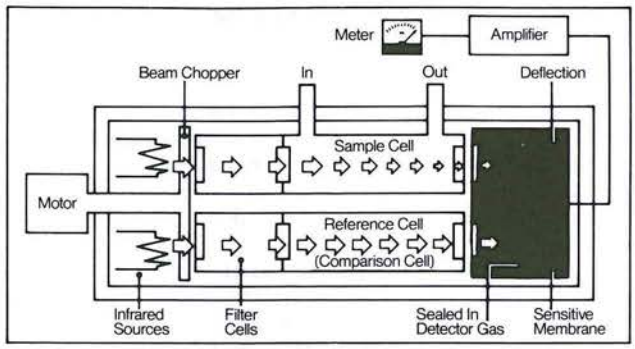


Figure V-119 — MSA Lira NDIR Analyzer, Model 3000.

Performance data

Least detectable quantity, sensitivity, and specificity are all application dependent. *Precision:* ± 0.5% FS. *Response time:* 90% in 5 sec; optional 90% in 3 sec. *Zero and span drift:* < 1% FS/day, typically < 2% FS/week. *Span check:* electrical circuit simulates presence of sample gas when activated by push-button on front panel.

J-W Mercury Vapor Sniffer

Bacharach Instrument Company
625 Alpha Drive
Pittsburgh, PA 15238

The J-W Model MV-2 Mercury Vapor Sniffer is a dual-range portable hand-held instrument for the detection and measurement of mercury vapors in working areas. Definite health hazards exist where mercury is produced, processed, stored and used, and the detector provides a convenient and simple means of reading the mercury vapor concentration on a meter and relating it to the published or established Threshold Limit Value.

Operating principle

The sample is drawn into the detector and through the absorption chamber by a small motor-driven suction fan powered by the battery. All that is required to put the detector in operation is to turn the control knob to the bias position, adjust to zero, set air knob to sampling position, and read the vapor concentration on the meter.

The vapors of some organic compounds such as benzene and its compounds, halogenated hydrocarbons and particulates absorb ultraviolet light at the lamp frequency. Normally this slight interference does not present a problem.

The detector has an efficient built-in filter which permits the meter to be zeroed in a contaminated atmosphere and then switched immediately to read the vapor concentration.

Physical description

The Model MV-2 is a self-contained battery-powered instrument housed in a lightweight steel case measuring 11⅜" × 4¾" × 4⅜" and weighs 6 lbs. The indicating meter is calibrated in milligrams per cubic meter of air. All controls and the carrying handle are mounted in the top of the case. The case itself houses the batteries, the 2537 Angstrom UV source lamp, the atomic absorption chamber, the photo-electric cell and all other operating components. A slip-on connection is provided in the end of the case for an extension probe when used. The probe is constructed of aluminum, measuring 12" long × 3.8" o.d. This instrument is powered by 12 volt Ni-Cad rechargeable battery which has 8 hours life under normal usage.

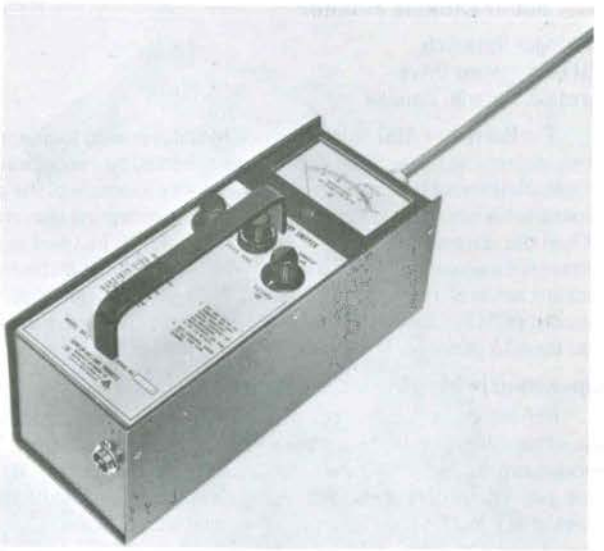


Figure V-120 — J-W Model MV-2 Mercury Vapor Sniffer.

Performance data

Meter ranges: 0–0.2 and 0–1.0 mg/m^3. *Sensitivity:* > 0.01 mg/m^3. *Accuracy:* ± 5% FSD.

AISI Sulfur Dioxide Monitor

Barringer Research
304 Carlingview Drive
Rexdale, Ontario, Canada

The Barringer AISI Sulfur Dioxide Monitor is used to quantitatively determine the amount of SO_2 being emitted by a source such as a stack without having to physically procure a sample of the gas. Operation is based upon correlation with the absorption spectra of SO_2 in the ultraviolet. Hence, normal skylight may be used as the ultraviolet source and measurement obtained with the instrument located several hundred feet from the source. Typically, the amount of SO_2 being emitted from a stack may be determined in less than 15 minutes.

Operating principle

Almost every gas has the property of absorbing radiation in the ultraviolet, visible, or infrared portion of the spectrum. This produces a characteristic absorption spectrum which is specific for that gas. Operation of the SO_2 monitor is based on the use of a correlation method which compares a selected portion of the spectrum of the gas being analyzed to a reference spectrum contained in the instrument. The reference spectrum consists of an enhanced photographic reproduction of a typical SO_2 spectrum. The photograph is used as a mask for comparison purposes during operation of the equipment.

As shown in Figure V-121, the correlation mask is permanently inserted in the exit aperature of the instrument. Light passes through the flue gas and then to the entrance slit. A vibrating refractor plate displaces the image of the entrance slit with a side-to-side motion. The light is then dispersed by a diffraction grating such that the portion of the spectrum containing the SO_2 absorption lines is swept back and forth across the mask. If sulfur dioxide is present in the flue gas, there will be a particular instant when the spectrum of the incoming light exactly matches the mask, as the exact same absorption pattern will be present. This matching is detected by means of a photomultiplier located behind the mask. Modulation of the signal received by the photomultiplier is indicative of the presence of sulfur dioxide, and the strength of the signal is proportional to the amount of sulfur dioxide present in the flue gas.

In operation, the viewing unit is first sighted on the target plume near the stack mouth. This is done using a built-in sighting telescope. The vertical aperature is then adjusted so that only a small area in the center of the plume fills the field of view. The viewing unit is then moved to one side of the plume to zero out the background SO_2 level and readings are obtained with the self-contained calibration cells. Finally, the viewing unit is again centered on the plume and the reading noted. These readings, together with the stack diameter (which is the path length of interest in this case) and the emission temperature of the gas yields the SO_2 concentration in parts per million.

Physical description

The instrument is comprised of three unts: the electronic unit, the viewing unit, and the tripod with the total weight under 100 lbs. Internal rechargeable batteries (8 hours operation) power this instrument. It also has an internal battery charger which operates on 115 VAC, 60 Hz power supply.

Figure V-121 — Dispersive system of AISI Sulfur Dioxide Monitor.

Performance data

Range: 1.0–2000 ppm-meters (Option 1) or 500–40,000 ppm-meters (Option 2). Sensitivity of Option 1 is 2 ppm-meters and of Option 2, 40 ppm-meters. *Field of view:* 0.15° horizontal; vertical is adjustable from 0° to 1.5°. Meter and chart recorder are located on the front panel. (*Note:* Option 1 is a high-sensitivity instrument designed for such applications as plume tracing. Option 2 is designed specifically for remote stack monitoring. They may not be converted in the field.

Model K-23B Mercury Vapor Meter

Beckman Instruments, Inc.
Process Instruments Division
2500 N. Harbor Boulevard
Fullerton, CA 92634

The Beckman Model K-23B Mercury Vapor Meter is designed to provide an instantaneous direct reading of the toxicity level of mercury vapor in an enclosed environment. Areas where this instrument finds application include: OSHA compliance monitoring, chlorine and caustic plants, mines, chemical laboratories, hospitals, wind tunnels, dry battery manufacturing facilities, thermometer manufacturing facilities, and dental laboratories.

Although mercury is a metal, it gives off a vapor which is toxic in concentrations exceeding 0.1 mg/m^3. Mercury spilled on a rough surface, such as a manufacturing facility's floor where thorough removal is virtually impossible, constitutes a potential hazard. Changing conditions of sunlight, temperature, and ventilation can often affect its vaporization to the extent that even a small quantity can contaminate an enclosed area within an hour. For this reason, it is essential that working areas in which mercury is used be checked regularly with a Model K-23B to indicate hazardous mercury vapor levels and aid in their elimination.

Operating principle

The Beckman Model K-23B is a portable, ultraviolet filter photometer tuned to a wavelength of 253.7 m — the wavelength at which mercury vapor absorbs light. A low-pressure mercury vapor lamp, located at the bottom of the instrument, acts as the light source. At the top of the instrument, a phototube measures the amount of light passing through the intervening space. Any mercury vapor present will reduce the quantity of light reaching the phototube in direct ratio to the vapor concentration.

To ensure optimum accuracy at all times, a calibration filter assembly is built into the meter. Filters, having known absorption factors, can be switched into the optical path of the meter to provide standard references for calibration. The calibration filter assembly ensures meter accuracy throughout the life of the instrument.

Physical description

The Model K-23B weighs 7 lbs and measures 13" × 8½" × 4½".

Figure V-122 — Beckman Model K-23B Mercury Vapor Meter.

Performance data

Ranges: 0 to 0.1 mg/m^3; 0 to 1.0 mg/m^3. *Accuracy:* ± 10% of reading or ± minimum scale division, whichever is larger. *Output:* 0 to 100 mV plus meter. *Noise:* 0 to 0.1 scale, ± 1.5% full scale; 0 to 1.0 scale, ± 0.5% full scale. *Power requirements:* 115 VAC, 50/60 Hz, 15 watts.

Model 1003 Ozone Monitor

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

The Model 1003 Ozone Monitor continuously monitors the concentration of ozone in the air in parts per million which can be read directly from the front panel. An analog output is available for continuous strip-chart recording, and a binary-coded-decimal (BCD) output enables direct interfacing with a computer or a printer. The ozone monitor can be readily integrated into an environmental monitoring and control system.

Figure V-123 — Dasibi Model-1003 Ozone Monitor.

Operation principle

Ozone concentration is measured by detecting the absorption level of ultraviolet light (UV) within a sample volume of air. As shown in Figure V-129, air entering the inlet divides into two gas lines. In one line, a gas filter removes the ozone. Both the unfiltered gas and the filtered gas enter a gas switch. The two gas lines are alternately connected by the gas switch to the absorption chamber.

The absorption chamber has two windows at opposite ends through which UV can enter or leave. The ultraviolet source is at one end of the chamber, and the sample detector is at the opposite end. A small portion of UV from the source is reflected into the reference detector. The UV which impinges upon the the sample detector has passed through the gas sample in the absorption chamber. The sample detector and its associated circuitry constitute the sample channel; the reference detector and its associated circuitry constitute the reference channel.

Measurement starts when a signal from the gas switch indicates that the filtered gas is flowing through the absorption chamber. At that time, the sample channel starts to measure photons and integrate the result. At the same time, the reference channel starts counting a standard number of photons. When this count is completed, the integration is halted. The same sequence is repeated for the unfiltered gas. The difference between the integrated results for the filtered gas and for the unfiltered gas is computed and displayed as the data output. This difference is a measure of the ozone concentration in the gas sample. The air is thus sampled and measured in continous cycles.

Physical description

The Model 1003 weighs 45 lbs and measures 5¼" × 15" × 18⅝"; 19" wide for optional rack mount version. Its power requirements are 105–130 volt, 50–60 Hz, 75 watts.

Specification

Measurement range: 0.01 to 9.99 ppm. *Sensitivity:* 0.01 ppm. *Accuracy:* ± 3% (based on Beer's law). *Scale factor:* adjustable to any standard. *Drift:* < 0.001 ppm/week non-cumulative. *Zero span:* ± 0.2%/°F << 0.001 ppm. *Repeatability:* 2% after 5 minutes warmup (for lowest drift, allow 1 hour warmup). *Interval:* 8 or 30 seconds. *Flow rate:* 7 lpm for 8 seconds interval; 1.0 lpm for 30 minute for 30 seconds interval. *Zero return:* 1 interval from 1.00 ppm.

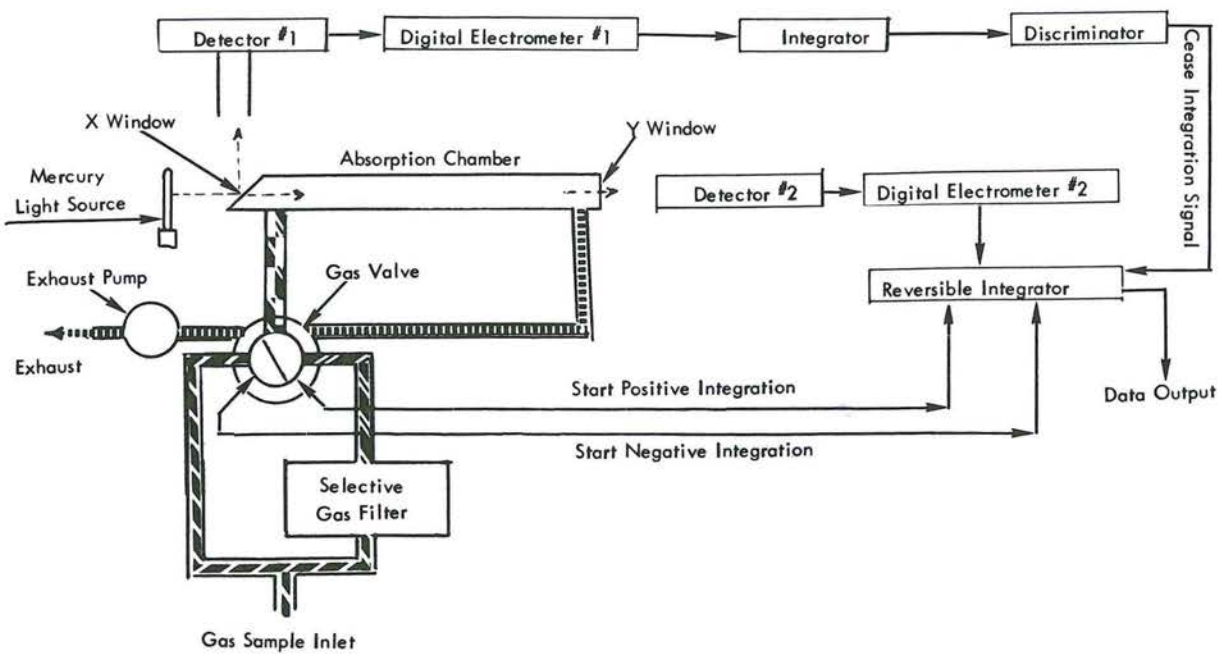


Figure V-124 — Block diagram of Model-1003.

Output panel: 0.01 to 10.00 ppm. *Optional analog:* 0 to 9.99 V; BCD (option): 8-4-2-1, standard TTL with data ready pulse. 0 level, 0.4 V max; 1 level, 2.4 V min. *Pulse width:* 1 millisecond.

Environmental: temperature, 32° to 120°F; meets vibration and shock constraints typically encountered in shipping, aircraft, and mobile vans; maintenance, 1000 hr MTBM (mean time between maintenance) under typical conditions; power requirement, 105 to 130 VAC, 50 to 60 Hz, 75 W.

Stack Gas Analyzers for SO_2, NO_2 and NO_x

Du Pont Company
Instrument Products Division
Wilmington, DE 19898

The Du Pont 460 Gas Analyzer Systems are designed for the continuous monitoring of SO_2 and NO_2 in stack emissions at power generating stations and industrial plants. The 461 Analyzer system is designed for source monitoring of nitrogen oxides. It measures NO_2 and analyzes for NO by converting it to NO_2.

Operating principle

The analyses are based on the strong ultraviolet absorption of $SO_2$and the visible absorption of NO_2. The Du Pont 460 Photometric Analyzer, using a patented split beam configuration, measures the difference in light absorption at two different wavelengths (see Figure V-125).

For SO_2 analysis, the 302 micrometer (μm) measuring wavelength is strongly absorbed by the SO_2; the 546 μm reference wavelength is not absorbed. Interference from any NO_2 in the sample is minimized since NO_2 absorbs almost equally at each of these wavelengths.

