Chapter 19

Direct-Reading Gas and Vapor Instruments

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Introduction

This chapter presents useful information about direct-reading instruments for analyzing airborne gases and vapors. The instrumentation that will be discussed is that which provides an onsite indication, in useful units (e.g. ppm, mg/m^3, etc.), of the presence of the contaminant(s) of interest. Frequently, these instruments are general, nonspecific detectors, but chemispecific detectors are also available.

Direct-reading instruments may be used for area, process, or personal monitoring, and it is convenient to describe three physical classifications for grouping these instruments: *personal* instruments are those instruments small enough to be worn by an individual, *portable* instruments are those easily carried by an individual, *transportable* instruments are those requiring a cart or other support for movement to or from the monitoring site. Ideally, these instruments operate from self-contained battery power, but many require line current.

In this chapter, the reader will find information on operational, physical, and performance characteristics for each of the instruments described. The instruments are grouped into the following classifications: electrochemical instruments, spectrochemical instruments, thermochemical instruments, gas chromatographic instruments, paramagnetic instruments, and an aerosol formation and detection instrument. In each section there is a general definition of the instrumentation to be described, an explanation of the principle of detection, and a brief discussion of conditions of application

for the instruments, including capabilities, restrictions, and limitations. At the end of the chapter is a suggested reading list for the reader who requires more in-depth information about a particular technique.

Regardless of the instrument chosen for use and the capabilities of that instrument, there is no substitute for knowledge of the capabilities and limitations of the instrument, as well as conditions in the proposed monitoring situation. Then, the most appropriate instrument can be chosen for a given application, meaningful data can be obtained, and, if necessary, effective solutions for contaminant control can be implemented.

Electrochemical Instruments

Electrochemical techniques involve the measurement of electrical signals associated with chemical systems.[1] These chemical systems are typically incorporated into electrochemical cells. Electrochemical techniques include instruments that operate on the principles of conductivity, potentiometry, coulometry, and ionization.

Conductivity (1.1–1.4)

Instruments that measure conductivity rely on the fact that charged species (ions) conduct electricity. Equally significant is the fact that at low concentrations, such as those concentrations typically found when these species are measured as workplace contaminants, conductivity is proportional to concentration. The fundamental equation for conductivity is given by

$$G = \frac{\Lambda C}{1000 K}$$

where: G = conductance in Siemens
Λ = equivalent conductance in Siemens per centimeter-equivalent
C = the concentration in equivalents per 1000 cm^3
K = a geometric term describing the electrochemical cell

A conductivity measurement depends on the space between, and area (size) of, a pair of electrodes and also on the volume of solution between them. Because conductance is the reciprocal of resistance, that is,

$$G = \frac{1}{R}$$

where R is resistance in ohms, the latter is sometimes measured since it is a more fundamental property. It should be noted that species monitored by conductivity need not be in an ionic form in the vapor phase but may be gases or vapors that form electrolytes, by chemical reaction, in solution.

Conductivity measurements are temperature dependent, having a temperature coefficient that can be on the order of 2% per °C. Instruments that *control* temperature may use thermostatted cabinets; those that *compensate* for temperature effects do so electronically.

A special case of conductivity instrumentation is one wherein a gold film is used to amalgamate mercury (Hg). In the mercury conductivity detector, the change in resistance of the *solid* film is measured.

Conductivity is, typically, a nonspecific technique in that any species ionizable under the given conditions will affect the measurement. The specific conductance, λ, of each ionizable species is important, for only when the conductivity of interfering electrolytes is either constant and/or negligible can the conductivity of the species of interest be measured.

There also are several solid-state devices that exploit electronic conductivity charges induced in metal oxide semiconductors.[2] Their principle of operation is based on the change in surface conductivity of a semiconductor, such as SnO_2, as a result of gas adsorption. The adsorbed gas may either directly affect the conductivity, or interact with the surface oxygen coverage, which, in turn, affects the conductivity. These instruments are relatively inexpensive, are easy to use, and can be used in oxygen-depleted atmospheres. They are typically used in screening applications and for hazard warning.

Conductivity instruments are primarily used for detection of corrosive gases, e.g., ammonia (NH_3), hydrogen sulfide (H_2S), and sulfur dioxide (SO_2). The conductivity analyzers are numbers 1.1 through 1.4 in the "Instrument Descriptions" section. They are most effectively used in isothermal environments at or near room temperature. Environments with few potential interferences are preferred. Chemical prescrubbers can be helpful.

Potentiometry (2.1–2.45)

Instruments that use a change in electrochemical potential as their principle of detection are most commonly represented by the pH meter. Potentiometry is strictly defined as the measurement of the difference in potential between two electrodes in an electrochemical cell under the condition of zero current. Gases and vapors can react with reagents effecting an oxidation/reduction, the extent of which is proportional to the concentration of the reacting gas. The fundamental equation governing a potentiometric reaction is the Nernst equation:

$$E_{cell} = E^o_{cell} - \frac{RT}{nF} \ln \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

where: E_{cell} = cell potential
E^o_{cell} = standard cell potential
R = gas constant
T = temperature
n = number of electrons involved in the electrode reaction
F = Faraday constant

Although the letters in brackets strictly represent the chemical activities of the reacting species, when considering dilute solutions, it is reasonable to approximate the activity using the concentration. This equation is simplified at room temperature (25°C) by converting to the base ten logarithm and substituting for the constants: R = 8.314 Joules mol^{-1} T^{-1}, T = 298 K, F = 96,485 Coulombs/mol. This results in the following equation:

$$E_{cell} = E^o_{cell} - \frac{0.0591}{n} \frac{\log [C]^c[D]^d}{[A]^a[B]^b}$$

The Nernst equation relates potential, E_{cell}, with temperature, the electronic state change of the species being oxidized or reduced, and the concentration of the species. When sampling with a potentiometer, the sampled analyte of interest would most likely be represented in this equation by one of the reactants, A or B.

Whereas potentiometry is basically a nonspecific technique, some degree of specificity may be obtained through the selection of the membrane through which the gaseous analyte must diffuse to enter the electrochemical cell, the selection of the reagent, and the type of electrodes used.

Potentiometers are listed as numbers 2.1 through 2.45 in the "Instrument Descriptions" section. They are used for the measurement of a variety of contaminants including carbon monoxide, chlorine, formaldehyde, hydrogen sulfide, oxides of nitrogen, oxides of sulfur, oxygen, and ozone.

Coulometry (3.1–3.22)

Coulometric analyzers have as their principle of detection the determination of the quantity of electricity required to affect the complete electrolysis of the analyte of interest. The amount of electricity required is proportional to the amount of analyte present. This analyte may be the contaminant requiring monitoring, or it may be a chemical with which the contaminant quantitatively reacts. Regardless, the equation governing coulometry is Faraday's:

$$W = \frac{qM}{nF}$$

where: W = mass of substance that is electrolyzed
q = charge, in Coulombs, required to completely electrolyze the substance
M = formula weight
n = number of electrons per molecule required for electrolysis
F = Faraday's constant: 96,485 Coulombs/mol

The quantity that an instrument must measure is q. This may be done either directly, by determining the integral (controlled-potential coulometry), or indirectly, by measuring the time required for electrolysis under conditions of constant current (constant-current coulometry). Both approaches work because of the following relationship:

$$q = \int i\, dt$$

where: i = current in amperes
t = time

Coulometry is, inherently, a very accurate technique that is fairly sensitive. Coulometric analyzers are numbered 3.1 through 3.22 in the "Instrument Descriptions" section. The vast majority of these instruments are configured as oxygen or oxygen deficiency monitors, although coulometric analyzers are also available for carbon monoxide, chlorine, hydrogen cyanide, hydrogen sulfide, oxides of nitrogen, ozone, and sulfur dioxide.

Ionization (4.1–4.15)

There are three types of ionization detectors: flame ionization (FID), photoionization (PID), and electron capture (ECD). All rely on the ability of their respective energy source (flame, lamp, or radioactivity) to ionize the species of interest.

Flame Ionization

In an FID, a gaseous sample is pyrolyzed in a hydrogen/air flame.[3] Pyrolysis produces ions and electrons that are carried through the plasma to an electrode gap, decreasing the gap resistance and allowing current to flow in the external circuit. Figure 19-1 shows a schematic of a typical flame ionization detector. The FID has a wide linear range, on the order of 10^6 to 10^7, and is a very sensitive detector able to detect on the order of nanogram quantities of organic compounds. As a result, this detector is excellent in trace analysis. Flame ionization is a nonspecific detection mechanism ideal for the detection of most organic compounds. The detector does not respond to, or responds very little to, common constituents found in air and water vapor. The user should be aware that electronegative compounds such as chlorine and sulfur (in the vapor phase) will depress the response.

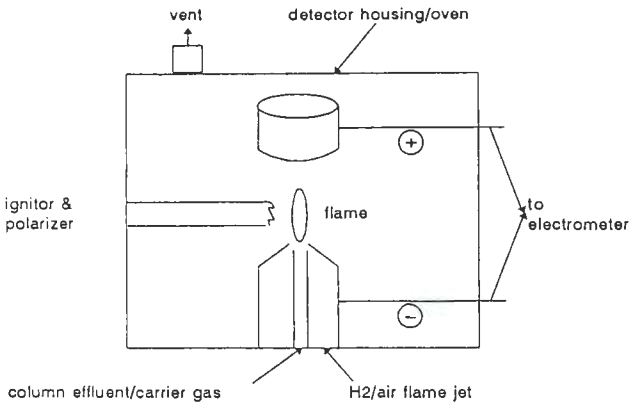


FIGURE 19-1. Schematic of Flame Ionization Detector.

Photoionization

Photoionization is a flameless ionization technique wherein the contaminant gas or vapor is carried into an ionization chamber where an ultraviolet lamp of known constant voltage causes the ionization of any species having an ionization potential less than the energy emitted by the lamp.[4] That is, photoionization occurs when a molecule absorbs a photon of sufficient energy to cause the molecule to lose an electron and become a positively charged ion:

$$RH + h\nu \rightarrow RH^+ + e^-$$

where: RH = molecule to be ionized
h = photon whose energy is greater than the ionization potential of RH
RH^+ = ionized molecule
e^- = electron lost in the process

The PID will have a high voltage positive bias electrode to repel the positively charged molecules accelerating them toward a negatively charged collector electrode. This, in turn, generates a signal at the collector which is proportional to the amount of ionized species. Figure 19-2 shows a schematic of a photoionization detector.

Photoionization is a nondestructive technique and somewhat selective through judicious selection of ultraviolet lamps of varying energies. Under optimum conditions, a PID can detect 5 pg of benzene and has a linear dynamic range on the order of 10^7.

Electron Capture

An ECD uses a radioactive source to generate the ions that are measured by this technique.[3] The radioactive source is usually H^3, Ni^{63}, or Kr^{85}. As the carrier gas, nitrogen, flows past the ion source, the nitrogen is ionized and slow electrons are formed that migrate to the anode, producing a steady current. Some molecules, said to have high electron affinity, have the ability to capture rapidly moving, free electrons from the radioactive source. When the molecules capture the electrons, they become stable, negative ions. This may happen by one of two mechanisms:

$$AB + e^- \rightarrow (AB)^- + energy \qquad AB + e^- \rightarrow A^- + B \pm energy$$

where: A and B = reactants

Figure 19-3 shows a schematic of an ECD. When samples with high electron affinity components are introduced into the chamber, the current flow, established through the ionization of the nitrogen, is reduced. Because the current reduction is a function of both the amount of sample present and its electron affinity, a calibration must be made separately for each sample component that is to be quantified.

An ECD is very selective, particularly for halogenated compounds, nitrates, conjugated carbonyls, and some organometallic compounds. This detector is very sensitive (as low as 0.1 pg) for the compounds it will detect, but its linear range is very low, about 10^2–10^3.

Both FIDs and PIDs are primarily used for the detec-

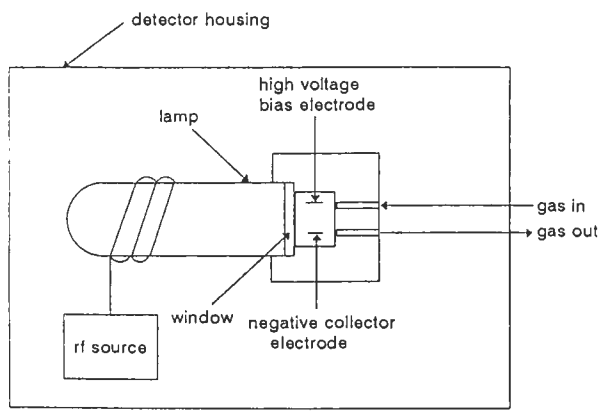


FIGURE 19-2. Schematic of a Photoionization Detector.

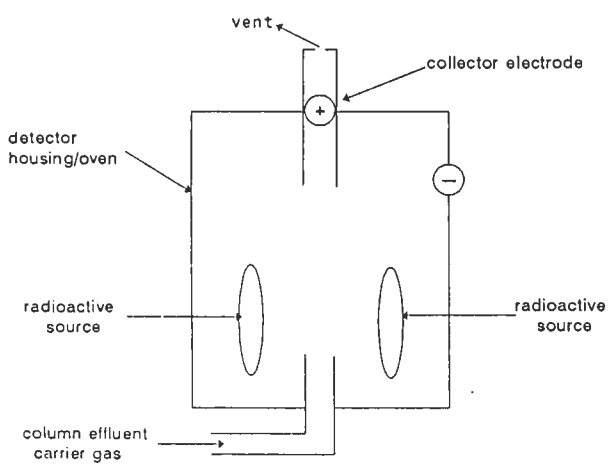


FIGURE 19-3. Schematic of an Electron Capture Detector.

tion of organic compounds, but the PID has some utility for inorganic compounds such as nitric and sulfuric acids, hydrogen sulfide, arsine, and phosphine. The ECD is useful for SF_6 and pesticide detection. Ionization detectors are numbers 4.1 through 4.15 in the "Instrument Descriptions" section. All three detectors are available as stand-alone instruments, as well as detectors for gas chromatographic systems, which will be discussed later in this chapter.

Spectrochemical Instruments

Instruments whose principle of detection is spectrochemical in nature include infrared analyzers, ultraviolet and visible light photometers, chemiluminescent detectors, and photometric analyzers.[5] Photometric analyzers include fluorescent and spectral intensity detectors. In general, spectrochemical analysis involves the use of a spectrum or some aspect of a spectrum to determine chemical species. A spectrum is a display of intensity of radiation that is emitted, absorbed, or scattered by a sample, versus wavelength. This radiation is related to photon energy via wavelength or frequency.

Infrared (5.1–5.16)

Infrared spectrometry (IR) involves the interaction of the infrared portion of the electromagnetic spectrum with matter. Specifically, that portion of the spectrum ranging in wavelength from 770 nm to 1000 μm, or 12,900 cm^{-1} to 10 cm^{-1} in wave number. The infrared portion of the spectrum is subdivided into three regions: the near-infrared (770 nm to 2.5 μm), the mid-infrared (2.5 to 50 μm), and the far-infrared (50 to 1000 μm). The terms "near," "mid," and "far" refer to proximity to the visible portion of the electromagnetic spectrum. Infrared radiation is not energetic enough to cause electronic transitions in molecules, but it does result in vibrational and rotational transitions. Nearly all molecules absorb infrared radiation, making the technique widely applicable. Because the IR spectrum of a given molecule is unique to that molecule, IR can be fairly specific and useful in compound identification. However, the possibility of overlapping peaks makes the use of any single wavelength IR measurement of an uncharacterized mixture risky.