For the NO_2 analysis, a 436 μm measuring wavelength and the 546 μm reference wavelength are used. SO_2 does not interfere since it has no absorption at either wavelength. An optical filter for blocking out wavelengths below 436 mm is installed between the lamp and the sample cell to eliminate photochemical reactions.

Figure V-126 — Du Pont 461 Gas Analyzer System for NO_x.

Figure V-125 — Du Pont 460 Gas Analyzer System for SO_2 and NO_2.

Either manual or automatic-operated filter switching mechanisms can be provided to allow one analyzer to be used for both SO_2 and NO_2 measurements.

The Du Pont sample handling system (Figure V-128) employs an air aspirator of Teflon® TFE resin to draw a sample continuously from the stack. Insulated and heated tubing of Teflon FEP resin is generally used for the sample line. The sample handling components, including the sample cell, are kept at elevated temperatures to avoid condensation and the associated problems of corrosion and nonrepresentative sampling. A vacuum-break system holds the sample cell pressure constant.

Since nitric oxide (NO) is essentially transparent in the visible and ultraviolet, quantitative conversion to NO_2 is required for its measurement by the Du Pont Photometric Analyzer. The Du Pont 461 Analysis System achieves this conversion by reaction, the sample containing NO with oxygen at 5 atmospheres pressure. This reaction is both rapid and reproducible. The Analyzer System provides a measurement without interference from particulates and most other constituents found in stack gases.

Specifications, 460 SO_2/NO_2 Analyzer Systems

Ranges: 0–200 ppm to 0–100% SO_2 or NO_2. *Speed of response:* 15 seconds or less. *Analyzer output:* linear, 0–10 mV standard, 4–20 mA and 10–50 mA available. Integrally mounted recorder optional. *Reproducibility:* 1% of full scale. *Accuracy:* ± 2% of full scale. *Linearity:* better than 2%. An optional calibration filter corresponding to a fixed SO_2 concentration is provided. *Utility*

requirements: 115V, 0 Hz, 2000 watts maximum (50 Hz available); compressed air at 30–80 psig. *Electrical classification:* general purpose; systems designed for Class I, Group D, Divisions 1 and 2 are also available.

Specifications, 461 NO_x Analyzer System

Ranges: 0–150 ppm to 0–100%. *Time cycle:* 5 minutes, including zero standardization, NO_2 and NO analysis. *Analyzer output:* linear, 0–10 mV standard; 4–20 mA and 10–50 mA outputs available; integrally mounted recorder optional. *Reproducibility:* 1% of full scale. *Accuracy:* ± 2% of full scale. *Linearity:* better than 2%. An optical calibration filter corresponding to a fixed NO_2 concentration is provided. *Zero standardization:* automatic. *Utility requirements:* 115 V, 60 Hz, 1000 watts; 50 Hz available; compressed air at 30–80 psig; cylinder oxygen, 60 psig or greater. *Electrical classification:* general purpose; systems designed for Class I, Group D, Division 1 or 2 are also available.

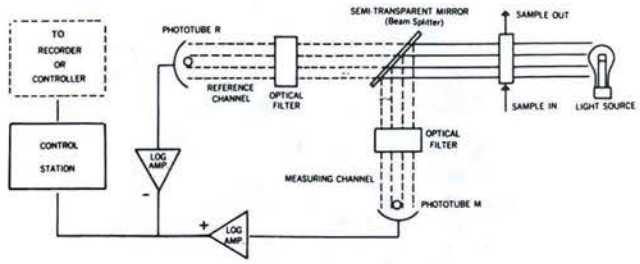


Figure V-127 — Schematic of split-beam photometer system used in the Du Pont 460 and 461 Gas Analyzers.

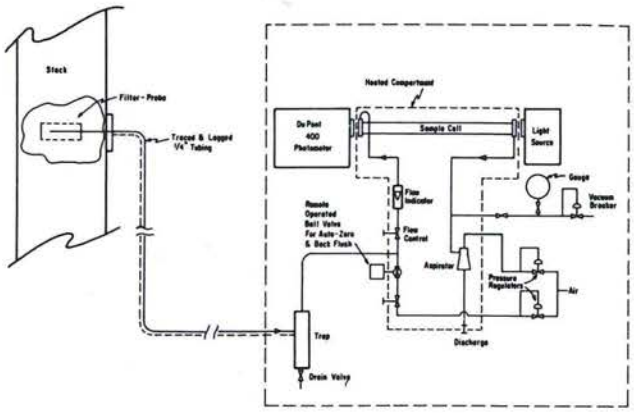


Figure V-128 — Du Pont 460 Gas Analyzer System (SO_2/NO_2) flow diagram.

SM1000 Air Monitoring Systems

Lear Siegler
Environmental Technology Division
One Inverness Drive East
Englewood, CO 80110

The SM1000 Monitoring Systems are tuned, second-derivative spectrometers which measure trace concentrations of nitrogen dioxide, nitric oxide, sulfur dioxide, ammonia, or various other compounds in complex, ambient-air mixtures. These instruments directly measure the narrow-band absorption of visible or ultraviolet radiation which is characteristic of the specific to the molecules of the compound being measured. This measured property is so proprietary to the individual molecules that an extremely high degree of interference rejection is possible with the SM1000 instruments. Furthermore, the direct monitoring of this physical property is performed in real time, without sample alteration, without sample conditioning, and without secondary reactions.

Operating principle

Derivative spectroscopy is concerned with the shape characteristics, rather than with the basic intensity changes, of a spectral distribution. The slope and curvature characteristics are often quite large, very specific, and largely independent of intensity. Because these shape characteristics are large, yet specific to individual compounds, extremely complex separations of component gases are possible, while the sensitivity over conventional spectrometric techniques increases by several decades. The SM1000 Air Monitoring Systems make full use of these advantages and open the way for monitoring ambient air where previously available techniques have been unsuitable due to their lack of specificity, low-end sensitivity, or excessive analysis time.

Physical description

The analyzer unit is 11" × 11" × 16", while the optical unit measures 8" × 34" × 16". Weight varies according to cell selected and application used. *Power requirements:* 115 VAC ± 10%, 60 to 400 Hz, 150 watts is standard; other power configurations are available. *Sampling rate:* single-component compound measurement is continuous. "Read" and "Test" modes are selectable from the front panel. "Read" mode output is ppm concentration and the "Test" mode output is one of several selectable test voltages. Instrument is equipped with a panel meter for direct readout and with connections for an analog recorder.

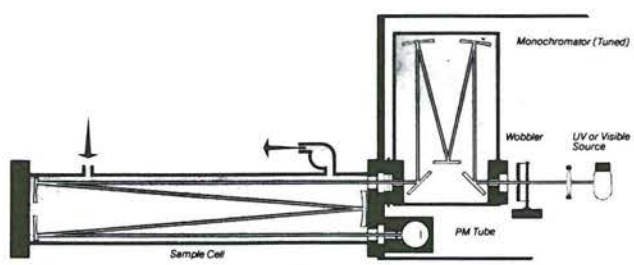


Figure V-129 — Schematic diagram of the Lear Siegler SM1000 Optical System.

Performance data

Materials detected are tuned, single-component monitoring of NO_2, NO, SO_2, or NH_3. Instrument may also be tuned to monitor any other compound which exhibits narrow-band absorption of ultraviolet or visible light radiation; e.g., acetylene, aniline, arsine, benzene, bromine, chlorine, formaldehyde, iodine, phenol, styrene, toluene, or many others. The instruments are capable of measuring compounds to which they are tuned in concentrations from 0 to 2.0 ppm (higher if necessary). The positive or negative response caused by a substance other than the one being measured by this instrument is < 0.005 ppm. The performance of the SM1000 Air

Monitoring Systems meets all Federal Equivalent and Reference Method specifications and is summarized as follows for the compounds NO, NO_2 and SO_2; standard ranges, 0 to 0.5 ppm; noise, 0.005 ppm; MDC, 0.010 ppm; zero drift, ± 0.015 for 12 and 24 hours; span drift, ± 5%/24 hr; rise and fall time (95%), 300 sec. *Precison:* for NO and SO_2 is 0.01 ppm, for NO_2 it is 0.02 ppm.

Molecular band absorption and the curvature of individual bands are unique properties. This provides the key to the high interference-rejection capabilities of these second-derivative spectrometers. In order to interfere with a measurement, a compound must exhibit narrowband absorption creating curvature in the intensity distribution at the identical wavelength and of the same magnitude as the compound of interest. Such stringent requirements for an interferent insure a highly specific measurement in the complex air mixtures typically found around major cities.

A span cell containing a relatively high concentration of the actual compound is provided for each instrument. This cell does not deteriorate with time, so it is a permanent optical standard of the compound being monitored. A switch on the front panel activates a solenoid that places the span cell in the light path, providing an easy method of obtaining accurate field calibrations in accordance with central laboratory standards, without generating a secondary gas.

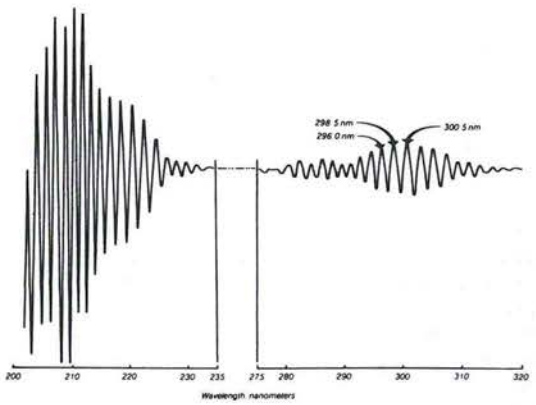


Figure V-130 — Sulfur Dioxide Second-Derivative Spectrum. Wavelengths: NO is monitored at 226.5 nm (UV); NO_2 at 448.0 nm (visible); NH_3 at 209.0 nm (UV); SO_2 at 296.0, 298.5, or 300.5 nm (UV).

SM400 Laboratory Derivative Spectrometer

Lear Siegler
(address above)

The SM400 Laboratory Derivative Spectrometer is a gas-phase, scanning analyzer that specifically identifies individual component gases in complex mixtures and accurately measures their concentrations. Identification is accomplished by directly detecting each compound's narrow-band absorption of ultraviolet or visible radiation — a physical property that is characteristic of and specific to each individual compound. The direct monitoring of this physical property is performed in real-time, without sample alteration or conditioning, and without secondary reactions.

Since there are a large number of compounds which exhibit characteristic narrow-band absorption spectra in either ultraviolet or visible wavelengths, the SM400 can be used for detection and measurement in a wide variety of applications. Included among the detectable and measurable compounds are most of the aromatic hydrocarbons, the aldehydes, metals in the vapor state, and a wide range of others, including many common air pollutants and complex mixtures of environmental interest.

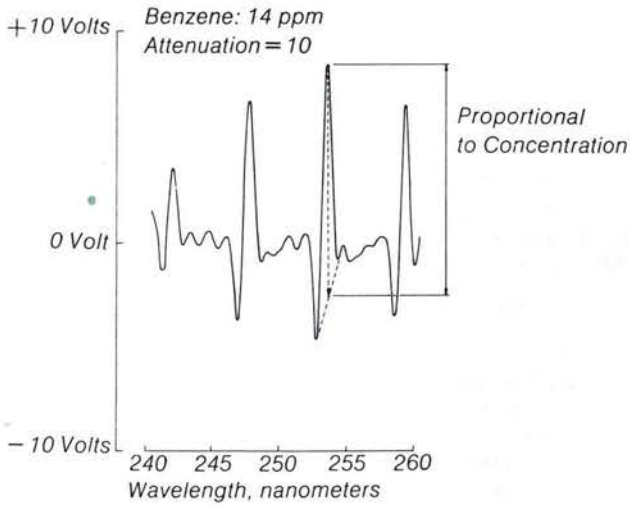


Figure V-132 — Benzene second-derivative absorption spectrum.

Figure V-131 — Lear Siegler SM400 Laboratory Derivative Spectrometer.

Operating principle

Derivative spectroscopy is concerned with the shape characteristics, rather than with the basic intensity changes, or a spectral distribution. The slope and curvature characteristics are often quite large, very specific, and largely independent of intensity. Because these shape characteristics are large, yet specific to individual compounds, extremely complex separations of component gases are possible, while the sensitivity over conventional spectrometric techniques increases by several decades. The SM400 Laboratory Derivative Spectrometer makes full use of these advantages and opens the way for highly specific and accurate analytical studies where previously available techniques have been unsuitable due to their lack of specificity, low-end sensitivity, or excessive analysis time.

Performance data

The SM400 is capable of identifying any compound which exhibits narrow-band absorption of ultraviolet or visible radiation. It is capable of continuously monitoring a single compound. A partial list of compounds which can be identified and measured using the SM400 is: acetaldehyde, acetylene, acrolein, ammonia, aniline, benzaldehyde, benzene, benzene in water, bromine, bromobenzene, 2,3-butanedione, carbon disulfide, chlorine, dimethylamine, ethylbenzene, formaldehyde, furfural, glyoxal, iodine, isopropylbenzene, metaxylene, naphthalene, nitrogen dioxide, nitric oxide, nitrobenzene, orthobromoaniline, orthochlorobenzene, orthoxylene, oxygen, ozone, paradichlorobenzene, paraxylene, Pest Strip, phenol, pyrrodiline, pyridine, styrene, sulfur dioxide, titanium tetrachloride, toluene, unsymmetrical dimethydrazine.

Low end detection extends down to the ppb concentration levels, and there is essentially no upper limit to the concentrations which can be detected. Where concentrations are so high that an unusually large portion of the light radiation is absorbed, the parthlength through the sample can be reduced the prevent total light absorption.

Molecular band absorption and the curvature of individual bands are unique properties. This provides the key to the high interference-rejection capabilities of the SM400. In order to interfere with a measurement, a compound must exhibit narrow-band absorption creating curvature in the intensity distribution at the identical wavelength and of the same magnitude as the compound of interest. Such stringent requirements for an interferent insure a highly specific measurement in the most complex gas mixtures.

The standard wavelength range is 2000 Å to 6000 Å. Selection of UV or visible light is manual from the front panel. The wavelength is displayed on the front panel in angstroms. Two standard, forward, scan speeds are provided and are selectable from the front panel — 25 Å/minute and 100 Å/minute. "Dwell" mode operation is available for continous, single-component analysis. Four time constants are switch selectable from the front panel — 1, 3, 10, or 30 seconds. Four attenuation ranges are switch selectable from the front panel — 0.33, 1.0, 3.3, or 10. *Resolution:* with the standard 100-micron silt width, the resolution is 4Å. Both 25 and 50-micron slit widths are available on request.

Physical description

The control unit is 24" × 20" × 15" and the sample cell unit is 9" × 58" × 24"; together their weight is 132 lbs. *Power requirements:* 115 VAC ± 10%, Hz, 150 watts; other power configuration are available. Sample flow through the cell may be continous (analysis is independent of sample-rate), or may be stopped to continuously analyze a fixed sample. Two standard, forward scan speeds are provided and are selectable from the front panel — 25 angstroms/minute and 100 antstroms/minute. "Dwell" mode operation is available for continuous, single-component analysis. Instrument output to an analog chart recorder may be switch selected to provide either the second-derivative spectrum (the compound is identified by the peak location, and the concentration is measured by the peak height) or a direct-absorption.

Instantaneous Vapor Detector

Sunshine Scientific Instruments
1810 Grant Avenue
Philadelphia, PA 19115

The Instantaneous Vapor Detector is intended primarily for the detection of mercury vapor, also can be used for the detection of other vapors in specified ranges of concentration. Additional vapors which may be detected are aniline, benzene, alcohol, diethyl acetal, illuminating gas, acetone, naptha, pyridine, toluene, xylene, and many other toxic vapors. With this device, toxic concentrations are immediately indicated and the detectors are used by manufacturers of electric apparatus, instruments, bulbs, glassware, fur and salt, by chemical, metal-mining and smelting industries, and by insurance companies and laboratories. The basic vapor detector is Model 38D. This model is not suitable for use in an explosive atmosphere. Model 38E is an explosion-resistant unit and may be used in sampling for the presence of mercury contamination in such an atmosphere by operating under a standard instrument procedure of continuous air purge. Model 38F incorporates a central meter to actuate an electrical circuit for alarms or lamps.

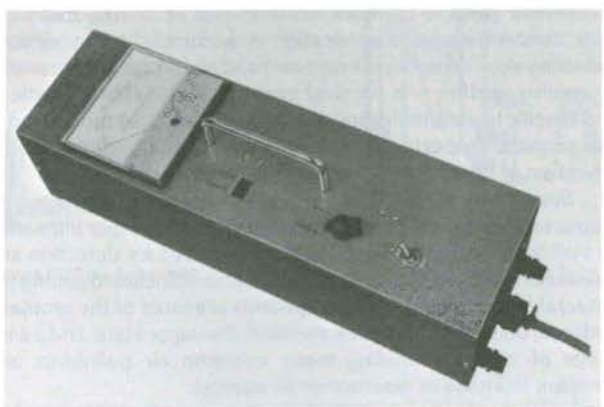


Figure V-133 — Instantaneous Vapor Detector, Model 38D.

Operating principle

Operation of the vapor detector is based on the fact that ultraviolet light is absorbed by vapors such as mercury. This same principle is also used for the detection of certain other vapors which have selective absorption characteristics for ultraviolet radiation. For this reason, the identity of the vapor under test must be known and the vapor must be free from other substances which will absorb or obstruct ultraviolet light. In addition, the vapor should be relatively uncontaminated by extraneous substances such as fog, dust, or smoke.

This instrument (all models) has an exposure chamber with a source of ultraviolet light at one end. Two phototubes are located near the other end of the chamber. One of the phototubes is connected to the germicidal lamp to maintain a constant level of radiation at the wave length of 2537 Angstroms. The other phototube senses the exposure chamber and, through a solid-state amplifier, indicates upon the panel meter.

Physical description

Model 38D measures 5" × 4" × 17", weighs about 8 lbs, and has power requirements of 25 watts, 120 VAC.

Performance data

This instrument is highly sensitive to low levels of mercury concentrations and in varying degrees is sensitive to the following

substances: acetone, aniline, benzene, benzyl alcohol, diethyl acetal, illuminating gas, naphtha, pyridine, toluene, xylene, and others. Its range is 0.01 mg/m^3 with an accuracy of ± 5% of full scale.

Features: warmup time < 15 minutes; < 1% change in reading for 10% line voltage variation. Low power consumption permits operation from a battery-powered inverter for complete portability. *Special options include:* explosion-resistant Model 38E, recorder output, single or dual set point meter (Model 38F), panel or rack mounting, audible/visable alarms, and systems for monitoring multiple locations.

Chemiluminescence Air Pollution Analyzers

AeroChem Research Laboratories, Inc.
Syborn Corporation
P.O. Box 12
Princeton, NJ 08540

AeroChem Chemiluminescence Air Pollution Analyzers, Models AA-1, -2, -3, -5, and -6, offer a single instrument with potential for measuring concentrations of oxides of nitrogen or ozone over a wide range such as encountered in the follow applications: 1) ambient air quality in stationary and mobile monitoring stations; 2) OSHA compliance testing; 3) industrial emissions from power plants, incinerators, stationary gas engines and nitric acid plants; and 4) exhausts from all types of fuel burning engines such as automobile, diesels, turbines, and jets. These instruments are particularly suitable for laboratory applications in which wide variations of concentrations and fast response times are required.

Other applications include the use of the monitor for multiple sampling with a cycle time as small as 30 seconds per point. Correct selection and installation of sampling equipment is extremely important. Sampling and other peripheral equipment is available and can be supplied for each individual application.

Figure V-134 — AeroChem Model AA-S Chemiluminescence Air Pollution Analyzer.

Operating principle

In the multifunctional NO-NO_x-O_3 chemiluminescence detector (Model AA-5), the sample gas being monitored and the second reactant — partially ozonated air (1% v/v) for NO/NO_x or NO/air for O_3 — are drawn into the reaction vessel, p = 250 Torr (135" H_2O), through separate inlets by means of a stainless steel bellows pump. Depending on the operating mode, the sample flows either through the NO_xconverter (NO_x mode) or bypasses it (NO and O_3 modes). The volumetric gas flow rates are set by sonic orifices at approximately 1.5 l (STP) min^{-1} and 0.5 l (STP) min^{-1} for the sample and second reactant gas, respectively. Rapid mixing occurs in the reactor and a chemiluminescent reaction takes place:

$$NO + O_3 \rightarrow NO_2 + O_2 + h\nu$$

The intensity of the light emitted is measured by the PMT and associated read-out devices (current meter and recorder). The light intensity, I, of the NO/O_3 reaction is given by: $I = k[NO][O_3]/P$ in which k = proportionality constant (rate coefficient, [ ] denotes concentrations, and P = pressure. At constant pressure and in the presence of a constant excess O_3 concentration, the intensity, and hence the phototube current reading, is directly proportional to the amount of NO in the sample gas flowing through the reactor. If O_3

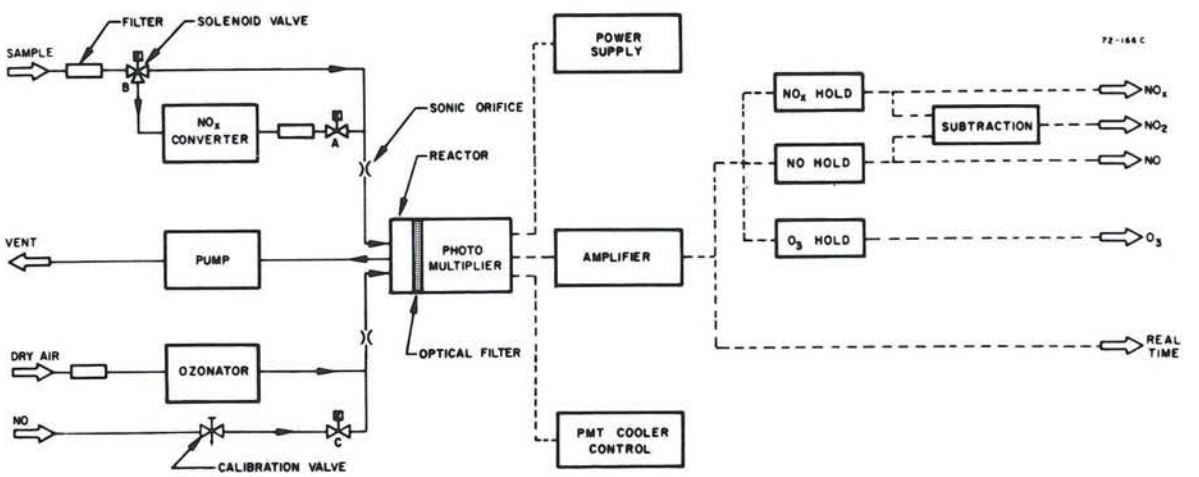


Figure V-135 — Schematic of Model AA-S NO-NO_x-NO_2-O_3 Chemiluminescence Monitor.

is to be monitored, the roles of NO and O_3 in this description are simply reversed. After calibration with a sample of know concentration, a continuous record of the concentration of the pollutant in the sample gas is obtained.

NO_x (= NO + NO_2) is measured by flowing the sample through a unique noble metal thermal catalytic converter before introduction into the reactor. Inside the converter the decomposition $2NO_2 \rightarrow 2NO + O_2$ takes place and the total NO_x is subsequently measured as NO in the reactor.

NO_2 is obtained by automatic electronic subtraction of the NO from the NO_x readings.

O_3 is produced for the reaction (NO/NO_x modes) by flowing dried room air through a self-contained electrical discharge ozone generator. If a source of O_2 is used instead of the dried room air, the performance of the analyzer is improved. In the O_3 measuring mode the same dried room air flow rate is drawn through the second reactant line, but the ozonator is de-energized and a solenoid valve is opened to introduce a calibrated volume flow rate of NO.

In the high sensitivity ranges the background current of the PMT varies with temperature. This effect is counteracted by placing the PMT in a thermoelectrically (air) cooled housing at a controlled temperature, 15°C (59°F), thus reducing the zero and span drift to negligible values. The temperature control system uses a thermistor detection element which forms one leg of a resistance bridge. The bridge current is amplified and used to control a thermoelectric cooler.

The reactor chamber is maintained at a controlled temperature, 43°C (110°F), to provide improved signal stability and minimize condensation of water present in the sample gas.

The NO_x converter efficiency is dependent on its operating temperature of 1000°C (1832°F). A silicon controlled rectifier (SCR) and its related circuitry are used to control this temperature.

Models other than the AA-5 may be somewhat different.

Physical description

Size and weight: 12¼" × 19" × 23" including room air dryer; 88 lbs. *Power requirements:* 490 watts. *Sampling rate:* 1.5 1 (STP) min^{-1}. The real-time value of the gas being measured is displayed on a 6" analog front panel meter and a rear panel recorder terminal. Also available at a rear panel recorder terminal are the continuous outputs of NO, NO_x, NO_2 and O_3, each updated every cycle. All recorder outputs are adjustable from 0 to 1 volt.

Performance data

Model AA-1 measures NO; Model AA-2 measures NO, NO_x; Model AA-3 measures NO, NO_x, O_3; Model AA-5 measures NO, NO_x, NO_2, O_3; Model AA-6 measures NO, NO_x, NO_2. *Usefull range:* 0.002 to 1000 ppm; full scale ranges from 0.1 to 1000 ppm. *Specificity:* no interferences in the NO and O_3 modes; NH_3 in NO_x mode, which is eliminated by use of a specific NH_3 chemical scrubber. *Response time:* 5 sec. *Average time:* gas residence time is < 1 sec; subsequent response to a step change is 90% in 5 sec. *Stability:* 1% in 24 hrs in 0.1 ppm FS. *Accuracy:* limited by calibration sample. Precision of span setting is 1% FS.

Model US400 Carbon Monoxide Analyzer

Bacharach Instrument Company
625 Alpha Drive
Pittsburgh, PA 15238

The Model US400 is designed for the continuous measurement of low concentrations of carbon monoxide in the field of pollution monitoring and control, monitoring of work areas, garages, ventilation systems, and industrial process streams. CO in air, or CO in many complex gaseous mixtures may be analyzed accurately and quickly.

Operating principle

The sample to be analyzed is passed through a heatless air dryer, an activated charcoal filter and a heat exchanger. The dryer removes moisture and the charcoal filter absorbs gases and vapors, particularly hydrocarbons which may cause interference if present in significant concentrations. The main functions of the heat exchanger are to precondition the sample and to provide a constant temperature for a variable range of input air temperatures. The conditioned sample is then brought into contact with a heated solid-state mercury oxide pellet. Determination of carbon monoxide is based upon the direct measurement of the mercury vapor reduced from the metal oxide by oxidation of the CO in the sample. The mercury vapor produced is the analog of the CO in the sample stream and permits the readout to be calibrated in terms of carbon monoxide. The mercury vapor is measured by means of an ultraviolet filter photometer, focused on the 2537 Angstrom line of mercury. Before being discharged to atmosphere, the sample is passed through an exhaust filter, where mercury vapor is removed.

The sample flow is under compression in order to provide flow control over a wide range of temperatures and to eliminate the problem of temperature dependence of needle valves. The sample flow is pressure regulated and then passed through sapphire orifices. The heat exchanger, reaction chamber and photocell are temperature stabilized by means of "stepless" fullwave phase proportional controllers.

Physical description

The US400 can be furnished suitable for bench mounting or installed in standard 19" panel, suitable for rack or panel mounting.

Figure V-136 — Model US400L with bench mounting cabinet.

The bench mounting unit is chassis mounted and enclosed in a strong metal case. Operating controls and push-button control switches with integral signal lamps are displayed on the front panel and are readily accessible. The sample-drawing pump and remotely operated flow control valves are enclosed in a separate housing. The US400L cabinet weighs 25 pounds. The sample control cabinet is 12" square and weighs 10 lbs.

Performance data

Range: lowest range 0–5 ppm. *Ambient temperatures:* 40°to 110°F. *Altitude range:* sea level to 5000 feet. *Warm-up time:* 15 minutes. *Sample flow rate:* 2 cfh. *Span drift:* ± 2% of FSD. *Lag time:* 5 seconds. *Response time:* < 10 seconds for 90% FSD. *Sensitivity:* 0.1 ppm/mV. *Reproducibility:* 2% of FSD. *Recorder outputs:* floating or ground reference. *Power consumption:* analyzer 80 watts; sampling system 300 watts. *Power supply:* 115V ± 10, 60 Hz ± 2. After restoration of power following a power failure, the instrument will automatically restart without requiring operator adjustments.

Carbon Monoxide Analyzer DIF 7000

Beckman Instruments, Inc.
Advanced Technology Operations
2500 Harbor Boulevard
Fullerton, CA 92634

Using the DIF (dual-isotope fluorescence) technique changes in carbon monoxide concentrations as small as 0.1 ppm can be detected. Also, the instrument can be left untended for as long as a month, with drift held to less than one percent of reading. Designed particularly for field use, the DIF 7000 is relatively insensitive to mechanical vibrations and shock. This ruggedness is achieved by using a solid-state infrared detector instead of the traditional gas-filled, capacitance-microphone detector.

Figure V-137 — Beckman Carbon Monoxide Analyzer-DIF 7000.

Operating principle

The dual-isotope fluorescence technique involves producing IR radiation spectra to match that of two carbon monoxide isotopes, $^{12}C^{16}O$ and $^{13}C^{16}O$. These spectra "time-share" a single sample chamber, producing a sequence of CO concentration and reference signals which are then sensed by a rugged, solid-state photodiode detector. Operated for peak sensitivity to CO, the detector is thermally stabilized at -30°C by a thermoelectric cooler.

Many short-term fluctuations commonly observed while making low-level CO measurements are due to responses to contaminants in the sample. Using two spectra in a single sample chamber minimizes interferences from water vapor, particulates, or other gases, as these effects are self-cancelling. The high specificity and stability attained in this design are directly attributable to using spectrally specific IR energy — the product of CO fluorescence.

Physical description

The DIF 7000 measures 5½" × 17" × 16¾", weighs 32 lbs, and mounts on a standard RETMA rack. Its power requirements are 115 VAC ± 10%, 50–60 Hz. The ranges are: 20, 50, 100, 200 ppm, with a sensitivity of 0.1 ppm. Its accuracy is ± 1% of reading, ± 1% of full scale (accuracy is relative to calibration source), and linearity is ± 1%, 0 to 200 ppm. *Specificity:* interferent H_2O, rejection — 10,000:1; CO_2, rejection —20,000:1. The error resulting from all other common interferents is less than 0.5% of range. *Opacity tolerance:* no degradation of accuracy when measuring in a medium of up to 50% opacity. *Noise:* 0.5 ppm peak-to-peak on 20-ppm range, increasing to 1.0 ppm on 200 ppm range. *Span drift:* (at constant temp) 1% of reading/month. *Zero drift:* (at constant temp) 1 ppm/week. *Span and zero temperature coefficient:* 0.1% of reading/°F change in ambient temperature. *Response time:* (90% of final reading) 8 seconds on 200-ppm range; 25 seconds on 20-ppm range. *Output:* 100 mV (other outputs up to 10 volts available on special order). *Impendance:* < 400 ohms. *Warm-up time:* 30 minutes to full accuracy. *Ambient temperature:* 32° to 122°F. Ambient relative humidity: 90%

Model 950A Ozone Analyzer

Beckman Instruments, Inc.
Process Instruments Division
(address above)

Based on an improved chemiluminescent detection method, the Model 950A provides reliable analysis over a wide selection of full scale ranges for ambient air monitoring.

To ensure safe operation, the Model 950A utilizes a non-hazardous 90% CO_2/10% C_2H_4 mixture as the reactant gas, instead of pure ethylene typically required for chemiluminescent analysis. An automatic shut-off valve is also incorporated into the flow control system for added safety. In the event of a power failure, the shut-off valve automatically closes, preventing further flow of the CO_2/C_2H_4 mixture into the reaction chamber.