Figure 19-4 shows a schematic of an infrared analyzer. These instruments consist primarily of six major sections: a source of infrared radiation, a wavelength selector, a sample cell, appropriate optics, a detector, and a signal processor/readout. Although Figure 19-4 shows the monochromator after the sample cell, wavelength selection can occur before the sample cell, after the sample cell, or both. Infrared spectrometry may be either a nondispersive or a dispersive technique. A nondispersive IR is a filter photometer employing interference filters designed for the determination of a specific pollutant, whereas a dispersive IR uses prisms or gratings to separate radiation into its component wavelengths to obtain a complete spectrum for qualitative identification.

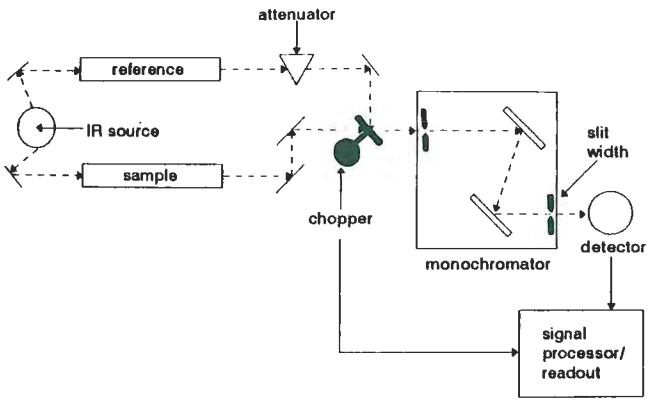


FIGURE 19-4. Schematic of Double Beam Infrared Analyzer.

Because it is an absorption technique, infrared spectrometry is governed by Beer's Law:

$$A = \varepsilon bc$$

where: A = absorbance
ε = molar absorptivity
b = path length
c = concentration

This equation shows the relationships between the amount of energy absorbed and the length of the path through the sample, and between the absorbed energy and the concentration of the species of interest. The dependency of absorbance on path length is significant in discussing parameters of interest because the longer the path length of the instrument, the more sensitive the instrument should be. In introducing Beer's Law, it is significant to note that the absorbance, A, is log P_o/P, where P_o is the original incident radiation, and P is the energy remaining after some is absorbed by the sample.

An additional instrument parameter of interest is the slit width. The slit width defines the window of energy seen either by the sample or by the detector. Figure 19-4 shows the slit width at the detector end of the instrument. The width of this slit is inversely proportional to selectivity and peak resolution.

The direct-reading infrared instruments are given in the "Instrument Descriptions" section as numbers 5.1 through 5.16. The instruments balance modest precision with selectivity and high throughput. Some instruments are designed as fixed wavelength monitors whereas others are capable of scanning the infrared spectrum. Some of these instruments are designed as general detectors for organics and subgroups such as hydrocarbons; others are more specific monitors for

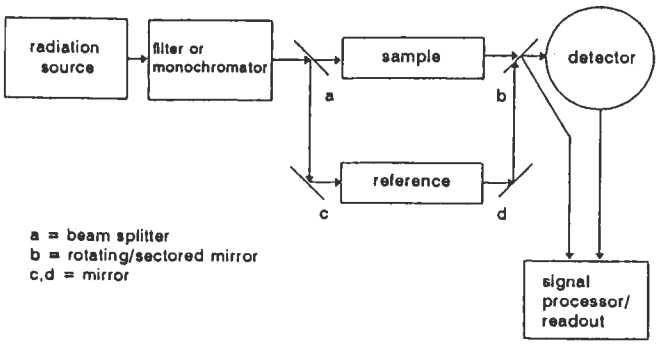


FIGURE 19-5. Schematic of a UV-VIS Spectrophotometer.

compounds such as methane, ethylene, ethane, propane, butane, vehicle emissions, carbon monoxide, carbon dioxide, and several freons. The user needs to be aware that certain ubiquitous compounds, like water, absorb very strongly in the infrared, and care must be exercised to avoid making measurements at or near these absorbances.

Ultraviolet and Visible Light Photometers (6.1–6.10)

Both ultraviolet (UV) and visible (VIS) light photometers operate on the principle of absorption of electromagnetic radiation. The UV is that portion of the electromagnetic spectrum having wavelengths from 10 to 350 nm. The actual spectral range for direct-reading UV instruments is closer to 180–350 nm, which is termed the "near UV," in deference to its proximity to the visible spectrum. The corresponding energy range for the UV is 3.6–7 eV for the near UV and 7–124 eV for the far, or vacuum, UV. The visible spectrum has longer wavelengths than the UV (350–770 nm) and correspondingly lower energies (1.6–3.6 eV). Like their infrared counterparts, the operational principle (energy absorption) of the UV-VIS instruments is governed by Beer's Law, and the techniques have the same relationships between absorption and concentration, and between absorption and path length. Although the relationship between absorbance and concentration is linear, the value typically measured in spectrophotometry is transmittance, T, whose relationship with absorbance is given by:

$$A = 2 - \log \%T$$

Transmittance is the ratio of the amount of energy passing through the sample (not absorbed) to the amount of incident energy. Measuring $\%T$ is preferable because it is a percent scale (as opposed to absorbance which is logarithmic), and the instrument is much easier to zero and span.

Figure 19-5 shows a schematic of a typical UV-VIS photometer. The instruments operating on the principle of energy absorption in the UV-VIS region are given in the "Instrument Descriptions" section as numbers 6.1 through 6.10. Most of these instruments are designed to analyze gaseous samples such as ammonia, mercury vapor (which absorbs very strongly at 253.7 nm), oxides of nitrogen, ozone, and sulfur dioxide.

A special case of visible spectroscopy is colorimetry, wherein the sample is mixed with a reagent selected to react with the contaminant of interest, forming a colored product. The ability of this colored, liquid product to absorb light in the visible region is exploited. This type of instrument, governed by the same chemical principles, can be used as a continuous monitor for a variety of compounds. The UV-VIS instruments are capable of detecting contaminants in the ppm range.

Chemiluminescence (7.1–7.6)

Chemiluminescence is a form of emission spectroscopy wherein spectral information is obtained from nonradiational activation processes.[6] In this case, the emitted energy results from species that are excited by chemical reactions and are returning to the lower energy state by emission of a photon. Chemiluminescence is based on the fact that in some chemical reactions, a significant fraction of the intermediates or products are produced in excited electronic states. The emission of photons from these excited electronic states is measured and, if the reaction conditions are arranged appropriately, is proportional to the concentration of the contaminant of interest. Two common chemiluminescence mechanisms are:

$$\begin{array}{lll} A + B \rightarrow I + I^* & & A + B \rightarrow P + P^* \\ \quad\quad\downarrow & & \quad\quad\downarrow \\ \quad I + h\nu \rightarrow P & & \quad P \rightarrow h\nu \end{array}$$

where: A and B = reactants
I = intermediate
P = product
$*$ = excited state
$h\nu$ = emitted energy

Three conditions must be met in order to have chemiluminescence take place. First, there needs to be enough energy to produce the excited state; second, there must be a favorable reaction pathway to produce the excited state; and, third, photon emission must be a favorable deactivation process.

The direct-reading chemiluminescent detectors are numbered 7.1 through 7.6 in the "Instrument Descriptions" section. They analyze gas phase samples and have been developed primarily for oxides of nitrogen and ozone. Because of the chemical reactions involved, the instruments have a high degree of specificity and have typical limits of detection on the order of 10 ppb.

Photometric Analyzers

This category includes fluorescence analyzers, flame photometric detectors, spectral intensity analyzers, and photometers, primarily reflectance. The first three techniques are all examples of emission spectroscopy wherein the excitation process is radiative in nature; the last category includes automated media advance samplers, branched sequential samplers, and paper tape stain development, all of which utilize photometric analysis.

Fluorescence (8.2, 8.3, 8.5)

Fluorescence is the emission of photons from molecules in excited states when the excited states are the result of the absorption of energy from some source of radiation. For most molecules, electrons are paired in the lowest energy or ground state. If a molecule absorbs energy from a sufficiently powerful radiation source, such as a mercury or xenon arc lamp, the molecule will become "excited," moving an electron to a higher energy state. When the electron returns to the lower, more stable energy condition, it releases the absorbed energy in photons. A significant characteristic of fluorescence is that the emitted radiation is of a longer wavelength (lower energy) than the exciting radiation. Figure 19-6 shows a block diagram of the components of a fluorescence instrument. An excitation wavelength selector is used to limit the energy to that which will cause fluorescence of the sample while excluding energy wavelengths that may interfere with the detection. The emission wavelength selector isolates the fluorescence peak. Detection is at right angles to allow measurement of the longer wavelength light emitted from the sample while avoiding detection of light from the source, which could cause large errors in measurement.

Fluorescence instruments are available for carbon monoxide and sulfur dioxide. They are numbers 8.2, 8.3, and 8.5 in the "Instrument Descriptions" section. Typical limits of detection are in the 5–10 ppb range.

Flame Photometric (8.4, 8.6, 8.14)

Flame photometric detectors can be adjusted to obtain selectivity for nanogram quantities of sulfur or phosphorous compounds. The detector works by measuring the emission of light from a hydrogen flame. Light from the flame impinges upon a mirror and is reflected to an optical filter that allows only light of either 526 μm (for phosphorous) or 394 μm (for sulfur) to pass through to the photomultiplier tube. Calibration with a flame photometric detector is critical because this detector exhibits little or no linearity. From the "Instrument Descriptions" section, numbers 8.4, 8.6, and 8.14 are flame photometric detectors. They have limits of detection in the low ppb range.

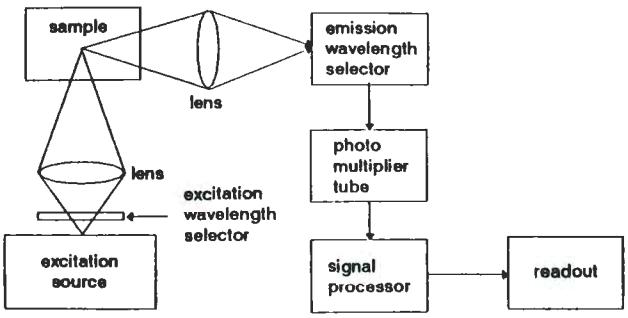


FIGURE 19-6. Schematic of a Fluorescence Spectrometer.

Spectral Intensity (8.8, 8.13)

Spectral intensity analyzers measure the radiant power of emission from an analyte due to nonradiational excitation. Two such instruments are available (numbers 8.8 and 8.13 in the "Instrument Descriptions" section). Both instruments are used for halide detection by measuring the increased spectral intensity of an AC arc (or spark) in the presence of halogenated hydrocarbons. The increased intensity can be related to the concentration of the halogenated compound by using a calibration curve based on the specific compound of interest. These instruments have limits of detection in the tens of ppm range and have limited selectivity, i.e., they can differentiate halogenated compounds from nonhalogenated compounds, but cannot differentiate between halogenated compounds.

Photometers (8.1, 8.7, 8.9–8.12)

The remaining instruments in this category are simply referred to as photometers. The instruments, numbers 8.1, 8.7, and 8.9 through 8.12 in the "Instrument Descriptions" section, have unique sampling characteristics and detection principles relative to the other instruments in this category (spectrochemical techniques), but they operate on spectrochemical principles nonetheless. The majority of these instruments allow for unattended sampling through the use of automated sampling media advance (i.e., tape samplers, rotating drum samplers, rotating disc samplers, and turntable samplers) or branched sequential sampling trains. These samplers typically involve a color change of the sampling medium and the analytic finish is measurement of the light reflected from the sampling medium. These instruments are useful for such toxic species as toluene diisocyanate, ammonia, phosgene, arsine, and hydrogen cyanide. The reflectance instruments can be quite specific through judicious selection of the chemistry for the sampler, and the ability to change the chemistry makes these instruments potentially useful for a wide variety of compounds.

Other instruments in this category include one de-

signed for the determination of CO. This instrument actually measures mercury that is generated via reduction of solid-state mercury oxide. The amount of mercury generated is equal to the quantity of carbon monoxide oxidized in the sample. The mercury is measured using a UV filter photometer. The other three instruments rely on the development of a color stain, wherein the intensity change or the development of the intensity change is measured via a photoelectric cell. These last three instruments are useful primarily for hydrogen sulfide, although one will determine other analytes as a function of the chemically impregnated paper used for color development. All the photometers have limits of detection in the low ppm range and are very specific for the contaminant(s) of interest.

Thermochemical Instruments

Gases and vapors have certain thermal properties that can be exploited in their analysis.[7] Of the instruments available for industrial hygiene applications, one of two thermal properties, conductivity or heat of combustion, is measured.

Thermal Conductivity (9.1–9.3)

Thermal conductivity detectors are relatively simple devices that operate on the principle that a hot body will lose heat at a rate that depends on the composition of the surrounding gas. That is, the ability of the surrounding gas to conduct heat away from the hot body can be used as a measure of the composition of the gas. In actual practice, a thermal conductivity detector consists of an electrically heated element, or sensing device, whose temperature at constant electrical power depends on the thermal conductivity of the surrounding gas. The resistance of the sensing device is used as a measure of its temperature. Thermal conductivity detectors are universal detectors, responding to all compounds. They have large linear dynamic ranges, on the order of 10^5, and limits of detection on the order of 10–8 gram of solute per mL of carrier gas (10–100 ppm for most analytes). Thermal conductivity detectors require good temperature and flow control. They are numbered 9.1 through 9.3 in the "Instrument Descriptions" section.

Heat of Combustion (10.1–10.35)

Heat of combustion detectors, comprising the largest single class of direct-reading instruments for analyzing airborne gases and vapors, measure the heat released during combustion or reaction of the contaminant gas of interest. The released heat is a particular characteristic of combustible gases and may be used for quantitative detection. There are two main mechanisms for the operation of heat of combustion detectors. The first relies on heated filaments. Upon introduction of the contaminant gas into the sample cell, the contaminant comes into contact with a heated source, igniting the contaminant. The resulting heat changes the resistance of the filament. The measured change in filament resistance is related to the gas concentration through the use of calibration standards.

The second mechanism used in heat of combustion instruments employs the use of catalysts via catalytically heated filaments or oxidation catalysts. This second mechanism may use one of two methods of detection: a measured resistance change, or temperature changes measured via thermocouples or thermistors.

Like thermal conductivity detectors, heat of combustion detectors are nonspecific, universal detectors. Some specificity can be introduced by manipulation of the temperature; that is, the combustion temperature may be controlled so that it is insufficient to combust interfering gases. From the second mechanism, some specificity may be introduced by careful selection of the oxidation catalyst.

As the category name implies, heat of combustion detectors are available as generic detectors for combustible gases. Some more specific heat of combustion detectors are available for carbon monoxide, ethylene oxide, hydrogen sulfide, methane, and oxygen deficiency. Most of these monitors read out in terms of percent of the lower explosive limit (LEL) or hundreds of ppm and the limits of detection are a function of the analyte of interest. These instruments are numbered 10.1 through 10.35 in the "Instrument Descriptions" section.

Gas Chromatographs (11.1–11.7)

In terms of detection of airborne gases and vapors, the detectors used in gas chromatographic (GC) analyzers have, for the most part, been discussed earlier in this chapter.[3,4] The most frequently used detectors in GCs designed for industrial hygiene applications are the FID and the PID. The reason gas chromatographs are being discussed separately is fourfold: there are several direct-reading gas chromatographs commercially available; they represent a distinct family of instruments in that they very specifically address the issue of separation (specificity), as well as detection, in industrial hygiene monitoring; they represent one area where a great deal of research and development is ongoing; and they most closely approximate the transfer of laboratory analytical techniques into the field.

Figure 19-7 shows a schematic of a GC. The sample is either injected into the GC using a gas-tight syringe or the instrument may be capable of obtaining its own sample via a built-in sampling pump. If the sample is

a liquid, the instrument must be capable of vaporizing the sample (e.g., using a heated injection port).

The actual separation of the sample into its component parts takes place on the GC column.[8] Columns are typically long tubes made of metal, glass, Teflon®, or fused silica. Columns in portable, direct-reading GCs are of two kinds: packed and wall-coated. A packed column contains a granular material used as a solid support which is coated with a chemical chosen for its ability to interact with the components of the sample. This chosen chemical is referred to as the stationary phase. Packed columns are generally from 4 or 5 cm to 1 meter or more in length and have external diameters on the order of 0.3 cm (1/8 in.). A wall-coated column tends to be longer (5 cm to 3 m or more) and narrower (i.d. from 0.1 to 1 mm) than packed columns. In a wall-coated column, there is no granular solid support for the stationary phase. It is, as the name implies, coated directly on the walls of the column. The long, thinner columns (i.d.'s < 0.5 mm) are sometimes referred to as capillary columns.

The sample is carried through the column by an inert (relative to the sample) carrier gas, which, depending on the direct-reading GC, may be helium, hydrogen, nitrogen, argon, carbon dioxide, or air. The separation is governed by the degree of interaction of the sample with the stationary phase and the properties of the carrier gas. All components of a mixture spend the same amount of time in the carrier gas, so their different elution times is a function of the time spent in the stationary phase. The elapsed time from injection until the detector "sees" a component of a mixture is that component's retention time. The retention time is a function of the physical properties of a component in a sample, whereas the size of the peak is a function of the amount. Figure 19-8 shows the component parts of a typical chromatogram.

The degree of separation of two components, as well as their relative retention times, depends, in part, on the temperature at which the system operates. Some portable GCs operate only at ambient temperatures; others are capable of heating the column.

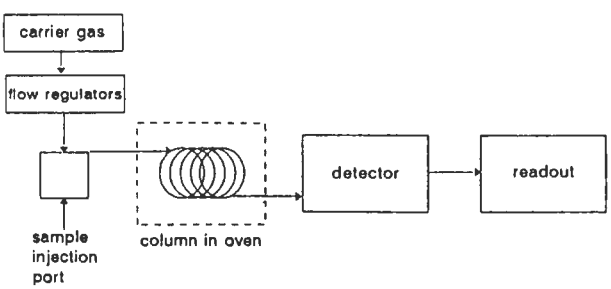


FIGURE 19-7. Schematic of a Gas Chromatograph.

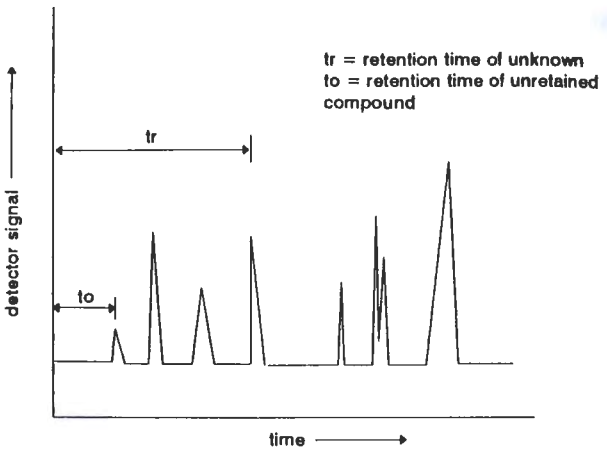


FIGURE 19-8. Schematic of a Typical Gas Chromatogram.

Once the component parts of a mixture elute from the column, they go into the detector. Portable GC detectors include flame ionization, photoionization, electron capture, ultraviolet, flame photometric, and thermal conductivity (which have already been addressed in this chapter), as well as nitrogen-phosphorous and argon ionization.

Because of their separation capabilities, GCs offer excellent selectivity combined with low limits of detection. The limits of detection are primarily a property of the individual detectors and are given in the detector discussions, but portable GCs generally have limits of detection at sub-ppm levels. Some limitations associated with portable GCs include the need for more user knowledge of the technique, size, and cost. The portable GCs are numbers 11.1 through 11.7 in the "Instrument Descriptions" section.

Summary

Many instruments are available for direct-reading analysis of gases and vapors. They operate on a variety of principles of detection and vary in performance characteristics such as linear range, specificity, and limits of detection. Direct-reading instruments represent a powerful tool in developing sampling strategies. That is, direct-reading instruments, when correctly used, can determine, in real or near-real time, those areas of high concentration, those workers at highest risk, and those processes with the highest emissions. Such information is useful in solving a variety of gas and vapor exposure problems. This information can guide the hygienist or safety professional in obtaining other more informative and useful samples requiring laboratory analyses. Used properly, direct-reading instruments can conserve resources, eliminating samples with results of "none detected."

References

1. Strobel, H.A.; Heineman W.R.: Chemical Instrumentation: A Systematic Approach, 3rd ed. John Wiley & Sons, New York (1989).
2. Gentry, S.J.: Appl. Occup. Environ. Hyg., 8(4), 260–266 (1993).
3. David, D.J.: Gas Chromatographic Detectors. Wiley-Interscience, New York (1974).
4. HNU Systems: Gas Chromatograph, Model 301, Instruction Manual. Newton Highlands, MA (1986).
5. Ingle, J.D.; Crouch, S.R.: Spectrochemical Analysis. Prentice-Hall, Inc., New Jersey (1988).
6. Hodgeson, J.A.: A Review of Chemiluminescent Techniques for Air Pollution Monitoring. Toxicol. Environ. Chem. Rev. 11:81 (1974).
7. Skoog, D.A.; West, D.M.; Holler, F.J.: Fundamentals of Analytical Chemistry, 5th ed. Saunders College Publishing, New York (1988).
8. McNair, H.M.; Bonelli, E.J.: Basic Gas Chromatography. Varian Aerograph, Berkeley, CA (1968).

Additional Reading

ACGIH: Volume 1, Dosimetry for Chemical and Physical Agents. William D. Kelley, Ed. American Conference of Governmental Industrial Hygienists, Cincinnati, OH (1981).

Cohen, B.S.: Air Sampling Instrument Performance. Appl. Occup. Environ. Hyg. 8(4) 227–229 (1993).

Cralley, L.J.; Cralley, L.V.: Patty's Industrial Hygiene and Toxicology, Vol.III, Theory and Rationale of Industrial Hygiene Practice. Wiley-Interscience, New York (1981).

Environmental Instrumentation Group, Lawrence Berkeley Laboratory: Instrumentation for Environment Monitoring Air. LBL-1. Technical Information Division, Lawrence Berkeley Laboratory, Berkeley, CA (1973).

Hosey, A.D.: History of the Development of Industrial Hygiene Sampling Instruments and Techniques. American Conference of Governmental Industrial Hygienists, Cincinnati, OH (1981).

Instrumentation for Monitoring Air Quality. R.C. Barras, Symposium Chairman. ASTM Special Publication 555 (74-76066). ASTM, Philadelphia, PA (1974).

Nader, J.S.: Source Monitoring. In: Air Pollution, 3rd ed., Vol. 3. Ch. 15, pp. 589–645. A.C. Stem, Ed. Academic Press, Inc., New York (1976).

Stevens, R.K.; Herget, W.F.: Analytical Methods Applied to Air Pollution Measurements. Ann Arbor Science Publ., Inc., Ann Arbor, MI (1974).

Instrument Descriptions

This section contains tables and short descriptions of the commercially available direct-reading instruments for gases and vapors. The tables are designed to provide an overview of the instrument features, sizes, and capabilities, whereas the descriptions give more detailed information and photographs. Each description is numbered and is cross referenced in the tables that appear at the end of the chapter. The descriptions are grouped by the operating principle upon which the measurement is based. The following instrument tables are included:

Table 19-I-1. Electrical Conductivity Analyzers
Table 19-I-2. Potentiometric Analyzers
Table 19-I-3. Coulometric Analyzers
Table 19-I-4. Ionization Detectors
Table 19-I-5. Infrared Photometers
Table 19-I-6. Ultraviolet and Visible Light Photometers
Table 19-I-7. Chemiluminescent Detectors
Table 19-I-8. Photometric Analyzers
Table 19-I-9. Thermal Conductivity Detectors
Table 19-I-10. Heat of Combustion Detectors
Table 19-I-11. Gas Chromatograph Analyzers

These tables reference instrument manufacturers by code letters; complete names and addresses are given in Table 19-I-12.

Electrical Conductivity Analyzers

19-1-1. Gold Film Mercury Vapor Analyzer

Arizona Instrument Corporation

The Model 411 Gold Film Mercury Vapor Analyzer is a portable instrument designed for mercury surveys in workplace environments. The Model 411 uses a patented Gold Film microsensor as the basis of detection. The sensor absorbs and integrates the mercury present in the sample, registering this as a proportional change in electrical resistance. The sensor's selectivity to mercury eliminates many interferences common to atomic absorption, such as water vapor, SO_2, aromatic hydrocarbons, and particulates. The Model 411 incorporates an internal pump and digital display with microprocessor control. Activating either the 10-second sample or the 1-second survey mode starts the pump that draws a precise volume of air over the Gold Film sensor. Mercury in the sample is adsorbed and integrated by the sensor. The microprocessor computes the concentration of mercury in mg/m^3 and displays the results on the digital meter until the next sample cycle is activated. Response time: sample mode, 10 seconds; survey mode, 1 second. Meter: LCD display. Construction: aluminum alloy. Flow rate: 0.75 L/min.

19-1-2. J-W Toxic Gas Alarms for NH_3, H_2S, and SO_2

Bacharach, Inc.

The Model MHO is used to continuously detect the presence of small concentrations of ammonia, H_2S, and SO_2 in the toxic range. Air is sampled by means of a vibratory pump, and H_2S in the sample is oxidized to SO_2. In the detection cell, the sample contacts a flowing stream of distilled water. Ammonia or SO_2 in the sample dissolves in the water, which increases the conductivity of the water. This conductivity change triggers a thyratron tube to turn on a relay and alarm signal. 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. A constant flow of distilled water is fed by gravity from a 1-gal plastic bottle mounted on the wall above the analyzer.

19-1-3. UltraGas-U3S Sulfur Dioxide Analyzer

Calibrated Instruments, Inc.

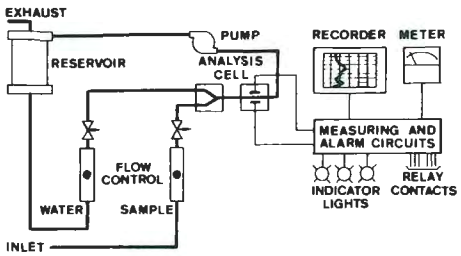
The UltraGas-U3S is a sampling and analysis device for measuring the concentration of SO_2 in air by the conductivity method. Existing interference components can be eliminated in most cases through suitable absorption traps so that measurement is selective. In the instrument, a constant and continuous stream of air and reagent mix in a reaction chamber. The conductivity of the solution changes in proportion to the concentration of SO_2. The conductivity change is determined in the detector by two electrode sections. The conductivity of the reagent is measured first in one section, and after reaction with SO_2, the conductivity is measured in the second section. The difference in the two alternating currents flowing through the two electrode sections is selected electronically by the recorder. A temperature-dependent resistance compensates for temperature changes.

19-1-4. Gas Analyzer System, Series 9000

Devco Engineering, Inc.

The Devco Engineering Series 9000 is designed specifically for the continuous monitoring of toxic gases or vapors in the atmosphere or of trace concentrations of contaminants in process streams. Typical applications include monitoring for CO_2, Freon®, or ammonia in refrigeration plants; continuous monitoring for SO_2 in air pollution studies; automatic bed cycling by continuously monitoring the effluent in solvent recovery systems; and measuring H_2S in air and hydrocarbon streams in petroleum refineries or sewage treatment plants. Analysis is based on measurement of electrical conductance in water due to ionization of the gas or vapor being monitored.

Prior to analysis, certain gases, such as H_2S or the



INSTRUMENT 19-1-4. Gas Analyzer System, Series 9000.

halogenated hydrocarbons, are treated by thermal decomposition or oxidation in a pyrolysis train; the emanating combustion products are then passed on to the analysis cell. This system is furnished in wall-mounting varieties, in NEMA type 12 enclosures, in freestanding relay rack-type housings, in portable packages (115 VAC, 60 Hz operated), or in fully explosion-proof construction. No special reagents are required; 2 quarts of water are required approximately every 30 days. Multipoint, sequential sampling systems are available to monitor up to eight points on a single instrument by means of a sample program assembly.

Potentiometric Analyzers

19-2-1. Series 200 and 300 Gas Detectors

AIM USA

The Series 200 and 300 Gas Detectors are designed to detect combustible gases, oxygen, and toxic gases. Applications include:

- Confined space entry survey work
- Industrial safety and hygiene
- Fugitive emissions and leak detection.

Instruments in the 200 and 300 Series are available to detect one, two, or three separate gases. Three data-logging formats are available:

- Alarm incident
- Time-interval sampling
- Location-survey testing.

Sensors are chemical-specific electrochemical for toxic gases and O_2, and nonspecific metal oxide for combustible gases. The metal oxide sensor comes standard with the one sensor version and is optional in the two or three sensor versions.

19-2-2. Series 500 Gas Detectors

AIM USA

The Series 500 Gas Detectors are designed to monitor for combustibles, O_2, H_2S, and CO in confined space entry applications. These instruments use metal oxide or Pellister sensors to detect combustibles and electrochemical sensors to detect O_2, H_2S, and CO.

Features of the 500 Series include audible and visual alarms, shock resistance case, and data logging capabilities for 1300 preset time intervals.

Accessories included with the instruments include:

- Power supply
- Manual
- Quick start card
- Confined space booklet
- Calibration hood
- Carrying case
- QC sheet
- Tool kit.

Operating temperature range: –20 to 50°C. Operating relative humidity range: 5% to 99%, noncondensing.

19-2-3. Sentinel® 44 Personal Multigas Monitor

Bacharach, Inc.

The Sentinel® 44 is designed to measure O_2, combustible gases, CO, and H_2S in confined-space entry applications. The Sentinel® is equipped with audible and visual alarms that are activated when preset instantaneous levels, short-term exposure limits (STELs), or time-weighted averages (TWAs) are exceeded. Other features include:

- Multi-gas LCD display
- Radio frequency interference (RFI) protection
- Data logging capabilities
- Removable battery packs.

Accessories include:

- Hand aspirator or motorized pump
- 10-in. or 36-in. probes
- Calibration kits and gases
- Remote earphone or pocket alarms.

Rechargeable leadacid gel cells can operate the instrument for 8–10 hrs per charge. The Sentinel® can operate in a temperature range of –20 to 50°C and a relative humidity range of 5% to 95%, noncondensing.

19-2-4. Mikrogas® Series Gas Analyzers

Calibrated Instruments, Inc.