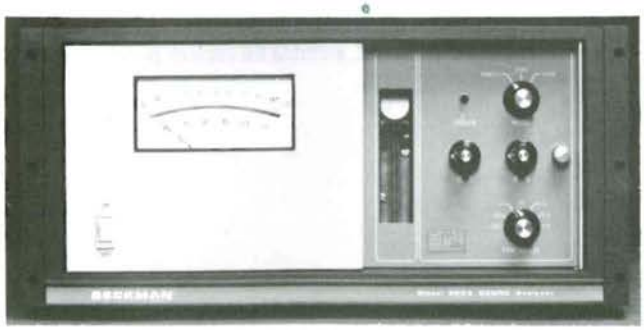


Figure V-138 — Model 950A Ozone Analyzer

Operating principle

The chemiluminescent detection method is based on the principle that ozone mixes with ethylene, resulting in a chemiluminescent reaction which provides a light emission directly proportional to the ozone (O_3) concentration in the ambient air sample.

During operation of the Model 950A, sample is admitted to the reaction chamber by an internal pump and flow control system at a constant flow rate of 400 cc per minute. The reactant mixture of CO_2/C_2H_4 is directed to the reaction chamber at a flow rate of 100 cc per minute. The intensity of the resulting light emission is then measured by a photomultipliter tube and associated electronics.

Performance data

Range: 0.025, 0.05, 0.1,0.25, 0.5, 1.0 and 2.5 P/10^6. *Noise:* 0% 0.000 P/10^6; 80% of span, 0.002 P/10^6. *Lower detectable limit:* 0.01 P/10^6 on 0.5 P/10^6 range. *Total interference equivalent:* < 0.005 P/10^6. *Zero drift:* < 0.005 P/10^6 per 12 hours; 0.001 P/10^6 per 24 hours. *Span drift:* ± 2% of full scale per 24 hours. *Lag time:* < 20 seconds. *Rise and fall time:* < 90 seconds. *Precision:* 20% of span, 0.003 P/10^6 80% of span, 0.004 P/10^6. *Ambient temperature:* 40° to 110°F (4° to 43°C); EPA designated at 68°F to 86°F (20° to 30°C). *Power requirements:* 105 to 125 volts, 50/60 Hz, 250 watts. *Outputs:* 10 mV, 100 mV, 1 V, 5 VDC. *Size:* 8¾" × 19" × 21 7/16".

Model 952A $NO/NO_x/NO_2$ Analyzer

Beckman Instruments, Inc.
Process Instruments Division
(address above)

The Model 952A ambient NO_2 monitor offers proven reliability and precision during field operation. The compact, self-contained unit features a heated, temperature-controlled reaction chamber for greater analytical stability, and a heated, temperature-controlled, carbon-base converter for NO_x analysis. The unique converter offers unlimited life and freedom from interference that may adversely affect other types of converters. Additionally, the Model 952A internally generates reactant ozone by exposing ambient air to ultraviolet (UV) radiation from a source lamp.

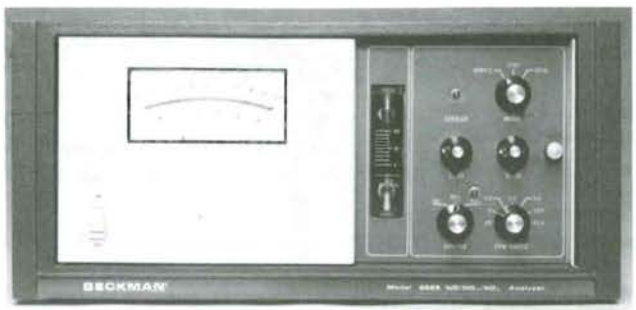


Figure V-139 — Model 952A $NO/NO_x/NO_2$ Analyzer.

Operating principle

The chemiluminescent detection method is based on the principle that nitric oxide (NO) reacts with ozone (O_3) to produce nitrogen dioxide (NO_2), 10% electronically excited nitrogen dioxide (NO_2*), and oxygen. Following the $NO-O_3$ reaction, the NO_2* molecules immediately revert to NO_2. This process emits photons that produce a light emission directly proportional to the NO concentration in the ambient air sample.

The detection method is the same for each parameter, but the analytical process differs slightly. For NO detection, the sample gas and the ozone are introduced directly into the reaction chamber for analysis. To determine NO_x ($NO + NO_2$) concentration, the sample is first routed through the converter where the NO_2 is converted to NO, and is then routed to the reaction chamber for analysis. NO_2 analysis is achieved by an electronic subtraction circuit that automatically cycles the analyzer between the NO and NO_x modes and then automatically determines the difference for a direct NO_2 output.

During operation of the Model 952A, air samples are admitted to the reaction chamber at a flow rate of 1.0 lpm, controlled by a back pressure regulator and flow restrictors. The reactant ozone is directed to the reaction chamber at a pre-set controlled flow rate. The intensity of the resulting light emission is then measured by a photomultiplier tube and associated electronics.

Performance data

Range: 0.25, 0.5, 1.0, 2.5, 5.0, 10.0, and 25.0 $P/10^6$. *Noise:* 0%, 0.002 $P/10^6$; 80% of span, 0.003 $P/10^6$. *Lower detectable limit:* 0.01 $P/10^6$. *Total interference equivalent:* 0.01 $P/10^6$. *Zero drift:* < 0.02 $P/10^6$ per 12 hours; < 0.005 $P/10^6$ per 24 hours. *Span drift:* $\pm 2\%$ of full scale per 24 hours. *Lag time:* 0.5 minutes. *Rise and fall time:* 1.5 minutes and 1.0 minutes, respectively. *Precision:* 20% of span, 0.005 $P/10^6$; 80% of span, 0.005 $P/10^6$. *Ambient temperature:* 40° to 110°F (4° to 43°C); EPA designated at 68°F to 86°F (20°C to 30°C). *Power requirements:* 105–125 V, 50/60 Hz, 500 watts maximum. *Outputs:* a) individual memory outputs for NO/NO_xNO_2, switch selectable for 10 mV, 100 mV, 1 V, or 5 VDC; b) primary output signal, switch selectable for 10 mV, 100 mV, 1 V, or 5 VDC.

Physical description

Size: 8¾" × 19" × 21 7/16".

Model 953 Fluorescent Ambient SO_2 Analyzer

Beckman Instruments, Inc.
Process Instruments Division
(address above)

Utilizing the fluorescent measurement technique, the Model 953 requires none of the support gases and reagents typically associated with SO_2 analyzers using flame photometric or coulometric methodologies. An internal zero gas scrubber permits ambient air to be used as the zero gas, eliminating the need for cumbersome zero air cylinders. An added feature is a Beckman-developed interferent reactor that eliminates interference due to polynuclear aromatics (PNAs) typically found in samples where dense automotive traffic prevails.

Figure V-140 — Model 953 Fluorescent Ambient SO_2 Analyzer.

Operating principle

Beckman's fluorescent monitoring methodology is based on the principle that SO_2 molecules fluoresce when irritated by ultraviolet (UV) light in the 1900–3900 Angstrom wave band. While the phenomenon does occur over this broad spectrum, the optimum excitation wavelength takes place in the narrow 2100–2300 Angstrom band. The Model 953 transmits a broad UV light band via a quartz deuterium lamp, and a narrow UV light band via a light-collimator assembly. The narrow UV light band passes through the sample reaction chamber where a blue sensitive photomultiplier tube then measures the resulting SO_2 fluorescence.

Performance data

Range: 0.25, 0.5 (EPA designated range), 1.0 (EPA designated range), 2.0 $P/10^6$ SO_2. *Noise:* 0.5 $P/10^6$ range, 0.001 $P/10^6$; 1.0 $P/10^6$

range, 0.001 P/10^6. *Lower detectable limit:* 0.5 P/10^6 range, 0.004 P/10^6; 1.0 P/10^6 range, 0.006 P/10^6. *Zero drift:* 0.5 P/10^6 range, $< \pm$ 0.005 P/10^6 per 24 hours; 1.0 P/10^6 range, $< \pm$ 0.006 P/10^6 per 24 hours. *Span drift:* 0.5 P/10^6 range, $< \pm$ 0.006 P/10^6 per 24 hours; 1.0 P/10^6 range, $< \pm$ 0.006 P/10^6 per 24 hours. *Precision:* 0.5 P/10^6 range, 0.003 P/10^6; 1.0 P/10^6 range, 0.003 P/10^6. *Total interference equivalent:* 0.5 P/10^6 range, $<$ 0.025 P/10^6; 1.0 P/10^6 range, $<$ 0.025 P/10^6. *Lag time:* 7.0 seconds and fall time, 3 minutes. *Ambient temperature:* 68°–86°F (20°–30°C). *Power requirements:* 105–125 VAC, 50/60 Hz (EPA designated for 60 Hz), 500 watts. Output: 10 mV, 100 mV, 1V, 5 VDC.

Physical description

Size and weight: 12.23" × 19" × 22.10"; approximately 90 lbs.

Friez® Ozone Analyzer

The Bendix Corporation
Environmental & Process Instruments Division
12345 Starkey Road
Largo, FL 33543

The Ozone Analyzer is used for ambient air monitoring, ozone waste treatment monitoring, and process control. It is sensitive only to ozone and not other oxidants.

Operating principle

The analyzer is based on the photometric detection of the chemiluminescence resulting from the flameless reaction of ethylene gas with ozone. There are no known interferences to this reaction. The extremely high sensitivity of this analyzer makes it ideal for ambient air monitoring for O_3. The only consumable chemical is ethylene gas. Weeks of maintenance-free, unattended operation may be achieved be using compressed gas cylinders.

Physical description

The Ozone Analyzer is housed within a cabinet which is suitable for either rack mounting or table top applications.

Figure V-141 — Bendix Friez® Ozone Analyzer.

Specifications

Recorder output: 0.1 VDC. *Amplifier ranges:* 0.01, 1.0 and 10 ppm O_3, full scale. *Electrometer time constants (damping):* 1, 10 and 40 seconds. *Internal air pump; zero (dark current) and span adjustments. Power requirement:* 115 VAC, 60 Hz, 250 watts.

Friez® Total Sulfur Analyzer

The Bendix Corporation
(address above)

The Total Sulfur Analyzer utilizes a flame photometric detector to measure the total sulfur content of ambient air.

Operating principle

A sample of air is burned in a hydrogen-rich flame and all the volatile sulfur is converted to energetically excited diatomic sulfur. Upon reaching a region above the flame, the sulfur undergoes a transition which results in the formation of unexcited sulfur atoms and an equivalent amount of light energy. The total sulfur in the sample can then be measured by monitoring the emitted light using a photomultiplier and recorder.

Physical description

The Total Sulfur Analyzer is housed within a cabinet which is suitable for either rack mounting or table top applications.

Figure V-142 — Bendix Friez® Total Sulfur Analyzer.

Specifications

Sensitivity: 0.01 to 10 ppm total sulfur. *Recorder output:* 0–1 VDC or 0–1 mV. *Log linearization:* between 0.01 and 1 ppm total sulfur. *Amplifier calibration signals:* 1×10^{-6}, 1×10^{-7}, 1×10^{-8}, and 1×10^{-9} amps. *Electrometer time constants (damping):* 1 and 10 seconds. External sample pump required; zero and full scale range adjust. *Power requirement:* 115 VAC, 60 Hz, 200 watts.

Halide Detector

GasTech, Inc.
Johnson Instruments Division
331 Fairchild Drive
Mountain View, CA 94043

Most halogenated compounds can be detected in concentration ranging from well below the threshold limit on up to several percent. Its primary field of application is by industrial hygienists in industrial solvent cleaning and fine chemical production facilities. It has also proven useful as process monitor. Response is a function of the type and number of halogen atoms, with greatest sensitivity obtainable on chlorine compounds.

Operating principle

The GasTech Halide Detector utilizes the phenomenon of increased spectral intensity of an AC spark in the presence of halogens in the atmosphere. The brightness of the spark in the ultraviolet region is directly proportional to the halogen content of the gas sampled. The increase in brightness, filtered through an ultraviolet transmitting filter, is monitored by a photocell and displayed on a panel meter.

Putting this principle to practical use, the sample is drawn through a flexible sampling line to a glass wool filter which removes any gross particulate matter or droplets. It then is drawn into the spark chamber and over the spark. Gases and spark decomposition products continuously exit from the chamber to the halide trap which is packed with activated charcoal. From this trap, the sample flows to the pump and through the flowmeter. It is then exhausted through the back of the case.

Any halogen compounds in the sample will cause the ultraviolet emission from the spark to brighten. This increase in spectral intensity will be detected by the photocell and will be indicated on the meter. Interpretation of this reading is made by relating the meter reading to a calibration curve based on the specific gas being tested.

Figure V-143 — GasTech Halide Detector.

Physical description

This continuously sampling instrument is 11" × 7" × 7", weighs 13 lbs, and has power requirements of 20 V, 50/60 Hz (also

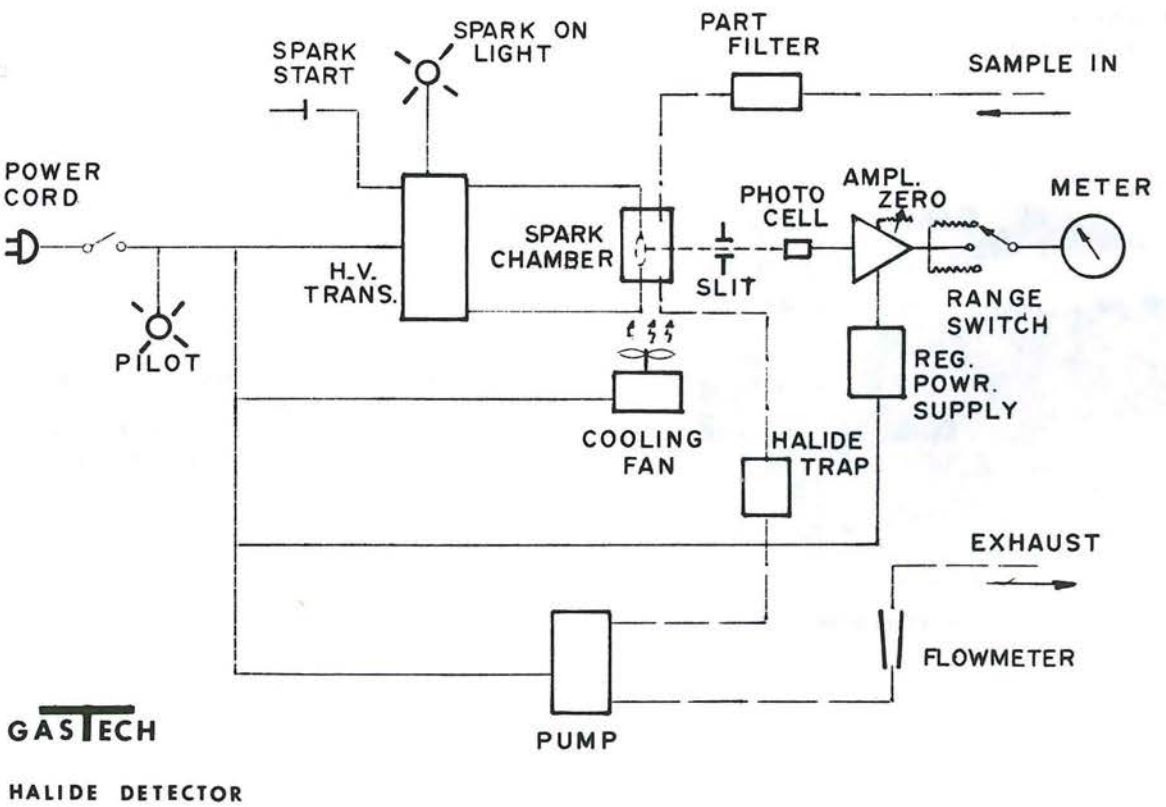


Figure V-144 — Block diagram for GasTech Halide Detector.

available in 230 V 50/60 Hz and 100 V 50/60 Hz versions). *Sampling rate:* continous. *Readout mode:* panel meter. Recorder output adjustable from 0–10 to 0–50 millivolts.