Mikrogas® instruments continuously measure concentrations of SO_2, HCl, H_2S, NH_3, Cl_2, $COCl_2$, COS, CS_2, HCN, and other gases in ambient air, industrial process streams, standing tanks, waste treatment facilities, and stack and incineration emissions using the conductimetric measuring principle. Extremely accurate and precise streams of sample gas and a liquid reagent of measured conductivity are volumetrically forwarded to a wet sampling head where they are combined. Thoroughly mixed in a reaction line, the sample gas and chemically changed reagent are

then again separated. The reacted conductivity level of the reagent solution is then monitored as it passes a temperature-compensated continuous measuring electrode. An electronic circuit determines the change in conductivity of the reagent solution. This change in conductivity is proportional to the concentration of gas being sampled. Operating temperature: 2 to 40°C.

19-2-5. Ultragas® Series Gas Analyzers

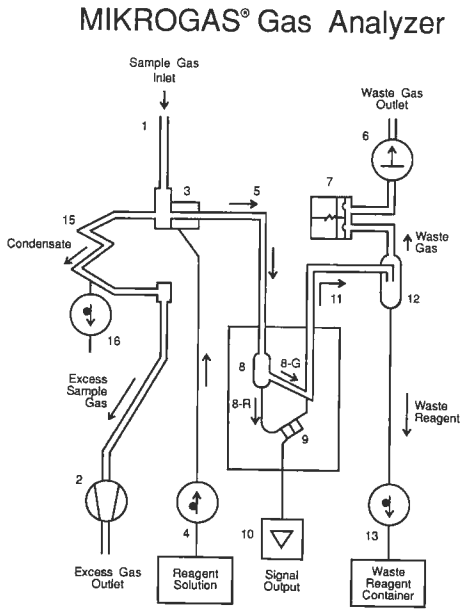
Calibrated Instruments, Inc.

Utilizing the principle of conductivity measurement, Ultragas® instruments provide continuous or batch analysis for laboratory and closed chamber research, and environmental, industrial process, ambient air, and stack applications involving one or more of the following gases: CO, CO_2, CH_4, NH_3, H_2S, SO_2, HCl, $COCl_2$, COS, CS_2, HCN, and other hydrocarbons. High precision pumps continuously forward a liquid reagent and sample gas stream to a temperature-compensated reaction line where both are combined in a constant volumetric ratio and thoroughly mixed. The conductivity of the reagent changes in proportion to the concentration of the gas being sampled and is measured by an electrode. Operating temperature: 2 to 35°C.

19-2-6. Gasman Personal Gas Detector

CEA Instruments, Inc.

The Gasman is a series of single gas, shirt-pocket-sized personal gas monitors for toxic gases, combustible gases, or O_2. All models have a large, front-mounted digital display with built-in back light. Visual and audible alarms are available for toxic gases to provide instantaneous and TWA warnings. The monitors are rugged and water resistant. They are radio frequency (RF) shielded



INSTRUMENT 19-2-4. Mikrogas® Series Gas Analyzers.

INSTRUMENT 19-2-6. Gasman Personal Gas Detector.

and are powered by four AA or rechargeable batteries. Models are available for O_2, H_2S, CO, SO_2, Cl_2, NO_2, NO, HCl, HCN, NH_3, and combustibles.

19-2-7. Series U Toxic Gas Detectors

CEA Instruments, Inc.

The Series U instruments are dedicated gas detectors in portable, wall-mounted, or multipoint configurations for a variety of contaminants. All instruments in this series use electrochemical-type sensors. The diffusion-type sensors are guaranteed for 2 years, provide rapid response, are solid-state, and are UL approved. Other features include low battery warning lights; built-in battery charger; high poison resistance to sulfur, lead, silicon, and halogenated compounds; and rugged, compact, leather carrying case. Operating temperature: –20 to +65°C.

19-2-8. TG-BA Series Portable Toxic Gas Analyzers

CEA Instruments, Inc.

The TG-BA Series Analyzers use a dedicated gas membrane, galvanic cell sensor. The analyzer is comprised of a sensor unit, a vacuum pump, and an amplifier unit. The gas permeates the membrane, causing a reduction in current at the surface of the working electrode. Response time: typically, one-third of full scale is achieved in less than 30 seconds. Alarm point: one-third of full scale (adjustable) with flashing red lamp (latching) and audible buzzer. Sampling distance: up to 30 ft. Sample flow rate: 0.5 L/min (adjustable). Recorder output: 0–10 mV (option 4 to 20 mA). Alarm contact closures: NO/NC, 250 VAC, 1A capacity. Operating temperature: 0 to 40°C. Dedicated units available for Cl_2, F_2, Br_2, H_2S, and many others.

19-2-9. Triple Plus Confined Space Monitor

CEA Instruments, Inc.

The Triple Plus is a multifunctional portable gas detector that can simultaneously monitor up to four different gases including combustibles, O_2, H_2S, CO, Cl_2, SO_2, NO_2, halons, HCl, HCN, and NH_3. The unit is microprocessor controlled and can be configured to pro-

INSTRUMENT 19-2-9. Triple Plus Confined Space Monitor.

vide alarms, TWAs, or peak hold values. Other options include audio or visual alarms, tamper-proof controls, optional air sampling pump, and an internal data logger. The unit weighs 2 lbs and can operate for 12 hrs on a single charge.

19-2-10. XP-302IIE Gas Detection System

COSMOS Gas Detection Systems

The XP-302IIE is an intrinsically safe, microprocessor-controlled portable instrument designed to monitor combustible gases, O_2, H_2S, and CO in ambient working environments and confined spaces. Features include:

- Audible and visual alarms
- 11 diagnostic messages
- Instantaneous and peak concentration
- Chart recorder and printer output capability
- 18-hr battery life.

Response time: within 40 seconds to 90% of final reading. Operating temperature range: 10 to 40°C. Standard accessories include:

- Soft carrying case
- 8-m gas sampling tube with floating probe
- External alarm with 8-m cable
- Dust filters A and B
- Alcohol filter
- Operation manual.

19-2-11. $O_2$25H Oxygen Meter

Dynamation, Inc.

The Dynamation oxygen sensor is a microfuel cell that has a life expectancy of 1 year before replacement is required. Cell replacement requires less than 1 min. The O_2–25H has low maintenance requirements because no chemicals or electrolytes need to be changed or added. The only control is a calibration adjustment that is used to set the meter at 20.9% O_2 before testing. Standard equipment includes a flexible cord and remote cable. This cable can be extended up to 8 ft for remote sampling; a 25-ft extension cord is an available option. Response time: 90% in less than 10 seconds. Temperature range: 0 to 52°C.

19-2-12. MONOGARD and dynaMite Personal Monitors

Dynamation, Inc.

The MONOGARD and dynaMite Series of pocket-sized instruments combine digital LCD and diffusion chemical cell sensing for CO, H_2S, O_2, SO_2, and NO. The units feature an audible, pulsating alarm and a visual flashing light when unsafe atmospheres are encountered. Each unit has a low battery alarm, test switch, and illuminated display switch for reading in dark areas. All alarm points are factory set and customer adjustable. MONOGARDs are enclosed in rugged aluminum cases with leatherette carrying cases. The dynaMite gives more than 250 hrs of continuous operation from its replaceable lithium battery. Operating temperature for the monitors ranges from 0 to 41°C or to 52°C. Response time is 90% of full reading in 30 seconds. Monitors warm up in less than 10 seconds. The expected sensor life is 1.5 years (6-month warranty).

19-2-13. Series 300 Air Pollution Analyzers

Eitel Manufacturing, Inc.

These analyzers are designed to provide drift-free performance and reliability for continuous, unattended monitoring. Systems for single or multigas determinations are available in ranges covering source emissions, occupational exposures, or ambient air concentrations. The gas sample flows across a membrane during its passage through the Faristor sensor. Some gas molecules diffuse through the membrane and dissolve in a thin liquid film where they undergo electrooxidation or reduction. An opposite reaction occurs at the reference, resulting in current flow in the load circuit proportional to the pollutant concentration. The sensor is plugged into the slot in the rear panel of the instrument and gas

INSTRUMENT 19-2-11. $O_2$25H Oxygen Meter.

connection is made through polypropylene fittings on the outside of the module.

Linearity: ±0.5%. Zero drift: ±0.5%/24 hrs. Span drift: ±1%/week. Response time: 5–15 seconds to 95%. Ambient temperature: 32 to 39°C. Temperature compensation: 4 to 52°C. Sample pressure: not greater than 15 psig. Sample flow: 0.5 to 2 L/min. Recorder output: 100 mV.

19-2-14. CGS Series, Omni 400, and Quad-400 Personal Gas Detectors

ENMET Corp.

These instruments are designed to detect toxic gases, combustible gases, and O_2 deficiency, and they meet all federal Occupational Safety and Health Administration (OSHA) confined space entry standards. Features include:

- Remote sensors
- RFI resistance
- Audible and visual alarms
- LCD displays.

Sensors include microfuel cell for O_2 with average life of 10 months; MOS gas sensor for toxic and combustible gases with average life of 3 years; solid-state, thin-film H_2S sensor; and an electrochemical sensor for CO. Instruments come with case, AC charger, manual, and 20-ft sensor cable. Test gas kits and calibration kits are also available. Operating temperature: –6 to 54°C.

19-2-15. Toximet Series Pocket-Size Toxic Gas Detectors

ENMET Corp.

The Toximet Series are personal, pocket-sized gas detectors that use an electrochemical sensor to monitor for toxic gases, O_2, or H_2. The instrument enclosure incorporates features that provide RFI/electromagnetic interference (EMI) protection, shock resistance, and surface mounting. The instrument normally operates 600 hrs continuously with power supplied by a replaceable 9-V battery. Accessories include a remote oxygen sensor on a 15-ft cable, hand aspirator, motorized sampling pump, and calibration kits for each gas. The Toximet can operate in temperatures from –5 to 45°C. Sensor life is 12 months for O_2 and 2 years for toxic gas cells.

INSTRUMENT 19-2-13. Series 300 Air Pollution Analyzers.

19-2-16. Ethylene Oxide Meter

Environmental Sensors Co.

The Ethylene Oxide Meter is a pocket-sized instrument that can measure ethylene oxide in hospitals, medical product manufacturing, and chemical processing industries. The instrument uses an electrochemical cell, where the working electrode of the cell is maintained at a fixed potential versus a reference electrode. The electrode is a gas diffusion type in which the ethylene oxide diffusing through a porous membrane is electrochemically oxidized. An active catalyst is bonded to a porous Teflon membrane that serves as a physical support and diffusion barrier. The output is governed by Faraday's Law and mass transport of ethylene oxide to the reaction surface. Operating temperature is 20 to 35°C.

19-2-17. Series G3000 Personal Monitors

GfG Gas Electronics, Inc.

The G3000 Series toxic monitors are hand-held, lightweight monitors available for CO (Microco®) and H_2S (Microtox®). Both the Microco and Microtox utilize diffusion input electrochemical cells. The cells are designed to last 1–2 years with little maintenance. A steel mesh diffusion screen and a Teflon membrane protect the unit from dust and splash water. The rechargeable, sintered metal Ni-Cd battery pack powers the unit for over 100 hrs of continuous operation on one charge. Both units use a three-chamber, 8-mm, high digital display. Operating temperature for both units is 0 to 53°C; response time is 15 seconds (T_{90}).

19-2-18. Polytector Personal Multigas Monitor

GfG Gas Electronics, Inc.

The Polytector combines three sensors into one hand-held, personal monitor. The monitor offers the option of diffusion sampling or the use of a continuous diaphragm pump. Several standard versions are available ranging from a three-channel gas detector to an atmospheric monitor and datalogger. The detection principle varies with the application requested; e.g., electrochemical for O_2, H_2S, and CO; catalytic combustion for methane or combustibles; N-type thermocouple sensor for temperature; and a thin film polymer for humidity. A variety of features are available, including automatic datalogging capabilities with 8K of RAM, automatic calibration and zeroing, clock and alarm functions, automatic operating mode, interfaceable with IBM PC, backup power supply, and continuous update of software capabilities. All units are housed in polyamid 12, crack-resistant plastic. Operating temperature for all units is 0 to 53°C. Optical/acoustic alarm system features four-character, 8-mm digital display. Response times vary from 1 (CH_4) to 15 seconds (CO).

19-2-19. Model CO260 Carbon Monoxide Monitor

Industrial Scientific Corporation

The CO260 Carbon Monoxide Monitor carries Mine Safety and Health Administration (MSHA) approval and is suitable for any work environment in which CO is a potential hazard. When equipped with an optional sampling pump and a length of flexible tubing, the CO260 also can take remote air samples of enclosed or confined areas prior to entry. The CO260 utilizes a diffusion-type electrochemical sensor. The digital LCD indicates CO concentrations over the range of 1 to 1999 ppm. Other features include audible and visual alarms for CO and low battery condition, replaceable alkaline batteries that provide 2400 hrs of continuous (non-alarm) operation, backlighting of display for low-light operation, a dust-tight stainless steel case, and many flexible accessories. Operating temperature range is –10 to 40°C.

19-2-20. TMX-410 Multigas Monitor

Industrial Scientific Corp.

The TMX-410 monitors for combustible gases, O_2, and toxic gases and is applicable for use in ambient air monitoring or confined space entry. The TMX-410 can also be upgraded for industrial hygiene applications by installation of a hygiene board that calculates STEL and TWA readings. Electrochemical sensors are used to measure toxic gases and oxygen, whereas combustible gases are measured using a catalytic, diffusion-type sensor. Features of the TMX-410 include audible and visual alarms and a rechargeable battery pack with a life of 10 hrs for continuous operation. Operating temperature: –15 to 40°C. Relative humidity range: 15% to 90%, noncondensing.

19-2-21. Portable Gas Analyzers, Series 1000

Interscan Corporation

The Series 1000 operates on the electrochemical voltammetric sensor principle and is designed for ambient portable survey analysis or fixed, round-the-clock use. The Interscan sensor is a leak-proof, two-electrode sensor, with a gel matrix inside the sensor that emits a free-floating electrolyte. Linearity: ±1% of full scale. Zero drift: ±1% of full scale (in 24 hrs, this is equilibrated and at a constant temperature with sensor properly maintained). Span drift: less than ±2% of full scale (24 hrs, equilibrated and at a constant temperature with sensor properly maintained). Lag time: less than 1 second. Rise time: 20 seconds to 90% of final value or better. Fall time: 20 seconds to 10% of original value or better.

19-2-22. Toxic Gas Dosimeters, Series 5000

Interscan Corporation

The Series 5000 dosimeters are available for monitoring CO, NO_2, H_2S, SO_2, and Cl_2 over a range of up to 10 times the respective TLV. The dosimeters provide alarm features and stored 1-min average concentrations values. The dosimeters utilize a diffusion electrochemical voltammetric sensor. The sensor is a leak-proof, two-electrode sensor, with a gel matrix inside the sensor that emits a free-floating electrolyte. The sample diffuses across a membrane into the sensor where the analog signal is converted to a digital format. One-min averages are computed and stored in random access memory. Nondestructive readout of the data is accomplished by plugging the dosimeter into a Metrosonics Metroreader where a variety of data is printed out. Rise time: 20 seconds to 90% of final value (or better). Fall time: 20 seconds to 10% of original value. Zero drift: ±1.0% of full scale (24 hrs). Span drift: ±1.0% of full scale (24 hrs).

19-2-23. PhD Gas Detector

McNeill International

The PhD and Cannonball® are gas detectors that can monitor up to four gases (O_2, combustible gas, and specific toxic gases) simultaneously. Features include supertwist LCD that automatically lights up in the dark and a built-in memory circuit that allows viewing of data on the screen in the field or downloading to a PC for analyzing, storing, or printing a hard copy. The PhD is classified as intrinsically safe in hazardous locations Class I, Groups A, B, C, and D.