Performance data

Detection limits: threshold limit concentrations of most halogen-containing compounds are easily determinable on the meter. The instrument also has a range adjust in arithmetic ratios of 1, 3 and 10 permitting expanded readings up to 10,000 ppm. Interpretation of readings is determined by use of calibration curves provided with the instrument. The instrument is generally not subject to interference from non-halogenated substances, but it is affected by the presence of sulfur and cyanogen compounds. Sensitivity to these compounds is an order of magnitude less than sensitivity to halides. Response time is 3 to 5 seconds with a precision of ± 3% and an accuracy of ± 5%. Line voltage changes will have an effect on readings, otherwise stability is in the neighborhood of ± 5% per day.

Model 1100 Ozone Meter

McMillan Electronics Corp.
Subsidiary of Columbia Scientific Industries
P.O. Box 9908,
Austin, TX 78766

The Model 1100 Ozone Meter is used for ambient air monitoring and other applications where a specific determination for ozone in the presence of other oxidants is required.

Operating principle

The Model 1100 Ozone Meter operates upon the Nederbragt principle of the chemiluminescent reaction between ozone and ethylene. A thermoelectric cooler which encloses all critical electronics including the photo-multiplier tube, dynode resistor chain, and electrometer circuitry helps to maintain operational stability. Since the ozone-ethylene reaction is specific for ozone, precise ozone concentrations can be measured in the presence of NO_2, SO_2 and other gases which cause errors in instruments employing the potassium iodide reaction with ozone.

Physical description

The bench mounting version is 10½" × 17" × 17½", while the rack mounting version is 10½" × 19" × 17½", weighing 40 lbs.

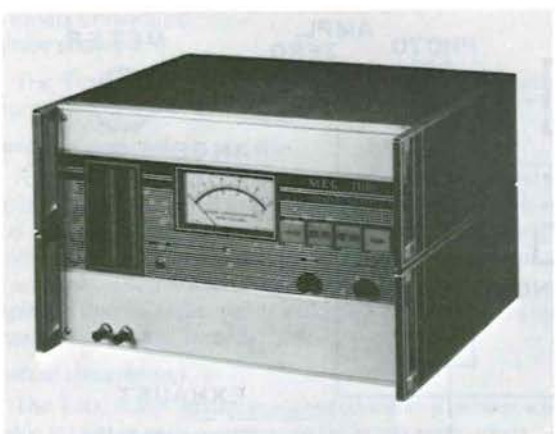


Figure V-145 — McMillan Electronics Corp. Model 1100 Ozone Meter.

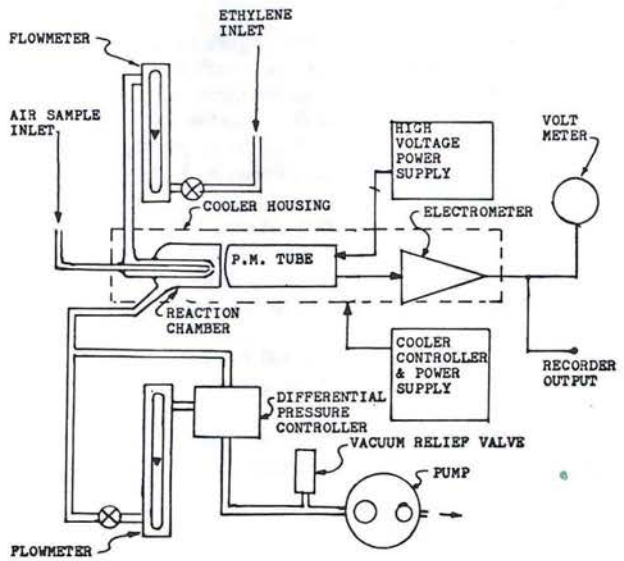


Figure V-146 — Schematic of Model 1100 Ozone Meter.

Electrical requirements: 105–125 V, 50–60 Hz, 200 Volt amps. *Ethylene consumption:* 15 cm^3/min.

Specifications

Sensitivity: 0.01 pphm (as measured at recorder output). *Ranges:* 0 to 10 ppm; 0 to 1.0 ppm; 0 to 5 ppm; and 0 to 10 ppm. *Time constant; selectable 1.0 second or 10 seconds. Known atmospheric interferences:* none. *Data display; panel meter, mirrored 4½" scale. Recording precision of measurement:* ± 1 % of scale range. *Electronic:* all solid-state except for photo-multiplier tube. *Operating temperature:* 10° to 45°C ambient. An optional portable Chemiluminescent Ozone Meter, Model MEC 2000, is also available. It is 7½" × 7" × 17", and weighs 12 lbs. It has ranges of 0–01, 0–0.2, 0–0.5, and 0–1.0 ppm.

Nitrogen Oxides Analyzer

Meloy Laboratories, Inc.
Instruments & Systems Division
6715 Electronic Drive
Springfield, VA 22151

The new Meloy Model NA530R Nitrogen Oxides Analyzer is designed to meet the most rigid requirements of both research investigations and environmental monitoring for NO, NO_2 and NO_x. It uses the chemiluminescence reaction of ozone with nitric oxide (NO) to conform to highly specific ambient air reference method requirements.

Operating principle

Two independent and simultaneous photometric measurement systems monitor for NO and NO_x. One system contains direct sample air and ozone, and the other contains sample air where all the NO_x has been converted to nitric oxide. The signals are subtracted for the nitrogen dioxide (NO_2) signal.

The chemiluminescence reaction is temperature sensitive causing several percent error if allowed to follow ambient temperature. High sensitivity and accuracy are obtained by controlling the temperature of the reaction chamber.

Figure V-147 — Meloy Model NA530R Nitrogen Oxides Analyzer.

Performance data

Ranges: 0 to 0.10 ppm, 0 to 0.25 ppm, 0 to 0.5 ppm, 0 to 1.0 ppm, 0 to 5 ppm. *Noise (RMS):* 0% URL, 0.002 ppm; 80% URL, 0.004 ppm. *Minimum detectable sensitivity:* 0.004 ppm. *Interference equivalent:* 0.005 ppm each interferent; 0.015 ppm total interferent. *Zero drift:* ± 0.007 ppm per 24 hours; ± 0.01 ppm per 7 days. *Span drift:* ± 0.013 ppm per 24 hours; ± 0.020 ppm per 7 days. *Lag time:* < 5 secs. *Rise and fall time (95%):* 0.5 to 6 minutes depending on range and TC position. *Precision:* 20% URL, 0.002 ppm; 80% URL, 0.003 ppm. *Linearity:* ± 1%. *Unattended operations:* 7 days (no adjustment of flow or electrical systems). *Sample air flow rate:* 1.2 lpm (max). *Dry air flow rate:* ozone generator, approximately 200 ml/min. *Power requirements:* 105 VAC to 130 VAC, 50/60/Hz, 300 watts. *Outputs:* meter, with selector switch to read NO, NO_2 or NO_x; recorder, each channel has separate outputs 0–10 V and 0–5 V adjustable to 0–100 mV. *Relative humidity range:* 0 to 95%. *Ambient temperature range:* 10° to 40°C.

Physical description

Weight: 27 kgs (60 lbs). Bench model case dimensions are 12¼" × 17" × 20". *Mountings available:* a) bench (standard) or b) rack (optional) width extended to 48 cm (19"). *Sample pump:* external, option N-10 or equivalent (must have the capacity to draw 2 liters of air/min at 200 Torr).

Ozone Analyzers

Meloy Laboratories, Inc.
(address above)

The Meloy OA 325-2R and OA 350-2R Ozone Analyzers have been designed to provide real time continous monitoring of ozone in ambient air.

Operating principle

The Ozone Analyzers' operation is based on the gas phase chemiluminescent reaction between ozone and ethylene molecules which produces light energy in the 300 to 600 nm region. In the presence of excess ethylene, the intensity of light produced is proportional to the concentration of ozone. This reaction has been found to be free of interferences from other gas present in ambient air. The ozone concentration is measured by introducing sample air into the reactor chamber where a special nozzle arrangement mixes the air with an ethylene stream. The light emitted is detected by a photomultiplier tube which converts this energy into an electrical current. This in turn is converted to a voltage, amplified to the output recorder jacks and displayed on the panel meter.

The analyzers are identical except the OA350-2R has a stable internal UV ozone source to produce a span point and also a zero air source.

Performance data

Range: 0–0.1 ppm; 0–0.5 ppm; 0–1.0 ppm; 0–5 ppm; 0–10 ppm. *Noise:* 0% URL, 0.003 ppm; 80% URL, 0.002 ppm. *Lower detectable limit:* 0.001 ppm; a) each interferent ± 0.002 ppm or better or b) (b) total interferents, 0.002 ppm or better. *Zero drift:* ± 0.002 ppm, 12 or 24 hours. *Span drift (% of reading):* 20% URL, ± 1.5; 80% URL, ± 2.5. *Lag time:* 0.1 min. *Rise and fall time:* 0.05 min. *Precision:* 20% and 80% URL, 0.001 ppm. *Temperature range:* 68° to 86°F (20° to 30°C). *Power requirements:* 105 to 125 VAC, 60 Hz, 250 watts.

Physical description

Weight and size: 40 lbs; 12.3" × 17" × 20" (31cm × 17 cm × 51 cm). *Mounting:* benchtop or 19" (48.3cm) rack (optional).

Sulfur Analyzer Model SA285

Meloy Laboratories, Inc.
(address above)

The Meloy Laboratories, Inc., Model SA285 Sulfur Analyzer provides continuous real-time monitoring of sulfur compounds in the parts per billion (ppb) range. It utilizes the Meloy patented Flame Photometric Detector (FPD) to provide dry analysis of sulfur in air samples.

Operating principle

The operating principle of the FPD utilizes the photometric detection of the 394 mu-centered band emitted by sulfur containing compounds in a hydrogen rich air flame. Its specificity arises from a geometric arrangement that optically shields the photo-multiplier tube from the primary flame and the employment of a narrow band-pass interference filter.

A new, unique temperature controlled flow system (TEMP-CON) requires no periodic adjustment and provides very stable air flow through an ambient temperature range of 10° to 40°C. The temperature control oven system for the detector and hydrogen flow systems provides temperature control to ± 0.3°C over the same ambient temperature range.

Performance data

Range: 0–50 ppb, 0–100 ppb, 0–500 ppb, 0–1000 ppb. *Noise (RMS):* ± 0.5% of FS maximum. *Minimum detectable limit:* 1% of FS. *Zero drift:* ± 1% FS/24 hr. *Span drift:* ± 2% FS/24 hr. *Lag time:* 10 sec. max. *Rise and fall time:* 90%, 25 sec. max. *Precision:* ± 1% of FS. *Linearity in ppb:* ± 1% of FS. *Available outputs:* a) meter, b) 10 VDC FS, c) 100 mVDC FS (adjustable from 10 mV to 5 V FS). *Unattended operation:* 14–28 days (no adjustment of flow or electrical system). *Sample flow rate:* approx. 200 ml/min. *Hydrogen flow rate:* approx. 140 ml/min. *Power requirements:* 300 watts, 115 ± 10 VAC. *Ambient operating temperature range:* 10° to 40°C.

Figure V-148 — Meloy Sulfur Analyzer, Model SA285.

Physical description

Weight: 50 lbs. *Case dimensions:* 12¼" × 17" × 20". *Sample pump:* internal.

Fluorescence SO_2 Analyzer

Meloy Laboratories, Inc.
(address above)

The instrument is an ambient sulfur dioxide analyzer designed using National Bureau of Standards patented method.

Operating principle

The Model SA700 is built for direct monitoring of SO_2 using a continuous UV source of high intensity and stability. The signal does not have any of the undesirable signal noises peculiar to pulsing or chopping techniques. The low noise characteristics assure rapid response while providing accurate and reliable data to better then ± 2% even on the most sensitive ranges. Sample flow rates of less than 500 cc/min allow the use of presently available precision Meloy Calibrators.

Performance data

Ranges: 0 to 250 ppb, 0 to 500 ppb, 0 to 1000 ppb, 0 to 5000 ppb, 0 to 10,000 ppb. *Noise (RMS):* ± 0.5% on 0 to to 500 ppb scale. *Minimum detectable limit:* 5 ppb or better. *Zero and span drift:* meets EPA specifications. *Lag time:* 10 seconds maximum. *Rise and fall times:* to 95%, 2 minutes maximum. *Linearity:* ± 1% FS. *Operating temperature range:* 20° to 30°C to EPA specifications. *Sample flow:* < 500 cc/min. *Interferences:* meets EPA specifications. *Output:* a) 0–10 volts; b) 0–100 mV, adjustable to 0–5 volts.

Figure V-149 — Meloy Fluorescence SO_2 Analyzer, Model SA700.

Physical description

This instrument is suitable for bench mounting; rack mounting available. It is 12¼" × 17" × 20" and weighs 44 lbs. The rack mount is 12¼" × 19" × 20. *Power requirements:* 300 watts maximum, 105 to 130 VAC, 60 Hz, (220 VAC and 50 Hz on request).

Phosphorus Gas Detectors/Analyzers

Meloy Laboratories, Inc.
(address above)

Meloy Laboratories offers monitoring of phosphorus by flame photometric detection as a companion or replacement capability in its sulfur analyzers. The capability is now available in Models PA 460 (integral log-linear amplifier) and PA 465 a lightweight portable unit with 12 volt battery supply.

Figure V-151 — Meloy Model PA 465.

Figure V-150 — Meloy Model PA 460.

Performance data

Range: 0.001–10 ppm for both models. *Minimum detectable sensitivity:* 0.001 ppm or less, both models. Rise time for Model PA 460 is 2–3 sec (nominal), < 10 sec max, and for the PA 465 it is 10 sec to 90% of full response. *Fall time:* < 7 sec for the PA460 and 3 sec for the PA 465. *Precision:* ± 1% of full scale for Model PA 460 and 2% for Model PA 465.

Physical description

Power requirements: PA 460 — 115 VAC, 60 Hz; PA 465 — 12 VDC; internal or external battery charger uses 115 VAC 60 Hz. The PA 460 unit is 19" × 12¼" × 20", weighs 40 lbs, and operates for 14 days or more. The PA 465 unit is 9" × 10" × 16", weighs 20 lbs, and operates for 4 hours. Its battery charger is 5" × 7" × 6".

Model 612 Atmospheric Ozone Monitor

REM, Inc.
3107 Pico Boulevard
Santa Monica, CA 90405

The REM Model 612 is a continuous monitor which measures atmospheric ozone in the range 0–200 pphm without interference from other air pollutant gases, e.g., NO_2, SO_2, Cl_2, etc.

Operating principle

This instrument is based on the chemiluminescent reaction between ozone and ethylene. It is designed for continuous operation. The ozone-ethylene reaction is specific for ozone. The light emission resulting from the reaction is detected by a photomultiplier which views the interior of the reaction flack 90° from the point of gas entry. The anode current is measured by a picoammeter.

Physical description

The instrument is provided for both a) mounting on laboratory bench, with tilt stand which elevates the front of the monitor by 2", and b) mounting into standard 19" rack. Cabinet measures 10" × 19¾" × 18"; weight is 36 lbs. The rack is 8.75 " × 19.06" × 16.94".

Performance data

Data display: digital four digit Nixie tube display with printer option. Printer will record date, time, and concentration of ozone. *Analog output:* 0–5 volts. *Sensitivity:* 0.01 pphm. *Range:* 0–200 pphm; 0–20 pphm; 0–2 pphm. *Time constant:* 4 sec (0–200 pphm); 2 sec (0–2 pphm); 4 sec (0–20 pphm). Response time of ethylene ozone reaction and instrument are instantaneous. Response time only applies when switching from one range to another, i.e, 0–20 pphm to 0–200 pphm range, etc. *Atmospheric interferences:* none. *Precision:* ± 1% (± least significant digit). *Linearity:* 0.01–200 pphm. *Electronics:* completely solid-state. *Power requirement:* 105–125 V, 50–440 Hz, single phase, 55 watts normal line. *Ethylene consumption:* 10 cc/min flow rate. *Operating temperature:* continuous duty at full load from 0 to 50°C, ambient.

Figure V-152 — REM, Inc. Model 612 Atmospheric Ozone Monitor.