19-2-24. Toxilog Toxic Gas Detectors

McNeill International

The Toxilog gas detectors are small personal monitors for the detection of toxic gases in applications where low cost, ease of use, and durability are prime considerations. The Toxilog is microprocessor controlled, which allows choice of alarms for ceiling values, STELs, or TWAs. It also allows the downloading of data

INSTRUMENT 19-2-21. Portable Gas Analyzers, Series 1000.

to a PC. All Toxilog monitors are shipped complete with sensor, calibration adapter, belt clip, a lanyard, and an alligator clip. The Toxilog is intrinsically safe for use in hazardous locations Class I, Groups A, B, C, and D.

19-2-25. Mark II Formaldemeter

MDA Scientific, Inc.

The Mark II Formaldemeter is a direct-reading instrument designed to measure formaldehyde concentrations below OSHA's new STEL. The Formaldemeter detects and measures concentrations from 0.3 to 99.9 ppm and is designed for in-plant screening and surveys. The instrument is compact, portable, and easy to operate with just the push of a button to display formaldehyde levels for compliance purposes. Accuracy at the low ppm levels is ±15%. The Formaldemeter operates from a standard 9-V battery and weighs under 7 oz. The instrument is calibrated using a convenient field kit.

19-2-26. Monitox Personal Alarms

MDA Scientific, Inc.

The Monitox Personal Alarms are pocket-sized monitors that are available for a variety of toxic contaminants. The units are available in digital readout/alarm and alarm only modes. The alarms can be coupled with the Chronotox Data Acquisition System to provide exposure documentation over time. The Monitox utilizes a diffusion gel-type electrochemical sensor. Sophisticated circuitry allows enhanced stability, sensitivity, and reproducibility while minimizing zero drift. Many features are available with the Monitox system, including a variety of alarm configurations, battery level indicator, easy calibration with the gas generator system, and long sensor life. Operating temperature range is 0 to 45°C; low temperature option for operation down to –30°C is available. Gas generator's power source is a 9-V alkaline battery, whose life is 800 functional checks.

INSTRUMENT 19-2-25. Mark II Formaldemeter.

INSTRUMENT 19-2-29. MiniCO™ IV Carbon Monoxide Indicators.

19-2-27. Models 60, 70, 80, and 90 Personal Toxic Gas Monitors

Metrosonics, Inc.

The Models 60, 70, 80, and 90 are compact, hand-held instruments designed to measure ambient air concentrations of CO, SO_2, NO_x, and H_2S, respectively. Three operation modes are available: diffusion mode for area sampling, continuous mode that draws approximately 1000 cm^3/min with a probe connected, and cycling mode where the pump operates for 2 out of every 30 min. Power is supplied by AA rechargeable Ni-Cad batteries that can operate 8 hrs continuous or 24 hrs with the pump off. The electrochemical sensors have a typical life of 1–2 years.

19-2-28. Series PM-7000 Personal Toxic Gas Monitors

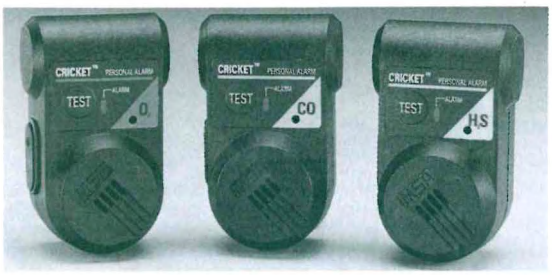
Metrosonics, Inc.

The PM-7000 uses electrochemical sensors to detect CO, H_2S, SO_2, Cl_2, NO_2, and NO for personal protection. The sensors utilize capillary diffusion barrier technology, which results in a direct response to volume concentration. The sensors are also cable mounted and can be clipped to clothing for readings taken in the breathing zone. Visual and ear piece audible alarms can be set for two user-selected gas concentrations. The PM-7000 can operate 720 hrs on a 9-V alkaline battery. Operating temperature: –5 to 40°C. Response to 90% of final reading ranges from 30 to 90 seconds, depending on gas.

19-2-29. MiniCO™ IV Carbon Monoxide Indicators

Mine Safety Appliances Company

The MSA MiniCO™ IV Carbon Monoxide Indicators are pocket-sized devices for measuring CO concentra-



INSTRUMENT 19-2-30. Cricket Personal Alarms.

tions in ambient air. They 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 electrooxidizes 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. An adapter with aspirator bulb, using standard MSA sampling lines, is available for remote sampling. The units are battery powered. The alarm set point is adjustable over the range of 25 to 500 ppm. All models have ±2% precision and accuracy, 90% response time in 30 seconds, a span drift less than 2% full scale/day, and zero drift less than 1% full scale/day. MiniCO indicators can be field-calibrated using the MSA Calibration Check Kit, Model R. Common interferents include SO_2, H_2S, NO_2, ethyl alcohol, and H_2.

19-2-30. Cricket Personal Alarms

Mine Safety Appliances Co.

The Cricket Personal Alarms are very lightweight, weighing less than 3 oz and can be worn clipped to a pocket, belt, lapel, or hard hat for hands-free operation. The instrument is only 1.25 × 3 × 2 in. in size. The Cricket series of personal alarms are miniature, battery-powered instruments designed to provide users with an inexpensive yet dependable way to monitor for O_2 deficiency, CO, or H_2S. The instruments operate continuously and sound an alarm if levels in the environment exceed preset levels (for CO and H_2S) or fall below a preset level (for O_2).

19-2-31. MSTox 8600 Personal Toxic Gas Monitor

MST Measurement Systems, Inc.

The MSTox uses an electrochemical sensor to detect toxic gases for personal protection. Audible and visual alarms can be field adjusted to activate at chosen "warning" and "alert" levels for a specific gas. The 8600 can also be used with an optical earphone or vibrating alarm for use in areas with high noise levels. Three different power supplies are available: a disposable pack that meets applicable intrinsic safety standards, a rechargeable pack that can be recharged 1000 times before needing replacement, and a J-Series pack available in general merchandise stores and intended for use in areas not requiring intrinsic safety. Battery life is approximately 2500 hrs.

19-2-32. ECOLYZER Portable Carbon Monoxide Monitor

National Draeger, Inc.

The Series 2000 ECOLYZER Portable Carbon Monoxide Monitor utilizes electrochemical oxidation at a potential-controlled, Teflon-bonded diffusion electrode for detection. Stability: noncontinuous (spot checking)—typical spot checking operation during a work day, signal decay <1%/24 hrs over the life of the instrument; continuous—signal decays by <1.5%/24 hrs over the first 25 days and <1%/24 hrs subsequently. Response time: 25 seconds. Precision and accuracy: 1.0% full scale. Sampling rate: 700 cm^3/min. Readout mode: meter (110 div. full scale) and recorder.

19-2-33. Personal Carbon Monoxide Monitor

National Draeger, Inc.

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 releases of high concentrations of gas. The monitor features an adjustable stroboscopic visual alarm as well as an audible alarm. The unit employs a diffusion sensor utilizing a three-electrode, electrochemical detection principle. Rise time: <60 seconds to 90% of signal. Accuracy: 5% of reading or ±1.0 ppm. Span drift: 2% of reading per day or 2 ppm. Zero drift: <5 ppm/day. Operating temperature range: 0 to 40°C. Relative humidity range: 5% to 90%.

19-2-34. ENOLYZER Model 7100

National Draeger, Inc.

The ENOLYZER Model 7100 is a portable, direct-reading instrument for simultaneous and separate determination of NO and NO_2. The unit may be operated by rechargeable Ni-Cd batteries or line current. The instrument sensor utilizes an electrochemical reaction at potential-controlled, Teflon-bonded diffusion electrodes. Response time: 90% NO, <5 seconds; 90% NO_2, <30 seconds. Precision and accuracy: ±1% full scale for NO; ±2% full scale for NO_2. Stability: noncontinuous (spot checking)—typical spot checking operation during a work day, NO and NO_2 signal decay <1%/24 hrs.

19-2-35. Dualarm, Trialarm, Quadalarm, and Multi-Pac Portable Multigas Monitors

National Draeger, Inc.

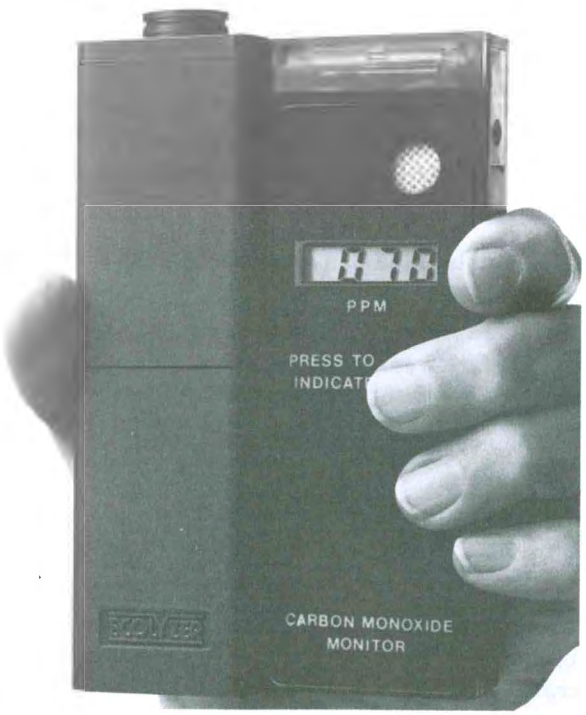
These multigas instruments are designed to monitor for explosive gases, O_2, CO, and H_2S in confined space entry applications or protection of workers in other potentially hazardous areas. Sensors include poison-resistant Pellister for explosives with typical life of 24 months, galvanic fuel cell for O_2 with typical life of 12

months, and 3-electrode electrochemical for CO and H_2S with typical life of 18 months. Response time to 90% concentration: 5–20 seconds for explosives; 5–25 seconds for O_2; and 5–60 seconds for CO and H_2S. Operating temperature: –20 to 40°C. Operating relative humidity: 5% to 95%. Alarms are visual and audible (85dB at 1 ft). Battery life is 8–12 hrs, continuous use.

19-2-36. EXOTOX Triple Gas Monitor

Neotronics

The EXOTOX Monitor offers the capability of monitoring O_2, combustible gases, and CO or H_2S in a single portable monitor. This monitor is specially designed for gas monitoring prior to entry into confined spaces and to give continuous protection to the individual while in the confined space. The EXOTOX utilizes electrochemical sensors for O_2, CO, and H_2S and low power Pellisters for combustible gases. The sample enters the instrument by diffusion or can be aspirated from a confined source to the instrument. Sensor response can be read from an LCD display or via audible or visual alarms. Features include a built-in elapsed time display, computed TWAs and STELs, full RF protection, fast sensor response, minimal drift, small size, and light weight. Operating temperatures: –15 to 50°C. Storage temperature: –20 to 55°C. Humidity: 0% to 100% (noncondensing). Drift 0.6% to 1.5% over 200 days. Digital LCD readout: 20 × 38 mm. Battery life: approximately 10 hrs per charge.



INSTRUMENT 19-2-34. ENOLYZER Model 7100.

19-2-37. NEOTOX Pocket Personal Monitors

Neotronics

The NEOTOX monitors offer individual, lightweight, pocket-sized protection against the hazards of O_2 deficiency and enrichment, CO, and H_2S. The monitor incorporates a visual LCD display and lockable alarms in an intrinsically safe unit that fits in the pocket. The NEOTOX line utilizes the same electrochemical sensors incorporated in the EXOTOX for O_2, CO, and H_2S. Features include a three-digit, top-mounted LCD; water-tight membrane switches; visual and audible alarms; low battery indication; full RF protection; belt clip for easy carrying; water- and dust-proof design; and fast sensor response. Units meet all international intrinsic safety standards. All monitors provide a 6-mm LCD digital display. Total drift for 200 days is between 0.06% and 1.5%. All are powered by 9-V dry batteries which have a life span of 200–300 hrs, depending on the monitor used.

19-2-38. Minigas Multigas Monitor

Neotronics

The Minigas is an intrinsically safe, pocket-sized portable gas monitor that can be used for confined space entry, spot checks, or continuous monitoring in hazardous areas. Models are available to monitor for one, two, or three of the following gases: flammable gas, O_2, CO, or H_2S. The Minigas features a water- and dust-resistant, die-cast metal case with RFI protection, interchangeable alkali dry cell or Ni-Cad battery pack with a low battery warning indicating when the battery is 30 min from exhaustion, and instantaneous audible and visual TWA and STEL alarms. Operating time: 8 hrs on Ni-Cad battery. Operating temperature: 0 to 40°C.

19-2-39. OTOX® 2002/2003 Carbon Monoxide Monitors

Neotronics

The OTOX® 2002/2003 monitors utilize an electrochemical sensor and can be used to detect CO in compressed air/respiratory panels or as an area monitor. The OTOX® features digital displays, two internal quick-set open/closed relays, and either 110- or 12-V power supplies. The battery can operate the instrument for 72 hrs continuously. Operating temperature: –15 to 50°C for the 2002 and 0 to 40°C for the 2003.

19-2-40. Ozone Recorder, Model 03T

Ozone Research and Equipment Corporation

This recorder is designed for atmospheric ozone measurement and ozone measurement in control rooms, laboratories, production plants, warehouses, etc. Ozone measurement is based on the iodometric principle incorporated into an electronic loop feedback servo system that allows continuous measurement of ozone concentrations to as low as 3 ppm. The Model 03T samples at the rate of 4000 cm^3/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. Response time: normal atmospheric change, 90% of true value in 2 min. Chart speed: 1 in./hr. Chart period: 31 days. Options: alarm circuit and meter for remote signal.

19-2-41. Ozone Measurement Instrument, Model MSA-3

Ozone Research & Equipment Corporation

This portable instrument is used to determine ozone in air or O_2 for applications such as in ozone test chambers, other confined sources, process streams, and in the atmosphere. The principle of measurement is based on the quantitative release of iodine from a buffered solution of potassium iodine in the titration with sodium thiosulfate of the released iodine. The Model MSA-3 employs the electrometric endpoint method, whereby the endpoint of the titration is indicated on a meter. In operation, the instrument is supplied with potassium iodide and sodium thiosulfate solution. With this method, there is no iodine volatilization factor because there is a fixed quantity of thiosulfate, and time (3–5 min) is the only variable. The measurement period ends upon the appearance of iodine, which is sensed electrometrically. Other features include a dry vane vacuum pump and Pyrex-unitized construction of the reaction assembly with integral platinum electrodes and spray jet. Sampling rate: 3000 cm^3/min.

19-2-42. Sulfur Dioxide Analyzer/Recorder

Process Analyzers, Inc.

The Titrilog II is an automatic instrument for the determination of oxidizable sulfur compounds such as H_2S, SO_2, mercaptans, thiophene, and organic sulfides and disulfides. This instrument can be used for measurement in the atmosphere, in gas streams, and in stack gases. The measurement 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. 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.