Halide Meter

Scott Aviation-Davis Instruments
P.O. Box 751
RT 29 North
Charlottesville, VA 22902

The Halide Meter is an instrument designed for field determinations of halogenated hydrocarbons in air. Its normal operating range is from 0–500 ppm of most substances, with a lower limit of detection of about 10 ppm. It is accurate throughout most of its range to about 10% of the amount being measured. The Halide Meter is most often used for determining perchloroethylene, trichloroethylene, carbon tetrachloride, methylene chloride, and similar chlorinated hydrocarbons in air.

Operating principle

Air containing halogenated hydrocarbons is passed through a chamber containing an AC electric arc between a copper electrode and a platinum electrode. A bright line spectrum of copper, designated as the Cu 1 spectrum, is produced when the air surrounding the arc contains halide vapors. The intensity of this copper spectrum is proportional to the concentration of halide vapors present, and the blue lines are measured with a blue-sensitive phototube fitted with a blue glass filter. The change in current output of the phototube is then measured by a DC vacuum tube voltmeter. The meter readings are converted to ppm using calibration curves such as those shown in Figure V-154.

Physical description

The Halide Meter is of all-metal construction, weighting 35 lbs and measuring 16" × 9¾" × 15". It is portable and is provided with a sturdy leather-covered metal handle. The instrument requires 110 VAC, 60-cycle, and is furnished with 25 feet of rubber covered cable. A 20-foot Tygon sampling hose is also provided with the instrument. Both the cable and sampling hose are conveniently wound on the inside of the instrument cover. A compartment is provided in the rear of the instrument for carrying spare electrodes, extra charcoal, etc.

Performance data

Any halogenated material in the air being sampled will cause the instrument to give a reading and, in this sense, the instrument is non-specific. It cannot, for example, differentiate carbon tetrachloride from trichloroethylene when the vapors are mixed. Inasmuch as most industrial exposures consist of a single solvent vapor, this limitation is not ordinarily serious. Non-halogenated materials, such as hydrocarbons, do not interfere, however, and mixtures of halogenated vapors with other vapors may be evaluated. The instrument is designed to operate at a constant sampling rate, indicated by a line on the rotameter, and small variations in this sampling rate are unimportant.

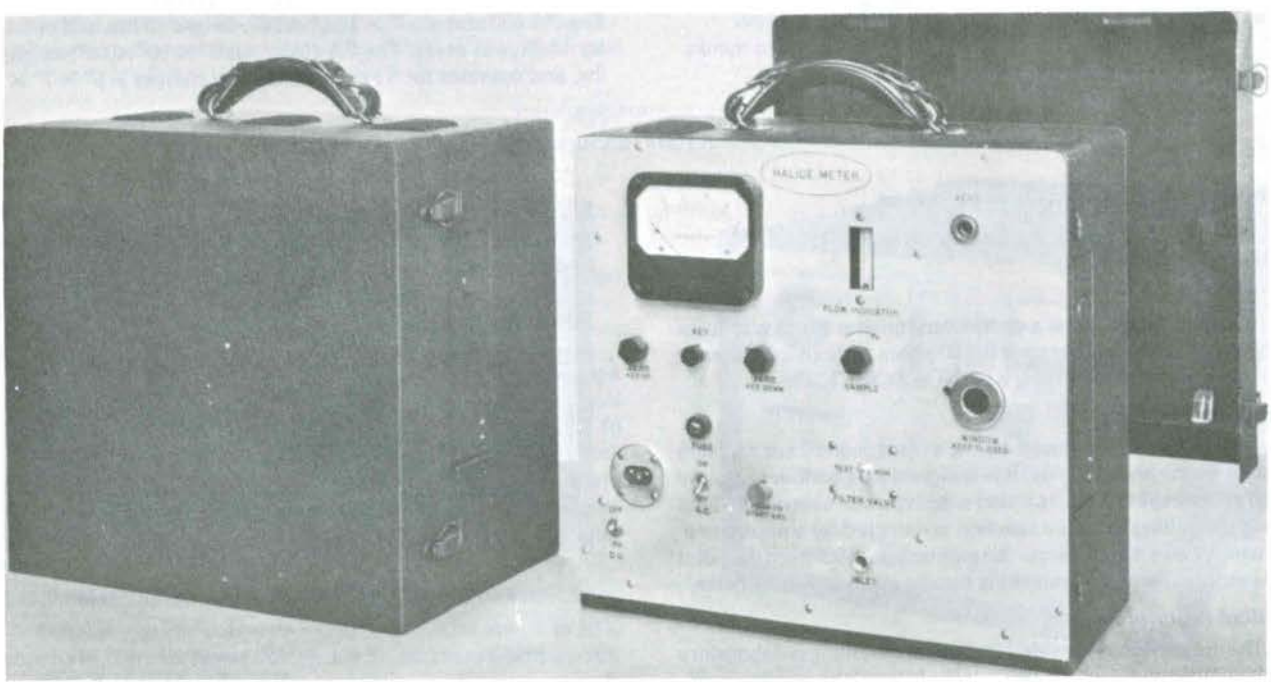


Figure V-153 — Davis Halide Meter: left; in carrying case, right; with front cover removed.

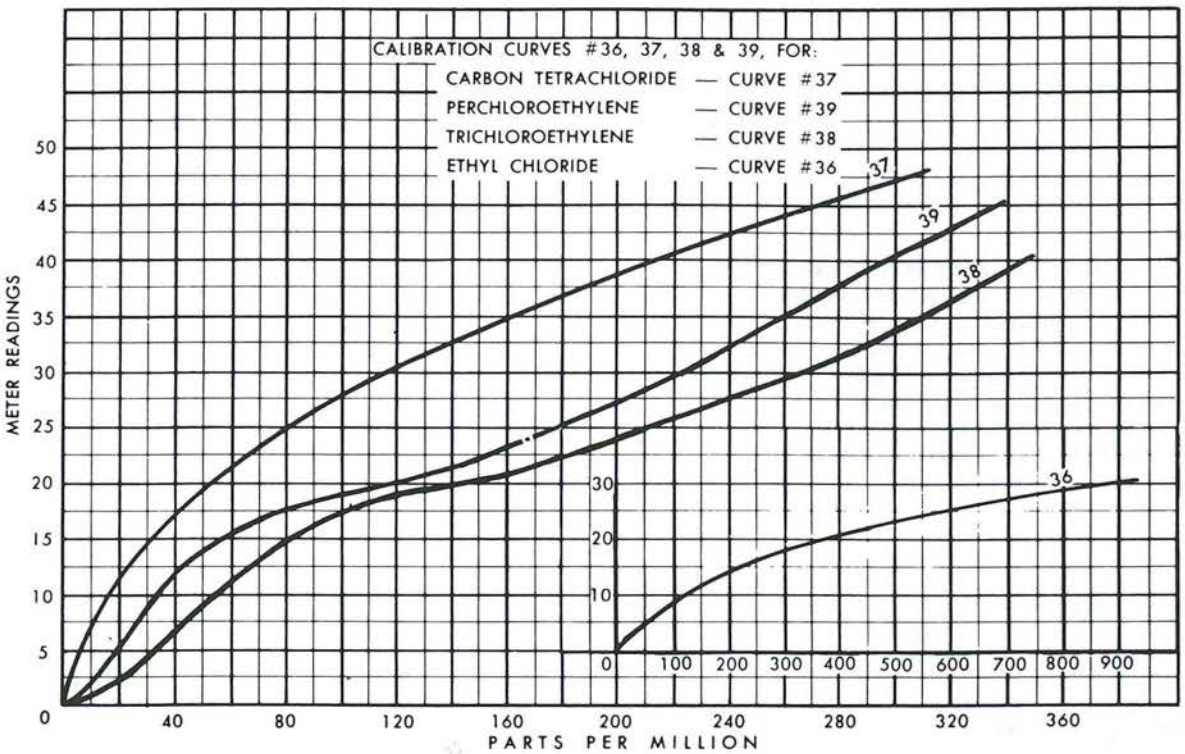


Figure V-154 — Typical calibration curves for the Halide Meter.

Model 270HA Sulfur Analyzer

Tracor Instruments
6500 Tracor Lane
Austin, TX 78721

Although the 270HA was designed primarily as an automated monitor for low level H_2 and SO_2 (the two common sulfur air pollutants), the 270HA can be used in a variety of other analytical applications simply by changing the column, sample loop size, and/or operating conditions.

The separation of H_2S, SO_2 and methyl mercaptan is shown in Figure V-157. A slightly higher column temperature was used to elute the methyl mercaptan in a reasonable time.

The analytical column can easily be changed to perform analysis of higher boiling compounds. A 10% carbowax on silica gel was used for the analysis of odorants in natural gas.

Figure V-155 — Tracor Model 270HA Sulfur Analyzer.

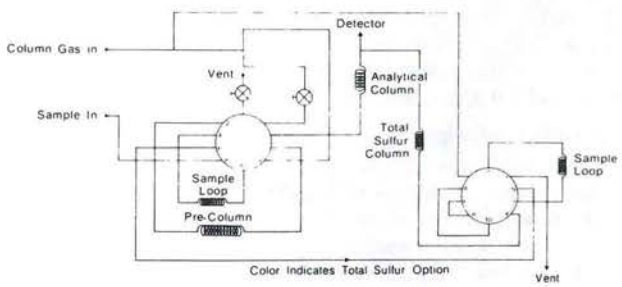


Figure V-156 — Flow schematic for Model 270HA.

Sample loop size and conditions of the versatile 270HA can be altered to perform sulfur compound analysis from parts per billion to unlimited upper levels of concentration.

Operating principle

Operating on gas chromatographic principles and utilizing the Tracor patented, sulfur specific, Flame Photometric Detector, the 270HA chromatographically separates and independently quantitates vapor-state sulfur compounds in gaseous media.

Precise sample volumes, reproducible to within ± 0.2 cc, are injected via fixed F.E.P. Teflon sample loops (9 cc standard). The unique 6-ft analytical column (a proprietary Tracor item) quantitatively separates the low molecular weight sulfur pollutants normally measured in air quality monitoring. Tracor's sulfur selective FPD detects and measures sulfur pollutants as low as 1 ppb (9 cc sample loop) without interference.

Models including total sulfur capabilities are optionally available.

Physical description

Size and weight: 9" × 19" × 24"; 60 lbs. *Power:* 115 V, 60 Hz. *Sampling rate:* cyclic (225 sec). *Readout mode:* dual output 0–10 mV FS (chromatographic) and 0–5 V FS (computer or data logger) for each of two ranges (0–100 ppb and 0–1 ppm).

Performance data

The 270 Ha samples ambient air for trace quantities of H_2S, SO_2. Total sulfur option available. It is easily adaptable to monitoring other vapor state sulfur compounds. Also applicable to stack or source concentration monitoring. Minimum detectable limit is 4 ppb. Its practical monitoring limit is 10 ppb with the upper limit of 1.0 ppm without external dilution. *Specificity:* sulfur compound specific; possible interferences high concentrations of CO_2 and/or hydrocarbons (1000 ppm). *Response time:* sampling is cyclic, maximum response time 225 sec. *Stability:* 1% per 24 hours; 2% per week. *Precision and accuracy:* < 1% deviation with stabilized system.

Figure V-157 — Chromatograph, showing separation of sulfur bearing vapors.

Hydrogen Sulphide Monitor

Fleming Instruments, Ltd.
Caxton Way, Sevenage
Hertfordshire, England

The Fleming Hydrogen Sulphide (H_2S) Monitor has been developed to meet the requirements of organizations who require work to be done in underground sewers, or in areas where there is a possibility of encountering toxic gases. One such gas is hydrogen Sulfide which, in concentrations of 200 ppm, will give serious toxic effects. The presence of H_2S is readily detected by smell in concentrations of 1.0 ppm upwards.

Operating principle

The basic principle used in the Type 533 Monitor is the continuous evaluation, by a sensitive photo-transistor, of the intensity of the brown stain produced by the action of H_2S gas on a lead acetate treated filter paper.

In practice, the filter paper is slowly wound past a sampling orifice by means of a clock-work mechanism. A small battery-operated motor-driven pump draws in the sample and after forcing it through a "wetting" chamber, directs it onto the surface of the filter paper.

Small concentrations of H_2S (as low as 0.1 ppm) result in a staining of the paper and the degree of stain is continuously evaluated by a stable and sensitive detector circuit. The change in current in the detector, caused by the change in the reflectivity of the paper, is applied to a switching circuit whose sensitivity may be set to a required level. This switching circuit in turn controls audible and visual warning signals. The warning level may be set and checked both before and during operation.

Physical description

Paper tape: Whatman B.D.H. No. 1 lead acetate filter paper, 1 cm wide × 5 meters long, i.e., at least 6 working days supply. *Paper tape drive mechanism:* clockwork motor with drive mechanism which also indicates the remaining operating time. *Pump:* miniature axial flow. *Battery:* 9.6 V 1000 mah. rechargeable battery. *Warning signals:* red warning light and audible tone. Distilled water is the "wetting" agent. *Size and weight:* 8" × 6" × 3", approx. 4 lbs.

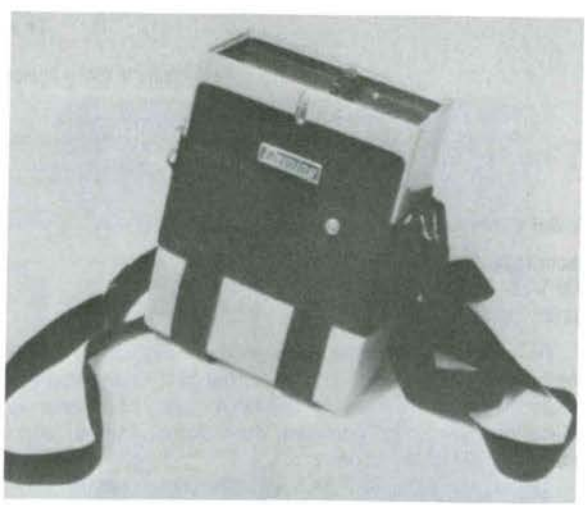


Figure V-158 — Fleming Type 533 H_2S Monitor.

Performance data

Sampling period to initiate warning signals is approximately 2 minutes (i.e., when set to 10 ppm sensitivity the device will trigger after 2 minutes sampling in a 10 ppm atmosphere.

Model 722AEX-A Gas and Vapor Analyzer

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

The 722AEX-A measures airborne H_2S either on the close range or on a limitless wide range when equipped with the System 400 orifice/manifold kit accessory. The 722AEX-A is a fixed station monitor.

Operating principle

The 722AEX-A operates by the exclusive Photometric method. The air sample enters the 722AEX-A through its louvered hood where it is exposed to a lead-acetate impregnated tape. The H_2S content changes the tape from white to a darker color. A photoelectric cell measures the color change and provides a meter deflection proportional to the H_2S content of the sample. This principle is specific to H_2S.

Physical description

The instrument is 21" × 13" × 13" and weighs 60 lbs. Its operating range is from 0 to 100 ppm and the sample is accepted directly through the louvers in the hood. The instrument's range can be extented indefinitely with the addition of PVC orifice/manifold runs. This System 400 wide range monitor is limited only by the number of orifices used and the length of the runs used. There are high/low alarm adjustments so that personnel can choose the amount of H_2S in the air the considers dangerous, as low as 1 ppm. Bells or horns are available also.

Performance data

The least detectable quantity is 1.0 ppm. The range is 0 to 100 ppm. This instrument is specific to H_2S; no other gases present can interfere with the meter reading. It is accurate to ± 2% and repeatable to ± 3% of full scale calibration. Accurate sample readings are ready in 3 minutes. Zero drift is 5% of full scale calibration.

Miniguard Personal Alarm Dosimeter For Toxic Substances

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

The Miniguard is designed to function as a personal dosimeter for chemically toxic gases and vapors. The continuously monitoring photocells connected to the integral audio alarm makes it ideal as a warning device to the wearer. Also, the readout provides total dose information that can be related directly to the OSHA or ACGIH 8-hr time-weighted averages.

Operating principle

The Miniguard is based on a dry, chemically impregnated, paper tape system, specifically sensitive to the substance being sampled. A piece of tape is inserted into the dosimeter and the dosimeter is put in shirt pocket or worn on belt, etc. The tape is exposed either by diffusion or aspiration, depending on the system involved. The exposed tape section and an unexposed reference section of the tape are continually evaluated by two balanced CdS photocells and when a preset stain density equivalent to a dose in ppm-hrs is reached, an audio alarm sounds. At the end of the exposure period, the tape can be removed and inserted into the readout device to provide a direct numerical reading of dose in ppm-hrs.