19-2-43. S100 Series Portable Gas Indicators

Scott Aviation

The S100 Series are intrinsically safe, portable instruments that can be applied to area monitoring, confined space entry, or personal monitoring. Instruments are available that can monitor for one, two, or three of the following: combustible gas, O_2, H_2S, and CO. Features of the S100 Series include dual low-battery alarms, liquid crystal display that illuminates for low ambient light conditions, and audible alarms for each measured variable. The S100 Series has memory capability to store the highest combustible gas concentration, peak CO or H_2S concentration, or the lowest O_2 measurement. Response time to 63% change: 10 seconds to LEL, 20 seconds for O_2, 45 seconds for H_2S, and 25 seconds for CO. Operating temperature ranges are –10 to 60°C for LEL and 0 to 40°C for the others.

19-2-44. Portable Gas Monitors

Sensidyne, Inc.

Sensidyne markets a wide range of pocket-sized personal monitors (Mini Monitors), portable survey monitors (Series SS2000 and SS4000 for semiconductor gases), and a variety of fixed gas detection systems. The Mini Monitors and Series SS2000 monitors utilize diffusion electrochemical cells specifically designed for each gas to be detected. The lightweight (7 oz), pocket-sized Mini Monitors feature a continuous LED light-illuminated digital display, dual alarm set points, intrinsically safe design, replaceable batteries, RFI/EMI protection, and easy calibration. Additional features on the hand-held Series SS2000 include long-life sensors (3 years expected life), rechargeable batteries, optional continuous operation from AC power, triple alarm system, and ability to withstand temperature extremes. Response time: <20 seconds for Mini Monitors, 10–15 seconds for SS2000, <30 seconds for SS4000. Battery life: over 100 hrs for Mini Monitors, 20 hrs for SS2000, 35 hrs for SS4000. Humidity range: 5% to 95% for Mini Monitors and SS2000; 20% to 90% for SS4000. Temperature range: 0 to 40°C for all monitors.

19-2-45. Portable Flue Gas Analyzer

Teledyne Analytical Instruments

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

The CO trace measurement is accomplished by an electrochemical sensor (6-month warranty). The sensor output is directly proportional to the CO concentration. Zero and span drifts are less than 2% in 24 hrs. A 90% of full-scale response is attained in 30 seconds or less. Operating temperature: 0 to 50°C. O_2 analysis is accomplished with Teledyne's Micro-Fuel Cell (1-year warranty), which produces an electrical signal that is

directly proportional and specific to the O_2 concentration in the flue gas. A 90% of full-scale response is attained in 13 seconds or less.

Coulometric Analyzers

19-3-1. EA-1 Gas Analyzer

Adsistor Technology, Inc.

The EA-1 Gas Analyzer is a portable instrument for detection of flammable and nonflammable gases in the ppm and percent LEL ranges. The EA-1 uses the Cold Sensor™ element, which does not burn vapor to detect gas. The Cold Sensor element operates on the principle of adsorption, the phenomenon that 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. 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 sensor's 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.

19-3-2. H_2S Sentox

Bacharach, Inc.

This instrument is a diffusion instrument used to detect H_2S gas in the range of 0 to 50 ppm. The H_2S Sentox operates on the oxidation-reduction principle. When exposed to H_2S gas, the metal oxide sensor is reduced and then returns to its normal oxide state when returned to an O_2 atmosphere. This change alters its ability to conduct electricity, which is proportional to the concentration of H_2S.

INSTRUMENT 19-2-45. Portable Flue Gas Analyzer.

INSTRUMENT 19-3-1. EA-1 Gas Analyzer.

19-3-3. J-W Oxygen Indicators

Bacharach, Inc.

The K Series of O_2 indicators are available in various models and ranges designed to meet the need for portable, fast-response indicating devices that measure in the low and medium O_2 percentage ranges. The Model GPK is a combined O_2/combustible gas indicating detector. Model HPK is a combination O_2/combustible gas indicator similar to the Model GPK except that it has two combustible gas ranges. Both of the combination detectors are also available in Bureau of Mines-approved versions. In the Model K O_2 indicators, the sample of the atmosphere to be tested is drawn into a self-generating electrolytical cell by means of an aspirator bulb. The current produced is directly proportional to the amount of O_2. Detector cell life for all models is 6 months and the detector cells may be reactivated. 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 SNIFFER Series Combustible Gas Indicators (19-10-4).

19-3-4. SNIFFER® 103 Portable Oxygen Deficiency Monitor

Bacharach, Inc.

The SNIFFER® 103 O_2 deficiency monitor is a lightweight, compact unit for use in entering into confined areas such as vessels, tanks, manholes, silos, pits, tunnels, shafts, or any other possible O_2-deficient areas. The SNIFFER 103 uses a diffusion electrochemical cell for O_2. The combustible model uses a catalytic (platinum bead) sensor. The sensor response is read on an LCD or it can trigger an audible or visual (LED) alarm. Other features include continuous operation for 10 hrs, low battery indicator, continuous safety (no on/off switch), intrinsically safe, 9-V alkaline battery operation, and a convenient belt/pocket clip.

Continuous operating time: 10 hrs at 25°C. Charging time: 1416 hrs. RFI rejection: no alarms will trigger with 5W radio at 2 ft. Audible alarms include 1-Hz pulse rate for high combustibles, 3-Hz pulse rate for low O_2, and a steady tone for low battery or sensor failure. Visual displays include an alarm symbol for both high combustibles and low O_2, a broken battery symbol indicating low battery, a 100% LEL display, and a 0% O_2 display.

19-3-5. Model 946 Trace Acid/Base Monitoring System

Beckman Instruments, Inc.

The Beckman Model 946 Trace Acid/Base Monitoring System continuously measures trace acid or base concentrations in a variety of process streams. Applications include 1) HCl in vinyl chloride monomer product, 2) HCl in catalytic reformer recycle hydrogen, 3) trace acids in various hydrocarbon streams, and 4) trace ammonia leakage. The system combines the gas or vaporized liquid sample with a metered flow of demineralized water using precise flow control. The gas/liquid mixture flows to a separator where the gas phase is exhausted at the top, and the liquid phase is drained out the bottom into a stainless steel pH flow chamber that measures the pH of the water. The system measures any pH shifts and correlates them to ppm to continuously monitor trace quantities of acids or bases in process streams.

Response: 90% in 3 min. Sample flow rate: liquid from 10 to 25 cm^3/min to vaporizer; gas from 5 to 10 L/min; demineralized water flow rate from 100 to 200 cm^3/min. Quality of water from 1 to 10 megaohm/cm^3 specific resistance (1 to 0.1 microohm/cm specific conductivity). Materials in contact with sample: stainless steel, glass, Teflon, Viton, and PVC. Sample temperature compensation: automatic, from 0 to 100°C. Ambient humidity limits: up to 99% RH. Ambient temperature limits: 0 to 50°C.

19-3-6. Model OM-11EA/OM-11 Oxygen Analyzers

Beckman Instruments, Inc.

The Beckman Models 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 O_2. They are frequently used in emission measurement consoles and other multiparameter analytical systems. The analyzers use electrochemical technology for polar-graphic O_2 analysis. The Models OM-11EA/OM-11 utilize a factory-charged, factory-sealed, disposable O_2 sensor. The sensor has automatic temperature compensation at both normal and high temperatures. Designed principally for engine exhaust analysis, the Model OM-11EA is suited for console mounting. For applications requiring a remote sensor, the Model OM-11 has a 15-ft interconnection cable that allows the small, compact pick-up head to be remotely located in the most advantageous position.

Speed of response: 100 ms for fast mode (90%). Zero drift: ±0.5% over 24 hrs. Span drift: ±1.0% over 24 hrs. Noise: <0.2% peak-to-peak. Linearity: ±0.2%. Outputs: 10 mV, 100 mV, or 5 VDC. Sample flow rate: 0.14–0.28 m^3/hr (2.36–4.7 L/min). Sensor control temperature: 40°C ± 1°C. Ambient temperature limits: 4.4 to 35°C. Ambient humidity limits: 0% to 95% RH.

19-3-7. Ozone Analyzer, Model 950

Beckman Instruments, Inc.

The Beckman Ozone Analyzer is designed for continuous monitoring of photochemical oxidants. The chemiluminescent method used is based on the principle that ozone reacts with ethylene to produce a light emission. 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 cm^3/min. A safety valve is incorporated on the ethylene flow and is designed to shut off the ethylene flow in the event of power failure.

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 optical ozone generator, which provides a convenient means of providing span checks, is available. 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. Response time: 90% in 3 seconds. Zero and span drift: less than 1% per day. Operating period: 7 days or more. Noise: 0.5%. Operating temperature: 4 to 38°C.

19-3-8. NO, NO_2, NO_x Monitor, Model 952

Beckman Instruments, Inc.

The Beckman NO, NO_2, NO_x Monitor is used to monitor the ambient atmosphere where the oxides of

INSTRUMENT 19-3-6. Model OM-11EA/OM-11 Oxygen Analyzers.

nitrogen concentration range between 0.1 and 10 ppm. The chemiluminescent detection principle incorporated in the Model 952 is based on 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. 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). In the flow control system, ambient air is employed for ozone generation by means of a pump and a UV lamp. Response time: 90% in 3 seconds. Zero and span drift: less than 1% per day. Operating period: 7 days or more. Noise: 0.5%. Operating temperature: 4 to 38°C.

19-3-9. Model OX630 Oxygen Analyzer

Engineering Systems and Designs

The OX630 is a portable unit that utilizes a maintenance-free galvanic electrode to measure atmospheric oxygen levels from 0% to 100%. The electrode has an expected life of 3–5 years at 25°C, 1 atmosphere pressure, and a concentration of 20.9% O_2. The OX630 is sold in a kit containing the meter, an electrode on a 5-ft cable, screwdriver for calibration, and a carrying case. Electrodes up to 100 ft can be manufactured upon request. Operating temperature range: 0 to 40°C. Response time: 95% of final reading in 30 seconds. Power: 9-V battery. Calibration: 20.9% in air.

19-3-10. Personal Oxygen Monitor, Model OX-80

GasTech, Inc.

The GasTech Model OX-80 Personal Oxygen Monitor is a pocket-sized, lightweight instrument designed to continuously monitor O_2 and sound an alarm at a preset level of 19.5%. A pushbutton activates a digital readout. The top-mounted sensor may also be used remotely for tank entry testing. The OX-80 O_2 sensor is a diffusion electrochemical cell in which O_2 produces a chemical reaction directly proportional to the sampled atmosphere. The electrochemical cell is guaranteed for 6 months of operation before reactivation. Standard accessories include a plug-in battery charger, belt clip, and wrist strap; 15-in. and 30-in. O_2 cell extension cables and lapel-mount repeater buzzer are optional.

19-3-11. Microox® Personal Oxygen Deficiency Monitor

GfG Gas Electronics, Inc.

The Microox® is a pocket-sized monitor with an easy-to-read digital display and optical/acoustical alarm to warn of O_2-deficient conditions. It is Model 3012 in the G3000 Series, which are in small, stainless steel cases and operate over 100 hrs continuously between battery charges. The Microox uses a fuel cell sensor and is available with a remote 25-ft sensor, an adjustable alarm, rechargeable batteries, and a stainless steel case that is dust and waterproof. Temperature: 0 to 53.3°C. Response time: T_{90} = 10 seconds. Cross sensitivity: partial pressure chlorine. Lifespan of sensor: 9–14 months. Display: 3-character digital, 8 mm high. Gas transport: diffusion.

19-3-12. Model OX231 Oxygen Monitor

Industrial Scientific Corporation

The OX231 Oxygen Monitor is designed to be intrinsically safe and carries MSHA approval. It is suitable for any work environment in which deficient O_2 levels are a potential hazard. This battery-operated, diffusion-type instrument is recommended for use in confined spaces such as manholes, tunnels, ships' holds, storage tanks, deep vats, closed compartments, and underground installations. The OX231 utilizes a diffusion electrochemical cell that can be replaced in the field without disassembling the case. Percent O_2 is displayed on a liquid crystal readout in increments of 0.1% O_2. Replaceable alkaline batteries provide 2400 hrs of continuous operation. Other features include audible and visual alarms of low O_2 levels and low battery condition, adjustable alarm level, backlighted display for low light situations, on–off switch to prevent accidental shutoff, and dust-tight stainless steel case. Temperature range: –15 to 45°C.

19-3-13. Scen-Trio

Lumidor Safety Products

Scen-Trio is a continuous sensing device for three different categories of gases: explosive, toxic, and O_2. Both visual and audible alarms are activated when preset threshold levels have been exceeded. This portable, battery-powered, multigas detector/alarm has a rechargeable Ni-Cd battery pack and self-powered O_2 fuel cell. It is rated intrinsically safe for Class I, Division I, Groups A, B, C, and D. Scen-Trio operates with reasonable accuracy of alarm settings within the temperature range of –5 to 45°C. Humidity range: 15% to 100% RH when calibrated in 50% RH atmosphere; the device will operate at lower RH (5% to 20% RH) with good accuracy if calibrated in a dry atmosphere.

19-3-14. LP-COM-19GR Oxygen Monitor

Lumidor Safety Products/e.s.p. Inc.

The LP-COM-19GR is a hand-held O_2 deficiency monitor that features a detachable probe for remote monitoring. The monitor is suitable as a personal warning device or as a preentry monitor for confined spaces.

The LP-COM-19GR utilizes a diffusion galvanic cell for measuring percent O_2 over the range of 0% to 50%. The cell should last for 1 year (warranted for 8 months). Other features include visual and audible alarm for low O_2 concentration and low battery, battery test switch, replaceable alkaline batteries, various length probe cords, easy sensor replacement, and a belt clip. Temperature range: –5 to 40°C.

INSTRUMENT 19-3-15. Portable Ozone and Oxidant Recorders.

19-3-15. Portable Ozone and Oxidant Recorders

Mast Development Company

The Model 724-2 Ozone Meter, Model 725-11 Nitrogen Dioxide Meter, and Model 725-21 Microcoulomb Detector are portable, nonspecific electrochemical instruments that are used for the detection of O_3, NO_2, NO, Cl_2, I_2, F_2, and other strong oxidant vapors in low air concentrations. The microcoulomb sensor is used in all three instruments. Selectivity for specific oxidants is related to the concentration, pH, and composition of the electrolyte used. 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. High concentrations of 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 microampmeters used on the Model 724-2 Ozone Meter and the Model 725-11 Nitrogen Dioxide Meter are calibrated directly in concentration units. Sampling rate: 140 cm^3/min. Rise and fall time: 1 min. Operating temperature range: 0 to 44°C. Unattended operating time: 3 days (except 30 days for Model 724-2L large reservoir ozone recorder).

19-3-16. Model 3300 Oxygen Monitor

MDA Scientific, Inc.

The Model 3300 is designed for the detection and measurement of percent O_2 in a variety of work environments. Typical applications include preentry monitoring, personal monitoring, and O_2 therapy monitoring. The Model 3300 utilizes a diffusion electrochemical cell that is stable over a wide range of temperatures and humidities. The monitor is internally compensated for temperatures over the range of 0 to 50°C. A variety of features are available, including a choice of ranges (0% to 25% or 0% to 100%), replaceable 9-V batteries, and alarm setting. Sensor charge life: approximately 1 month. Response time: 10 seconds (90% response). Battery life: approximately 300 hrs.

19-3-17. Models 8060/8061 Oxygen Deficiency Monitors

Matheson Gas Products

The 8060 and 8061 are portable oxygen monitors that can be used for monitoring of ambient air or confined space entry. The sensor is a galvanic cell that consists of a noble metal electrode, a base metal electrode, and an electrolyte in aqueous solution. In the preserve of oxygen, current flows from the noble metal electrode to the base metal electrode. Two probes are available: the 8060 has the sensor at the end of an extendable 3-ft coiled cable and the 8061 is equipped with the sensor at the end of a 16-ft cable on a spool. Response time: 2–4 seconds. Operating time: up to 20 hrs powered by 2 AA rechargeable Ni-Cad batteries. Sensor life: 18–24 months. Temperature range: 0 to 45°C.