Physical description

The Miniguard is 5" × 1¼" × 2½" and weighs approximately 12 oz, including battery. It is powered by 3 AA size batteries (life: 2 to 3 weeks, plus). The sampling rate is by diffusion or 0–250 cc/min, depending on system and range. Readout is directly in ppm-hrs.

Performance data

Materials sampled: currently available: H_2S, $COCl_2$; available soon: TDI, NO_2, Cl_2, SO_2, CO, NH_3. *Detection limits:* various ranges available; standard and range based on current TLV set by OSHA. *Specificity:* no significant interference. *Response time:* variable, dependent on alarm setting.

Figure V-159 — MDA Miniguard Dosimeter for H_2S, and readout device.

The Miniguard alarm and dose readout units are calibrated, using known concentrations of appropriate toxic gas and cross-checked with wet, chemical methods at time of manufacture. Field calibration and adjustment is facilitated by using a secondary standard of known density stain. The dose alarm function can be set over a wide range of exposure, depending on individual requirements.

UNICO CO and H_2S Alarms

The Bendix Corporation
Environmental & Process Instruments
12345 Starkey Road
Largo, FL 33543

The UNICO CO and H_2S Alarms are designed to protect personnel in industrial plants, chemical, petroleum and mining industries from the harmful effects of over-exposure. Used as an area monitoring instrument, the alarm's function is to warn of increase in concentration before dangerous levels are reached.

Operating principle

The UNICO Carbon Monoxide Detector/Alarm Models 901, 902 and 1000, and the Hydrogen Sulfide Alarms, Models 44, 4000, and 4400 are detecting alarms and not analyzers. There are no meters to read or dials to adjust. They employ a simple analytical technique, and a patented detecting sensor called the Detectotab. The Detectotab responds to the presence of carbon monoxide or hydrogen sulfide by changing color. This change is detected by the photo-optical system which automatically opens a relay and sound an alarm when concentrations are greater than preset values.

The UNICO Detectotab, shown in Figure V-162, is the activating sensor in all UNICO Carbon Monoxide Detector/ Alarms. It is molded of high impact polystryrene and provides a chamber and reservoir (A) for the sensitized silicone gel reagent. The chamber (C) is defined by two parallel screens of corrosion-resistant mesh which proper seating. An indentation in the Detectotab (B) together with a mechanical dent (F) in the module sensor cell retains the detectotab securely in the proper position relative to the optical path between lamp (D) and photocell (E). When exposed to carbon monoxide, a chemical reagent changes from its initial translucent straw color to brownish-black stain. The color change in the detecting silica gel is measured photoelectrically in the sensor head continuing the zinc cadmium photocell and exciter lamp.

The sensor head is a plug-in module and can be remotely located up to 1000 ft from the instrument. Replacements are available at a nominal charge.

A mechanical dent in the sensor head is provided to hold the detectotab securely and to give proper alignment between the lamp and photocell, even under vibration and shock. Tested at 5 G vibration, 0–500 cps and 59, 11 millisecond shock. The shockproof miniature lamp is guaranteed for 50,000 hours or five years. The

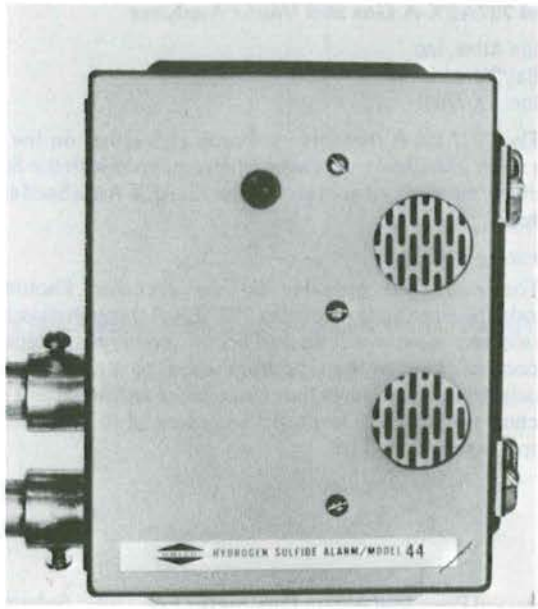
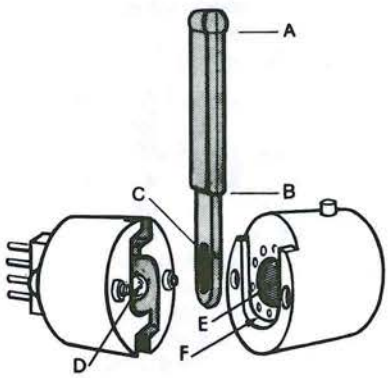


Figure V-161 — UNICO Model 44 Hydrogen Sulfide Alarm.



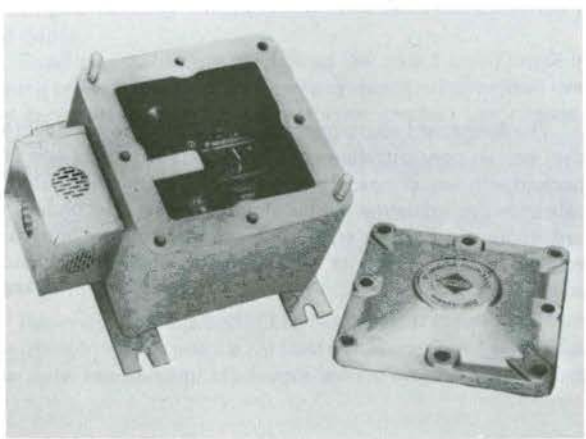


Figure V-160 — UNICO Model 902 Carbon Monoxide Alarm in explosion-proof housing.

TABLE V-13
Response Time for Carbon Monoxide Alarm System

CO Concentration (ppm)	Typical Alarm Response Time (adjustive)	Effect
50	1 hour	TLV for continuous 8-hour exposure
100	20 minutes	No effect in 4 hours
600	6 minutes	Headache, fatigue, nausea in 1 hour
1000	3 minutes	Unconsciousness within 1 hr; dangerous to life
3500	80 seconds	Fatal in less than 1 hour

molded chamber in the sensor head which holds the detectotab is so constructed that the heat from the exciter lamp creates a "chimney" effect drawing air over the reactor chamber surface of the detectotab. An airflow of 200 cc/min is obtained assuring proper sampling with no maintenance or possibility of pump failure or wear. The response time for the Carbon Monoxide Alarm system is shown in Table V-13.

The detectotab sensor head, and relay used in the Hydrogen Sulfide Alarms are of essentially the same design used in the CO alarms except for the absorbing chemical in the detectotab.

Physical description

Models 901, 902, and 1000 are used to detect CO, while Models 44, 4000, and 4400 detect H_2S. Models 901 and 44 measure 9½" × 7" × 4" and weigh 6.5 lbs. Models 902 and 4000 are 10" × 8" × 6.2" and weigh 36 lbs. Models 1000 and 4400 are designed for mounting up to five units on a 19" panel. *Mounting:* Model 901, weather resistant metal; Model 44, case for wall mounting; Model 902, explosion-proof case, Class I; Model 4000, Group D, Class II, Groups E, F, S, and Class III. All models have the power requirements of 110 V, 60 Hz.

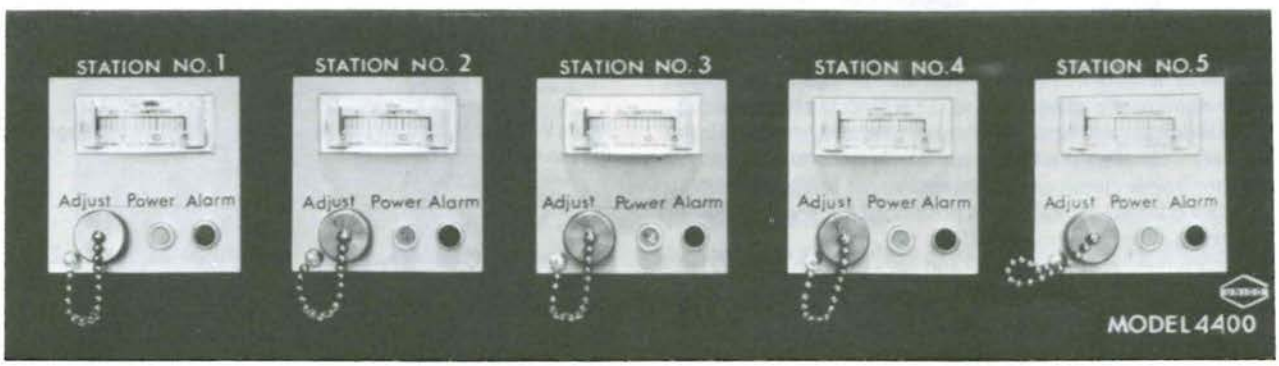


Figure V-163 — UNICO Model 4400 rack mounted H_2S Alarm.

Oxygen Analyzers

Milton Roy Company
Hays-Republic Division
4333 S. Ohio Street
Michigan City, IN 46360

Model 633-II Suppressed Oxygen Analyzer and Model 635-II Magno-Therm Oxygen Analyzer are used to determine the oxygen content of gas mixtures where higher accuracy and repeatability are required than are possible with zero based analyzers. The units can be operated without an external receiver and are compatible with most milliamp and millivolt DC receivers.

Operating principle

Model 633-II. Oxygen is paramagnetic, i.e., is attracted to a magnetic field. All other gases except nitric oxide (NO) and nitrogen dioxide (NO_2) are diamagnetic, i.e., are repelled slightly from a magnetic field. Paramagnetism diminishes with increasing temperature. The paramagnetic properties of oxygen are employed in the Model 633-II analyzer to produce a "magnetic wind," which is proportional to the concentration of oxygen. Measurement of the cooling effect of this "magnetic wind" provides a measure of the oxygen concentration. Since NO and NO_2 are seldom encountered in significant amounts, they generally do not interfere with the O_2 measurement.

As seen in Figure V-164, a glass tube (1) is vertically inclined in the ring type gas passage block (2). Two identical, electrically self-heated, nickel windings (3a and 3b) are wound on the outside of the glass tube (1). These windings form two legs of a Wheatstone bridge circuit. Winding (3a) is situated between the poles (4a and 4b) of the strong permanent magnet.

Sample gas flows through the bypass block (2) from (5) to (6). If the sample gas is paramagnetic (oxygen), it is attracted by the magnetic field between poles (4a) and (4b). This gas is pulled into tube (1) and heated by winding (3a). With increasing temperature, the paramagnetism of the gas decreases. Cooler gas at the entrance of tube (1) tries to push the heated gas out of the magnetic field, producing a force in the direction of (3a) to (3b).

Conversely, in the vertically inclined, heated glass tube (1), the chimney effect, due to thermal convection, forces the gas in the direction from (3b) to (3a), opposed to the force caused by the magnetic effect. The cell inclination is adjusted so that at a certain oxygen concentration in the sample gas the chimney effect is of the same magnitude as the magnetic effect. Both effects cancel each other, and no gas flows through tube (1). This condition is called the "compensation point." At oxygen concentrations lower than

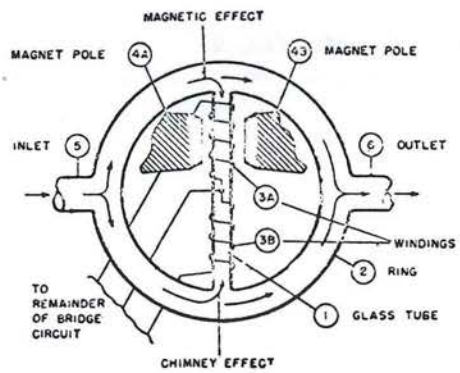


Figure V-164 — Analyzing cell of Model 633-II Suppressed Range Oxygen Analyzer.

that of the compensation point, the chimney effect becomes stronger than the magnetic effect, causing a continuous gas flow in direction (3b) to (3a).

This gas flow cools winding (3b) and heats winding (3a). The resulting temperature difference changes the resistance values of windings (3a) and (3b), and misbalance of the Wheatstone bridge. This voltage unbalance is proportional to the amount of oxygen in the sample gas. It is amplified and impressed on the receiver indicator pen drive motor windings. Rotation of this motor positions the indicator pen of the receiver to show oxygen content of the sample gas in percent oxygen.

Model 635-II. In this model, operation of the measuring cell is based upon a physical phenomena, magnetic wind, which is due to the unique paramagnetic properties of oxygen and the effect of temperature upon paramagnetism. A sectional view of the analyzing cell is shown in Figure V-165. In this figure, the glass covered platinum wire spirals (1a and 1b) are located in the oblong cavity of a stainless steel block (2). The cavity is partitioned vertically by screens (3). The platinum wire spirals form two legs of a Wheatstone bridge circuit and are heated by the bridge current to approximately 200°C. Spiral (1a) is positioned between the poles (4) of a strong permanent magnet (5).

Sample gas enters the cell at (6) and exits through outlet (7) of the gas passage block (8), diffusing through the screens (3) to spirals (1a) and (1b). The analyzer operation is described by making assumptions as follows:

Condition A: The sample gas contains no oxygen. In this event, sample gas enters, and diffuses as described above to spirals (1a) and (1b). A chimney action develops around the spirals, cooling both equally. The equal cooling produces equal resistance changes which cancel each other, leaving the Wheatstone bridge measuring circuit balanced.

Condition B: The sample gas contains oxygen. Oxygen in the sample gas is attracted to the field of magnet (5) where it is heated by spiral (1a), losing paramagnetism as it is pushed out of the field by cooler, more magnetic gas. The result is an additional gas flow (magnetic wind) on spiral (1a). This causes additional cooling and unbalanced resistance in spiral (1a)'s windings relative to the resistance in spiral (1b). The Wheatstone bridge measuring circuit unbalance is proportional to the oxygen content of the gas sample. The voltage unbalance is amplified and impressed on the built-in indicator.

Physical description

Both models measure 27½" × 9⅞" × 12 5/16" and weigh 115 lbs. The electronic and measuring units are housed in separate, explosion-proof, weatherproof aluminum cast cases, electrically and mechanically coupled together. These analyzer are applicable for use in Class I, Groups C and D, Class II Groups E, F and G and Class III classifications and require 115 volts (100–130 V), 47–63 Hz, 100 watts power.

Performance data, Model 633-II

Ranges: oxygen concentrations, < 30% — minimum span of 1% and maximum span of 10%; > 30% — minimum span of 2% and maximum span of 10%. *Typical ranges:* 20–21 and 16–21% O_2; 98–100 and 90–100% O_2 (other ranges available on request). *Output:* a) millivolt output — 0–50 mV DC into potentiometer load; b) current output — 1 to 5 mA DC into O to 6000 ohm load; 4 to 20 mA DC into 0 to 1500 ohm load; 10 to 50 mA DC into 0 to 600 ohm load. *Ambient temperature:* between 30° and 120°F. *Sample gas condition:* dew point of sample must be below ambient temperature and dust must be below 5 ppm; pressure must be held within ± 1.5% of pressure at which analyzer is calibrated. *Temperature:* up to 120°F. Stated flow rates are are 0.2 cfh, 15 cfh, and 30 cfh; other flow rates on special request. Must be constant within ± 15%. A divided flow assembly is used for flow rates greater than 0.2 cfh. *Response time:* response 3 to 4 seconds, initial; time constant (63.2% of final reading) 6 to 8 seconds. *Sensitivity:* 0.01% O_2. *Accuracy:* ± 0.5% of span below 30% O_2; ± 3% above 30% O_2. *Reference accuracy:* ± 1%.

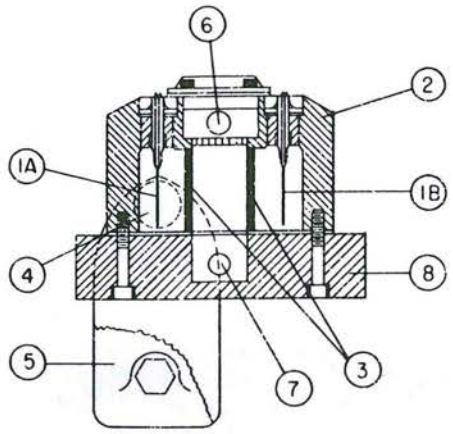


Figure V-165 — Sectional view of sensing cell in Model 2 635-II Magno-Therm Oxygen Analyzer.