19-3-18. Oxygen Indicator Models 245, 245R, and 245RA

Mine Safety Appliances Company

MSA Oxygen Indicators are hand-held devices for measuring atmospheric concentrations of O_2 over a range of 0% to 25%. Model 245 is designed primarily for

INSTRUMENT 19-3-18. Oxygen Indicator Models 245, 245R, and 245RA.

checking O_2 content in mines, and the sensor 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. The oxygen indicator detects O_2 by a galvanic sensor cell containing a gold cathode and lead anode in a basic electrolyte. In operation, O_2 diffuses through the cell face to initiate redox reactions which, in turn, generate a minute current proportional to the O_2 partial pressure. 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. Safety provisions: Model 245RA is equipped with an audio alarm that is factory set to activate when the O_2 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 O_2 concentration rises above alarm setpoint. Response time: 90% in less than 20 seconds. All models can be calibrated quickly with uncontaminated fresh air, 20.8% O_2.

19-3-19. Passport Personal Alarm

Mine Safety Appliances Company

The Passport is a small, lightweight, water-resistant personal alarm instrument that is capable of monitoring up to five different gases. The instrument is housed in a rugged, easy-to-carry, metal-filled polycarbonate case that is also EMI-resistant and antistatic. The instrument is simple to operate with just the push of a button. It monitors combustibles, oxygen deficiency, and up to three toxic gases (CO, H_2S, SO_2, NO, NO_2, Cl_2, HCN, HCl). An add-on low flow pump module gives the user the option of using diffusion or pumped sampling.

19-3-20. Toxgard® Indicator, Model C

Mine Safety Appliances Company

The MSA Toxgard® Indicator, Model C, is a continuous monitoring instrument for use in the detection of H_2S, HCN, and CO. The instrument operates on the principle of an electrochemical polargraphic cell that oxidizes the gas of interest in proportion to its partial pressure in the sample atmosphere. Safety provisions: tamper-resistant controls, audible and visual alarms. Response time: 50% in 30 seconds, typically 90% in 120 seconds. Span and zero drift: 1%, 1-day maximum.

INSTRUMENT 19-3-19. Passport Personal Alarm.

INSTRUMENT 19-3-20. Toxgard® Indicator, Model C.

19-3-21. Multi-Component Monitoring System for Air Pollution

Philips Electronic Instruments

This series of instruments allows continuous, automatic field monitoring of ambient air quality. Five of the measuring modules (SO_2, NO_2, NO, CO, H_2S) use the principle of coulometry, as used for the Model 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. CO is measured indirectly by the iodine released when CO is passed through heated iodine pentoxide. NO is measured as NO_2 after oxidation. Selective filters ensure that each module is specific for the pollutant it is to measure. Chemiluminescence was chosen for O_3 measurements. This is specific for O_2 and depends on the emission of light by Rhodamine B when exposed to ozone.

The modules are contained in a standard steel-framed, glass-reinforced plastic case for wall or panel mounting. One telemetering module provides up to 19 channels for control and data transmission. Span drift: <2% in 24 hrs after a stabilization period; 5% for O_3. 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 occurring in the atmos-

phere. 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. Maintenance: 3 months continuous operation without the need for service and/or maintenance.

19-3-22. Series 330 Personal Safety Oxygen Monitors

Teledyne Analytical Instruments

The Series 330 uses a disposable electrochemical cell which, in the presence of O_2, produces an output signal linear with and specific to O_2. This instrument has an integral meter readout and is applicable for use in confined space entry and occupational surveys.

Flame Ionization Detectors

19-4-1. Hydrocarbon Gas Analyzer

Columbia Scientific Corporation

The HC5000 performs real time and continuous dry analysis of hydrocarbon gases utilizing a 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 FIDs operating in the gas chromatograph (GC) mode. Noise: ±0.05 ppm CH_4. Lag time: <15 seconds. Rise and fall time to 90%: <30 seconds. Zero and span drift: ±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: approximately 200 ml/min; hydrogen flow rate: approximately 140 ml/min.

19-4-2. Organic Vapor Analyzer

Foxboro Company

The Organic Vapor Analyzer (OVA) is designed to measure trace quantities of organic materials in air using a hydrogen flame ionization detection system. It has a single logarithmically scaled readout from 1 to 100,000 ppm or with a 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. The instrument response is read on a hand-held meter assembly or can be read using the external monitor signal. An audible detection alarm is provided; it can be preset to any desired level and has a frequency modulated tone that varies as a function of the signal level. The standard instrument includes an audible flame-out alarm, battery test indicator, and internal electronic calibration.

Standard accessories include instrument carrying and storage case, high-pressure, fuel-filling hose assembly, and AC battery charger. Response time: <2 seconds. Sample flow rate: nominally 2 L/min. Fuel supply: 75-cm^3 tank of pure hydrogen at maximum pressure of 2300 psig, fillable while in case. Service life: hydrogen supply and battery power — 8 hrs operating time, minimum. The umbilical cord is 5 ft long with connectors for electrical cable and sample hose. In-line disposable and permanent particle filters are standard; activated charcoal filters are optional.

19-4-3. Advanced Vapour Monitor — AVM

Graseby Ionics

The AVM is designed primarily as a survey monitor or a leak detector. A wide variety of toxic vapors can be monitored in ppb levels for short- or long-term periods. This rugged instrument provides real-time monitoring; data can be stored in an ancillary data logger. The hand-held unit can be operated for 5 hrs continuously from internal batteries. Some of vapors that can be detected by this radioactive ionization detector include TDI, TDA, aniline, o-toluidine, dimethyl sulfate, anesthetics, and nerve or blister agents.

19-4-4. Photoionization Analyzer

HNU Systems, Inc.

The Photoionization Analyzer is a portable analyzer used for the measurement of gases in industrial atmospheres. The sensor consists of a sealed UV 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. The field created on an electrode drives any ions formed by adsorption of the UV light to the collector electrode where the current (proportional to concentration) is measured. This instrument consists of two separate units: a sensor and a readout, connected by a 3-ft, shielded, multiconductor cable with electrical

INSTRUMENT 19-4-2. Organic Vapor Analyzer.

connector. The case for the readout module is constructed of drawn aluminum. The sensor's outer body is of aluminum and engineering thermoplastic. Output signal available: 0- to 10-mV recorder jacks. Standard accessories include an AC battery charger and a 3-ft, Teflon-lined telescoping probe for sampling hard-to-reach places. Response time: <5 seconds. Operating time: minimum of 8 hrs on 12-VDC rechargeable batteries.

19-4-5. Atmosphere Monitors

Ion Track Instruments, Inc.

Three units are available from Ion Track Instruments: the Atmosphere Monitor for continuous monitoring of gas streams, the SF_6 Detector/Chromatograph for use as a tracer to detect gas system leaks, and the Leakmeter for use as an industrial leak detector designed for detection of leaks of SF_6 tracer gas or any gases that are responsive to the detector. All three units utilize an electron capture detector; the SF_6 Detector/Chromatograph includes a gas separation column. All three units sample at a rate of 250 cm^3/min and use a meter as the readout mode. The SF_6 Detector/Chromatograph is extremely specific because of the gas chromatograph column. Response time is 1 second for the Leakmeter and the Atmosphere Monitor and 15 seconds for the SF_6 Detector/Chromatograph.

19-4-6. GasCorder Portable Toxic Gas and Vapor Monitor

Mine Safety Appliances Company

The Baseline Series GasCorder Monitor is designed to detect low concentrations of volatile organic compounds (VOCs). It features both a graphic display screen and a built-in disk drive for recording data. It is designed for industrial hygiene applications, fugitive emission monitoring, or use at HazMat or remediation sites for field sampling and analysis of toxic gases, hydrocarbons, organic vapors, and other hazardous materials. It is available as either a flame-ionization detector (FID) or as a photoionization detector (PID). The GasCorder is equipped with user prompts, a flat-panel backlit LCD screen, and both alpha/numeric or trend data display. The 1.4-megabyte floppy disk records all data generated by the monitor for later review on the display, or for downloading into a PC. Monitoring parameters can be preprogrammed, and long-term unattended operation is possible with optional auto calibration module (and support gases for the FID version).

INSTRUMENT 19-4-6. GasCorder Portable Toxic Gas and Vapor Monitor.

INSTRUMENT 19-4-5. Atmosphere Monitors.

19-4-7. Photovac TIP

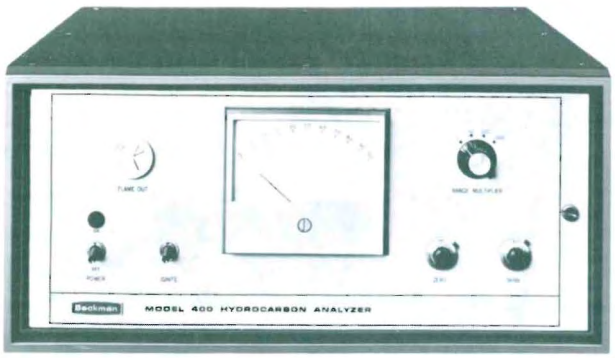
Photovac International, Inc.

The Photovac TIP, which stands for total ionizables present, is designed to measure any airborne contaminant that is detectable by photoionization. In operation, a small pump continuously draws sample air into an ionization chamber that is flooded with UV light. The molecules of most light permanent gases (including the air gases H_2, helium, and N_2) are unaffected because they require an ionization energy higher than that generated by the 10.6-eV lamp in order to become ionized. However, any gases or vapors in the air stream that have ionization energy levels below that generated by the lamp are ionized. Inlet flow rate: 275 ml/min. Display: 3.5-in. LCD (0–1999 counts, illuminated). Charge/discharge time: approximately 16 hrs/4 hrs; charger provided. Low battery indication: at 95% discharge. Signal outputs: 1-V full scale, analog concentration, and modulated pulse for external (optional) earphone. External power: 12 VDC, 0.4 A (TIP has internal regulation). Linearity: 0–100 ppm ± 10%; 100–1000 ppm ± 15%. Response time: 3 seconds (10% to 90% full scale, 10 ppm benzene).

19-4-8. Model 400 Hydrocarbon Analyzer

Rosemount Analytical Inc.

The Model 400 employs the FID method for use in a variety of engine exhaust applications. Its single-unit



INSTRUMENT 19-4-8. Model 400 Hydrocarbon Analyzer.

case is designed for panel, rack, or bench mounting. Case design permits front, top, and rear access to simplify maintenance. Noise: less than ± 0.5% of full scale. Zero and span drift: ±1% of full scale per 24 hrs. Response time: 90% of full scale in 0.5 seconds at bypass flow rate of 3000 cm^3/min. Output: 10-mV, 100-mV, 1-V, or 5-VDC selectable is standard; 40 to 20 mA, 10 to 50 mA DC, optional. Fuel gas requirement: hydrocarbon-free air. Sample requirements: 500–3000 cm^3/min at 5–10 psig, input, depending on desired response time. Ambient temperature limits: 0 to 43°C. Ambient humidity limits: 95% RH. Safety features: flame-out indicator, integral flame arrestor, and automatic fuel shutoff.

19-4-9. Portable Flame Ionization Meter

Scott Aviation

The Portable Flame Ionization Meter, Model 11-654, is used to detect trace hydrocarbons in air. Applications of the instrument include 1) measurement of hydrocarbons as atmospheric pollutants; 2) monitoring for fuel leaks in storage areas or during fuel transfer and loading operations; 3) measurement of hydrocarbons in liquid oxygen or inert purge gas; 4) monitoring for toxic concentrations of solvents or process chemicals in manufacturing areas, ventilating systems, or storage areas; or 5) monitoring of manholes, sewers, and drains for accumulations of toxic or explosive gases. The basic principle of operation of this detector is ionization of hydrocarbon molecules in a hydrogen flame. Sample flow is obtained by an internal diaphragm-type pump. The fuel flow (40% hydrogen; 60% nitrogen) is controlled in two stages by a pressure regulator followed by a constant differential-type control. All controls necessary for operation of the system are mounted on the front panel. Recorder output terminals are available on the rear panel as are the fuses, sample inlet and exhaust connections, fuel supply controls, and electrical power input. Speed of response: varies directly with sample flow rate; 2–3 seconds, exclusive of external sample transport.

19-4-10. Hydrocarbon Analyzers, 400 Series

Teledyne Analytical Instruments

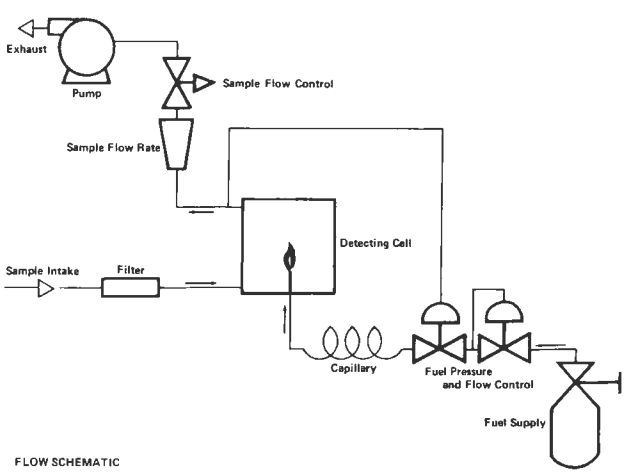
The TAI Series 400 flame ionization analyzers are continuous monitoring devices designed to measure trace quantities of total hydrocarbon contaminants in a gaseous atmosphere. The analyzer may be used to 1) detect hydrocarbons and atmospheric pollutants, 2) monitor for fuel leakage or toxic solvents, and 3) monitor combustion efficiency by measuring hydrocarbon emissions. In the Series 400, there are three models: Model 402 for positive pressure sampling, Model 403 for portable atmospheric sampling, and Model 404 for portable, high-temperature sampling. Constant temperature is maintained by a solid-state, thermistor temperature controller. Gas flows are regulated by maintaining a constant pressure across a sintered stainless steel restrictor in lieu of capillary tubing. 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 change from 10 to 1000 ppm. Noise less than ±0.5% full scale. Drift: <1% full scale per day. Output: linear signal meter readout provisions for 0- to 5-mV DC recorder. Ambient temperature: 4 to 38°C. Flow rate: 100–400 ml/min of sample, 40–50 ml of fuel (200 ft^3 cylinder lasts 3 months); fuel mixture of 40% hydrogen and 60% nitrogen. Pressure rating up to 100 psi.

19-4-11. AID Models 580B and 585 Portable Organic Vapor Analyzers

Thermo Electron Instruments

The AID 580 and 585 are portable monitors that use a PID. The PID uses a high-energy UV lamp to ionize a sample that is drawn into the instrument. In general, the PID will respond to most organic compounds. It is



INSTRUMENT 19-4-9. Portable Flame Ionization Meter.

sensitive to methane, ethane, and most of the permanent gases. The sampling rate is 500 ml/min for the AID 580 and 50 ml/min for the AID 585, each regulated by a positive displacement pump. Internal, rechargeable batteries provide 8 hrs of continuous use. No fuel or compressed gases are required. The AID features an integral audio alarm that can be preset to any level. In addition to the normal LCD, an optional strip chart recorder may be operated from the recorder terminals provided on the back panel. The instrument displays information by a linear digital display. As with all PIDs, limited specificity is available by changing the energy of the photoionization lamp. Both instruments are equipped with a 10-eV lamp; an optional 11.8-eV lamp is available. 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.