Performance data, Model 635-II

Output: 0–50 mV DC into potentiometer load. *Current:* 1–5 mA DC into 0 to 6000 ohm load; 4 to 20 mM DC into 0 to 1500 ohm load; 10 to 50 mA DC into 0 to 600 ohm load. *Dual ranges:* 0–5 and 0–25%, 0–10 and 0–25%, 0–25 and 0–100% or 0–50 and 0–100%. *Flow rate:* 2, 15 or 30 cfh; may vary ± 50% from the specified flow rate; divided flow assembly bypasses 90 to 95% of total sample flow. Pressure may vary ± 10 mm Hg from pressure at which analyzer is calibrated; pressure compensator optional. *Composition:* dew point must be below 120°F and dust content must be below 5 ppm. *Response time:* initial response is 1 second; time constant (63% time) is 9 seconds. *Accuracy:* ± 1.0% of FSD or ± 0.20% oxygen (whichever is greater). Ranges up to and including 0–50% oxygen are linear within ± 1% FSD. A 0–100% range is slightly non-linear (± 3% FSD) and requires a correction curve. Ambient temperature: 30° to 120°F.

Paramagnetic Oxygen Analyzer

Scott Aviation-Davis Instruments
P.O. Box 751
RT 29 North
Charlottesville, VA 22902

The Scott-Davis Oxygen Analyzers (Series 11-4500), are systems for measuring the oxygen content of an atmosphere in the range 0–5% to 0–50%. They are available as single or multiple point systems.

Operating principle

The Davis Para-Magnetic Oxygen Analyzer operates on the principle that magnetic lines of flux passes through oxygen more easily than any other gas. Oxygen is paramagnetic, i.e., it is attracted by a magnetic field. This paramagnetic property of oxygen,

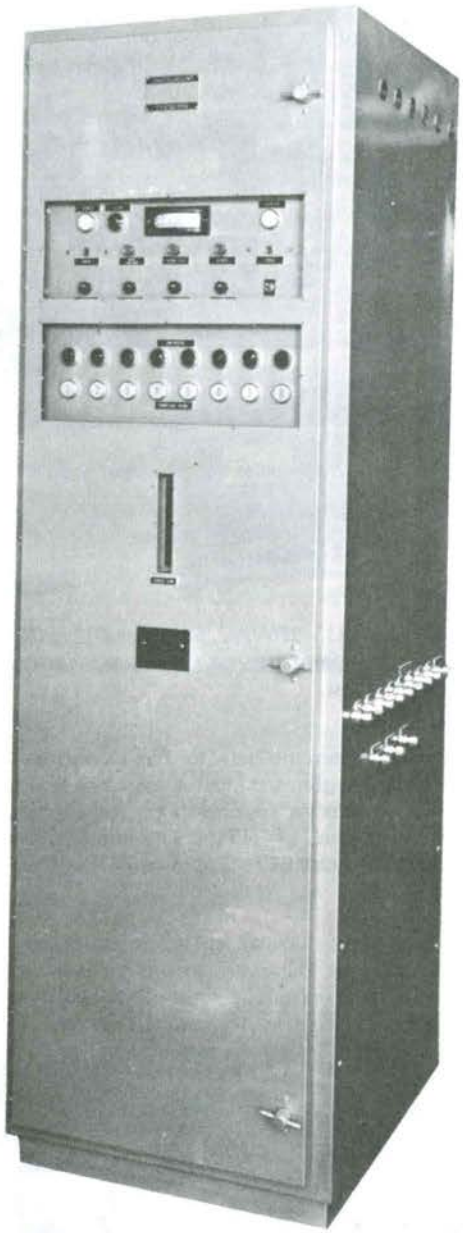


Figure V-166 — Scott-Davis Multiple Point Paramagnetic Oxygen Analyzer in dust-tight cabinet.

caused by its atomic and molecular structure, is inversely proportional to its absolute temperature. When oxygen is heated, it loses its paramagnetic property and becomes diamagnetic (repelled by a magnetic field).

The oxygen analyzing cell contains two electrically heated, glass covered precision resistors. They form two legs of a Wheatstone bridge circuit. The magnetic field, from a slide-mounted permanent magnet, passes through the analyzing chamber when the magnet is in the ON or analyzing position. Only one of the resistors (the active filament) is located within this magnetic field.

As the sample gas passes through the oxygen analysis cell and over both resistors (filaments) the oxygen is attracted to the magnetic field of the *active* measuring filament. The gas sample is heated, loses its magnetic property, and is forced out of the magnetic field by cooler, more magnetic oxygen bearing gas.

A circulation of gas sample magnetically induced in the analyzing cell, produces a cooling of the active filament. This cooling effect is in proportion to the oxygen content of the gas.

The filament not in the magnetic field, but also exposed to the sample flow, is a reference filament. This filament provides compensation for variations in cell temperature, and other temperature changes that might otherwise introduce measurement errors.

Resistance of both active and reference filaments is changed due to their respective changed temperature. The difference in resistance produces a voltage proportional to the amount of oxygen present in the sample gas.

Physical description

Systems are available in self-standing cubicles (Figure V-166) or wall mounting cabinets. Typical cubicle dimensions are 78" × 24" × 24". The Model 11-4500-WI Single Point Analyzer is 18" × 22" × 10". Power requirements are 115 VAC, 60 Hz.

Performance data

Measurement is continuous, automatic and requires no operator. Removal of magnetic field from analyzing cell provides immediate zero check. Similarly convenient is normal oxygen content of air (21%), a rapid span check for 0–25% range, and serves as an intermediate calibration point for higher spans. Speed of response is 10 seconds for a 90% full scale reading, (exclusive of sample line transport lag. Accuracy is ± 5% at full scale deflection.

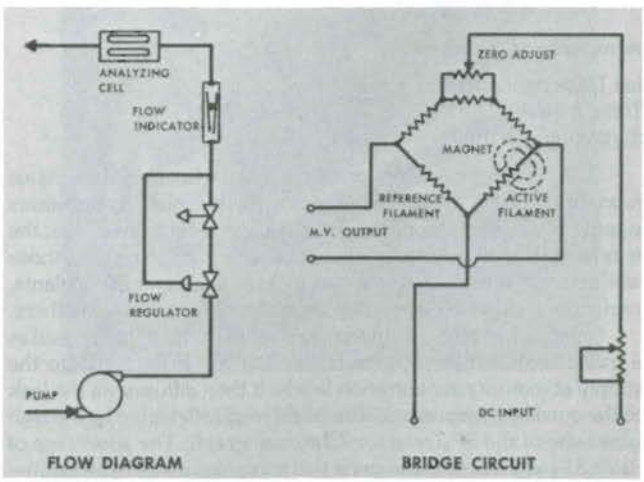


Figure V-167 — Schematic diagrams for Scott-Davis Paramagnetic Oxygen Analyzers.

Atmospheric Gas Detectors

Environment/One Corporation
2773 Balltown Road
Schenectady, NY 12309

The Environment/One atmospheric gas detectors measure trace concentrations of gases and vapors such as mercury, sulfur dioxide, and ammonia.

Operating principle

The nucleogenic technique used involves the selective creation of submicrometer particles from gas molecules. This is accomplished by a variety of reactions such as photochemical, pyrolysis, acid base, and others. The particles created are proportional in number to the gas concentration and are counted in the Condensation Nuclei Monitor Model RICH 100.

The Condensation Nuclei Monitor operates on the principle of a cloud chamber in which water is condensed upon submicroscopic air particles to produce micrometer size droplets. A constant flow air sample is periodically diverted through a humidifier and then into the cloud chamber where a fixed volume expansion of the sample occurs, providing a super saturation of at least 300% which produces a cloud.

This cloud attenuates a light beam that is focused on a solid state light-sensitive element. As the light value is decreased, an electrical pulse is created which is amplified and rectified into a direct current proportional to the condensation nuclei concentration in the sample. The expanded volume is then pressurized to the original atmospheric condition and flushed out. In this manner, near constant flow is achieved. The total measurement cycle is one per second.

Physical description

The Condensation Nuclei Monitor, Model RICH 100 is 14" × 8" × 13" and weighs 37 lbs. It operates from 115 VAC, 60 Hz power and draws 60 watts; 115–220VAC, 50 Hz, and 12 or 24 VDC units are also available. Information on the various gas converters is available upon request.

Figure V-168 — Condensation Nuclei Monitor, Model RICH 100.

Performance data

The elemental mercury detector has a concentration range from 10 to 2000 nanograms/m^3 with a response time of < 5 min. The sulfur dioxide detector's concentration range is from 0.005 to 5 ppm with a response time of < 10 sec. The ammonia detector has a concentration range of 0.01 to 1 ppm and a response time of < 10 sec.

Atmosphere Monitor

Ion Track Instruments, Inc.
Three A Street
Burlington, MA 01803

The Atmosphere Monitor can be used whenever continuous monitoring of gas streams or an atmosphere containing pollutants is required. In typical applications, the alarm is set to operate at the maximum permitted safe working concentration to protect those working in the area. These areas include film processing plants, refrigeration rooms, degreasing areas, assembly areas and others.

The SF_6 Detector Chromatograph is increasingly being used as a tracer to detect gas system leaks. The SF_6 is injected into the supply at minute concentration levels. It then diffuses via the leak to the outside environment. The SF_6 is readily detected by the high sensitivity of the SF_6Detector/Chromatograph. The advantage of using SF_6 as a tracer in the gas is that it enables a leak to be located in an area already saturated by gas. In addition, it enables a leak location to be pinpointed even in the presence of multiple leaks.

The Leakmeter is an industrial leak detector designed for detection of leaks of SF_6 tracer gas or any gases which are responsive to the electron capture cell fitted to the instrument.

Operating principle

All three units utilize an electron capture detector with the SF_6Detector/Chromatograph including a gas separation column.

Figure V-169 — Ion Track Atmosphere Monitor.

Physical description

The Atmosphere Monitor measures 95 cm × 50 cm × 75 cm and weighs 22 kg. The SF_6 Detector/Chromatograph is 45 cm × 40 cm × 75 cm and weighs 10 kg. The Leakmeter measures 43 cm × 39 cm × 73 cm and weighs 14 kg. All three units sample at a rate of 250 cc/min, require 110 V power, and utilize a meter as the readout mode.

Performance data

All three units respond to sulfur hexafluoride (SF_6), carbon tetrachloride, and the freon family. Detection limits range from 0.1 ppm for certain freons to 0.00001 ppm SF_6.

The SF_6 Detector/Chromatograph is extremely specific due to the gas chromatograph column. Response time on the Leakmeter and Atmosphere Monitor is one second, and 15 sec for the SF_6 Detector/Chromatograph. All instruments are extremely stable with no drift and are precise and accurate allowing for quantitative and qualitative laboratory, environmental and industrial applications.

Figure V-170 — Ion Track, Model 505, SF_6 Detector/Chromtograph.

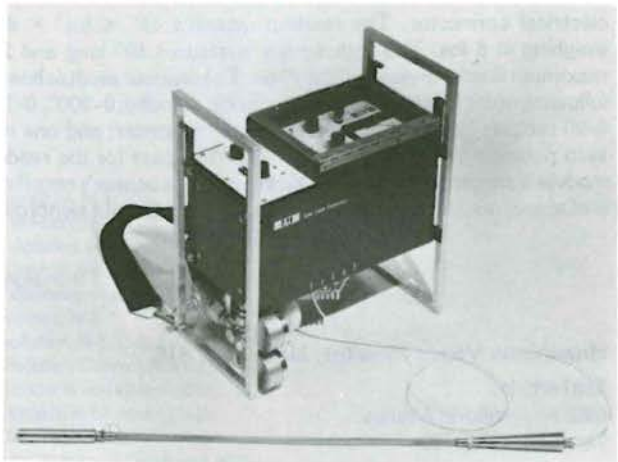


Figure V-171 — Ion Track Gas Leak Detector.

Photoionization Analyzer

H-Nu Systems, Inc.
30 Ossipee Road
Newton, MA 02164

The Photoionization Analyzer is a portable analyzer employing a new technique for the measurement of gases in industrial atmospheres. The instrument is similar to a flame ionization analyzer in its response to many organics but is safe because of the absence of a flame. The instrument is sensitive and can detect less than 0.2 ppm of many organics, however, methane gives no response. The instrument is lightweight, operates on rechargeable batteries, has a mineral warm-up time, stability, and requires no hydrogen or additional gases for operation.

Operating principle

The process is termed photoionization since the absorption of ultraviolet light by a molecule leads to ionization via:

$$R + h\nu \rightarrow R^+ + e$$

where R^+ is the ionized species and $h\nu$ is a photon which has an energy $\geq$ the ionization potential of the species.

The sensor consists of a sealed ultraviolet light source that emits photons which are energetic enough to ionize many trace species (particularly organics) but do not ionize the major components of air such as O_2, N_2, CO, CO_2, or H_2O. A chamber adjacent to the ultraviolet source contains a pair of electrodes. When a positive potential is applied to one electrode, the field created drives any ions formed by adsorption of the UV light to the collector electrode where the current (proportional to concentration) is measured.

Figure V-172 — H-Nu Photoionization Analyzer.

Physical description

This instrument consists of 2 separate units; sensor and readout connected by a three foot shielded multi-conductor cable with

electrical connector. The readout mesures 11" × 5¼" × 8¼", weighing < 8 lbs. The high sensor measures 10" long and 2½" maximum diameter and weighs 20 oz. The readout module has the following on its front panel: battery check; standby; 0–2000, 0–200, 0–20 ranges; 10 turn counting span potentiometer; and one turn zero potentiometer. The meter is 4½". The case for the readout module is constructed of drawn aluminum. The sensor's outerbody is of aluminum and engineering thermoplastic. *Output signal available:* 0–10 mV recorder jacks. Standard accessories include: a) AC battery charger; and b) teflon lined telescoping probe, three feet in length for sampling inaccessible places.

Performance data

Sensitivity: better than 0.2 ppm benzene. *Ranges:* 0–20, 0–200, 0–2000 ppm. *Response time:* < 5 seconds. *Operating time:* minimum of 8 hours on 12 VDC rechargeable batteries.

Hazardous Vapor Monitor, Model GC 810

XonTech, Inc.
6862 Hayvenburst Avenue
Van Nuys, CA 91406

The Model GC 810 Vapor Monitor is a portable automatic gas chromatograph with a preconcentrator which can be used to measure hazardous vapors in industrial environments. Applications include hazardous vapor identification, fugitive emissions measurement, workplace surveillance, spill monitoring, confined spaces monitoring, continuous ventilation dust monitoring, and process control monitoring.

Operating principle

The Model GC 810 comes equipped with an electron capture or argon ionization (H^3 source 150 mCi) detector. The monitor can be used to automatically sample ambient air or used manually to handle injections.

In the manual mode the instrument may be operated for one cyle in calibrate or analyze. Multiple calibration cycles may be performed automatically. Pump and sample injections may be bypassed with starting up of the Retention Time Clock. In the automatic mode the instrument will take a sample, inject it into the GC using the XonTech gas sample valve, compute the area under each peak, display the results and retention time, print a report at the end of the cycle, and begin a new cycle.

Physical description

Sampling time: 2 sec to 5 min. *Sampling rate:* up to 1000 cc/min. *Power:* 12 VDC or 120/220 VAC (rechargeable battery). *Fuel:* carrier gas, helium. *Alarm limits:* 1–999% of calibration. *Recorder output:* 0–1 VDC. *Alarm indication:* audible and visual alarm. *Column and detector temperature:* 60° to 200°C.

Performance data

Range: 10 ppb to 100 ppm. *Sensitivity:* as low as 5 ppb. *Time response:* 20 sec to 30 min. *Warmup time:* 20–30 min. *Automatic calibration:* 2 to 120 per calibration.

Air sampling instruments

for evaluation of atmospheric contaminants

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