19-4-12. Models 710 and 712 Portable Total Hydrocarbon Analyzers

Thermo Electron Instruments

The AID 710 and 712 are designed as portable ambient monitors for use in the detection of fugitive emissions and other types of leaks with FIDs. The AID 710 and 712 are comprised of two units: the side pack and a gun. Samples are drawn in by a positive displacement pump at the rate of 1.5 L/min. The unit requires the availability of an external source of hydrogen to recharge the internal hydrogen supply. The AID 710 and 712 operate off an internal, rechargeable battery pack that supplies a minimum of 8 hrs of power. The unit is provided with a high-level audio alarm and a flame-out indicator 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. The response time of the unit is 5 seconds, 90% full scale. A zero and span potentiometer is provided on the front panel of each unit.

19-4-13. Model 910 Organic Vapor Meter

Thermo Electron Instruments

The AID 910 Organic Vapor Meter is designed as a stationary monitor for most organic vapors in air, excluding methane, ethane, propane, and a few others. The AID 910 operation is based on the principle of photoionization. The PID uses a high-energy UV lamp to ionize the sample that is drawn into the instrument. The AID 910 comes confined to two sizes; a bench-mount unit and a NEMA enclosed unit. The sampling rate is variable up to 4 L/min 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 with this unit. No fuel or compressed gases are required. The 910 is equipped with an audible alarm for low-level and high-level indications. Using a standard 10-eV photoionization lamp, the 910 may detect a minimum of 0.1 ppm benzene in air matrix. The instrument displays all data on a linear LCD. As with any PID, the specificity can be varied by the energy of the ionizing lamp. Response time depends on the variable flow rate; 2.5 seconds at maximum flow rate. Span and zero calibration adjustments are found on the front panel of the 910.

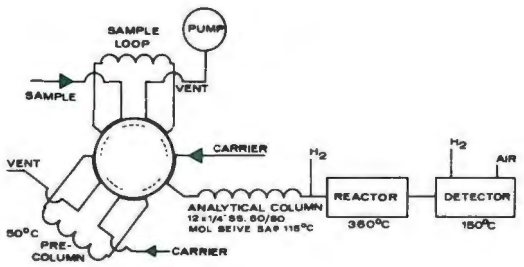
INSTRUMENT 19-4-11. AID Models 580B and 585 Portable Organic Vapor Analyzers.

INSTRUMENT 19-4-12. Models 710 and 712 Portable Total Hydrocarbon Analyzers.

19-4-14. Model 680 Portable Hydrocarbon Vapor Meter

Thermo Environmental Instruments, Inc.

The Model 680 is a portable, intrinsically safe fugitive emissions monitoring system. The flame ionization technique utilized by the 680 can sample over a 0–20,000 ppm range, with a sensitivity of 0.1 ppm methane. User programmable software capabilities entail response factor settability, self-calibration adjustment, storage of up to 10 calibrations in memory, and automatic data logging of up to 4000 sample readings by time, date, concentration valve, and location code. Additionally, via bidirectional RS-232 communications, the 680 can interface with commercially available fugitive emission database computer software systems. Operating time: 10 hrs per charge.



INSTRUMENT 19-4-15. 350F Analyzer for CO/CH_4 and Total Hydrocarbons.

19-4-15. 350F Analyzer for CO/CH_4 and Total Hydrocarbons

Tracor, Inc.

The Tracor 350F Analyzer combines a gas chromatographic column with an FID and can be used to measure concentrations of CO, methane, and total hydrocarbons. CO reacts with hydrogen in the presence of reduced nickel catalyst to quantitatively produce methane. The FID is coupled to the reactor for the measurement of the methane reactant. Selectivity is attained by using a precolumn prior to the analytical column that removes all interferents, passing only CO and CH_4. The analytical column then permits separate identification and quantification 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. An integral flame-out H_2 cutoff is incorporated. The analytical column is housed in a heated mandrel oven. Temperature control is within 0.05°C, assuring reproducibility of analytical time. A panel-mounted pyrometer with a four-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.

Infrared Photometers

19-5-1. Open Cell Nondispersive Infrared (NDIR) Gas Detector, Model 5600

Astro International Corporation

The Model 5600 is designed for fixed-station monitoring of combustible gases in chemical plants, ships, well-logging operations, refineries, drying ovens, drilling platforms, sewage digesters, mines, and tunnels. IR energy from the IR source passes alternately through two narrow band interference filters and the sample gas; it is then reflected by a spherical mirror to the solid-state detector. The sample filter wavelength is selected for line spectra absorbed by gases analyzed. Synchronous detection, calculation of dual wavelength ratios, and reference and sample signal processing are then performed to eliminate drift associated with alternate IR detectors. The Model 5600 has compensating circuitry for IR source and detector aging. 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. Output: 0–1 VDC, 0–10 VDC, 4- to 20-mA DC fault alarm (relay); two independent settable alarms. Response time: 8 seconds. Zero and span drift: ±2% (nonaccumulative).

19-5-2. Models 864/865 Nondispersive Infrared Analyzers

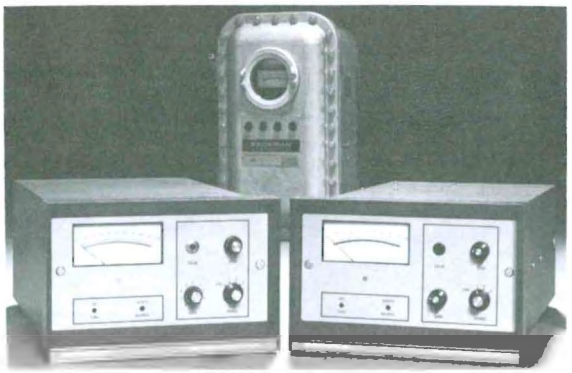
Beckman Instruments, Inc.

The Beckman Models 864/865 Nondispersive Infrared Analyzers are designed for precise determination of a given chemical component concentration in vehicle emissions. Applications include vehicle emissions, automotive research and development, and automotive certification testing. The Models 864/865 utilize NDIR radiation absorption, which is produced from two separate energy sources. The infrared beams pass through two cells: a reference cell containing a nonabsorbing background gas and a sample cell containing a continuous flowing sample. Noise: 1% of full scale. Zero and span drift: 1% of full scale/24 hrs. Response time (electronic): variable, 90% in 0.5–26 seconds (15 field-selectable speeds). Sample cell length: 4–38.1 mm. Sample flow rate: nominal 500–1000 cm^3/min. Sample pressure: 15 psig. Maximum ambient temperature range: 1 to 49°C. Output (field selectable): 0–10 mV, 0–100 mV, 0–1 V, 0–5 VDC. Nonlinear output standard; plug-in linear output optional.

19-5-3. Model 866 Ambient CO Monitoring System

Beckman Instruments, Inc.

The Model 866 is designated as a reference method for ambient CO monitoring. Model 867 is also available for monitoring CO in vehicle exhaust. The Model 866 monitoring system combines the Model 865-17 non-



INSTRUMENT 19-5-2. Models 864/865 Nondispersive Infrared Analyzers.

dispersive infrared (NDIR) analyzer, the Automatic Zero/Span Module, a Beckman-developed Automatic Flowing Reference Panel, and a Pump/Sample Handling Module into a self-contained system. Model 866 utilizes NDIR radiation absorption. The infrared beam passes through two cells: a reference cell containing a nonabsorbing background gas, the other cell containing a continuous flowing sample. Noise: <0.2 $P/10^6$. Total interference equivalent: less than 1.5 $P/10^6$, per U.S. Environmental Protection Agency (U.S. EPA) specifications. Zero drift: ±0.5 $P/10^6$ per 12 and 24 hrs. Span drift: ±1%/24 hrs. Electronic response time: 0.5–26 seconds, field selectable, U.S. EPA-designated at 13 seconds. Ambient temperature limits: 0 to 50°C; U.S. EPA designated at 20 to 30°C. Outputs: 10 mV, 100 mV, 1 V, and 5 VDC available from auto zero/span module; 4- to 20-mA DDC optional.

19-5-4. Model 1301 Gas Analyzer

Bruel and Kjaer Instruments, Inc.

The Model 1301 Gas Analyzer is a fully self-contained, transportable Fourier Transform Infrared (FTIR) spectometer that utilizes photoacoustic detection and is designed for field use. The unit can be used as both an analyzer to determine what gases are present and as a monitor for concentration measurements. Any gas or vapor that has an infrared absorbance between 4000/cm and 650/cm can be detected. Detection limits are typically in the range from 0.1 to 10 ppm. The dynamic range is 4 orders of magnitude. The unit has extensive internal data handling and data storage capabilities, along with a built-in disk drive and graphics screen. Serial and parallel interfaces allow for the transfer of data to various peripherals and computers. Zero drift: detection limit over 3 months. Span drift: 5% of reading over 3 months.

INSTRUMENT 19-5-3. Model 866 Ambient CO Monitoring System.

INSTRUMENT 19-5-4. Model 1301 Gas Analyzer.

19-5-5. Toxic Gas Monitor Type 1302

Bruel & Kjaer Instruments, Inc.

The Toxic Gas Monitor Type 1302 is designed for the continuous measurement of various toxic gases. Typical applications are area monitoring for process emissions and perimeter monitoring for accidental releases. The monitor can operate unattended for months at a time. The Multigas Monitor 1302 is a portable unit that has typical applications for occupational exposure, tracer gas analysis, and indoor air quality assessment. The measurement technique used in both instruments is based on infrared photoacoustic spectroscopy. This method is based on the fact that when a gas absorbs modulated light, it emits sound proportional to the concentration of the gas. During operation, air is pumped into the measurement chamber. The chamber is sealed and irradiated with modulated, narrow band, infrared light. If the toxic gas of interest is in the air sample, sound is emitted and measured with a microphone. The signal is processed and the result is transmitted to the controlling computer. Selectivity is controlled by fitting the monitor with the appropriate optical filter for the gas of interest. A wide range of filters is available, covering the useful region of the

INSTRUMENT 19-5-5. Toxic Gas Monitor Type 1302.

INSTRUMENT 19-5-7. Riken RI-550A Gas Analyzer.

infrared spectrum.

The Toxic Gas Monitor is remotely controlled from a personal computer that can be positioned a considerable distance from the monitor. The monitoring system can incorporate from 1 to 254 monitors connected to one computer. The Model 1302 has 32 KB of memory and 80 character display. It has a measurement time of 30 seconds for one gas and up to 100 seconds for five gases. Span drift: 2.5% of reading in 3 months. Zero drift: detection threshold concentration in 3 months.

19-5-6. Riken RI-411A Portable CO_2 Indicator

CEA Instruments, Inc.

The Riken RI-411 is a lightweight CO_2 infrared gas monitor with digital readout and audible alarm. The unit is applicable to food-related industries, brewers, mushroom growers, greenhouse horticulture, welding, office ventilation systems, cooling systems, hazardous environments, laboratory and research projects, etc. The Riken RI-411 utilizes NDIR absorption to measure CO_2 in air. The unit is Ni-Cd battery operated and microprocessor controlled. The readings of CO_2 concentrations can be continuous or averaged over 1, 3, or 15 min. Averaged readings are held on the display until needed by the user. The RI-411 has a solid-state detector, an illuminated dot-matrix digital display, and a recorder output and can operate on AC using an optional DC power supply. Audible alarms: high CO_2, 5000 ppm (short pulse, optional 25%), averaging period (long tone), and low battery (continuous tone). Response time: 10 seconds to 90% indication. Calibration: zero, calibration using nitrogen or air cylinder (zero gas); span, calibration using cylinder of CO_2 in air. Ambient temperature range: –10 to 40°C. Ambient humidity range: 10% to 90% RH. Recorder output: 0- to 10-mv DC (linear). Auxiliary charger available for charging or continuous operation on 115-VAC adaptor. Operating hrs: about 6 hrs continuous.

19-5-7. Riken RI-550A Gas Analyzer

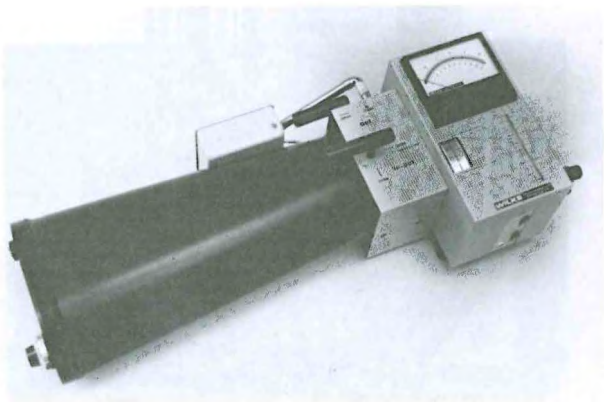
CEA Instruments, Inc.

The Riken Infrared Gas Analyzer Model RI-550A is a single gas, lightweight, infrared analyzer designed to measure CO, CO_2, methane, ethylene, ethane, propane, or butane levels. This instrument operates on the 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. Response time: <10 seconds to 90% response. Zero and span drive less than ±2%/8 hrs of full scale. Sample flow rate: 6 L/min, normal, variable. Calibration is by internal span gas canister and/or built-in mechanical reference filter. Ambient temperature range: 0 to 40°C. Ambient humidity range: 0% to 90% RH. Warm-up time: 30 min after power switch ON (usable after 3 min). Recorder output: 0- to 10-mV DC (internal resistance 100 ohms).

19-5-8. Miran Gas Analyzers

Foxboro Company

The Miran Gas Analyzers utilize NDIR absorption. Both the optical path of the gas cell and the wavelength can be varied to give specificity and sensitivity. 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 (2.5–14.5 μm). The Miran 101 is a lighter weight analyzer that reads directly in concentration 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. Miran-I Variable Filter Gas Analyzer: sampling rate, 28 L/min; readout mode, full scale ranges (0–0.025, 0–0.1, 0–0.25, and 0–1); absorbance units: 0%–100% transmittance. Miran 101 Specific Vapor



INSTRUMENT 19-5-8. Miran Gas Analyzers.

Analyzer: sampling rate, approximately 15 L/min (cell volume, 2.25 L); readout mode, direct reading in concentrations. Response and averaging time: <1 minute. Stability: drift <0.004 absorbance units at 23.25°C, 3.5 M.

19-5-9. Model RI-413 Portable Freon® Monitor

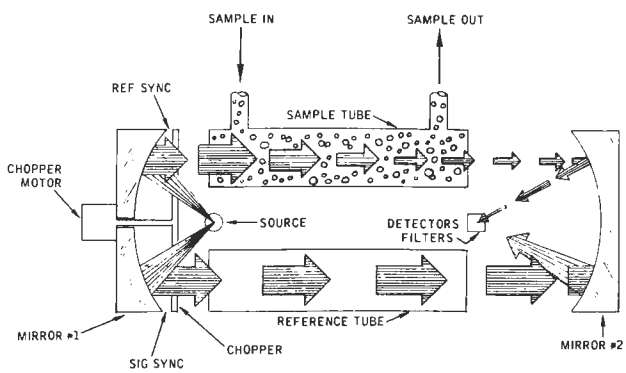
GasTech, Inc.

The Model RI-413 is a portable instrument capable of measuring Freons® R-11, R-12, R-22, R-113, R-114, and R-502 in ppm concentrations. This instrument is ideal as a leak detector and survey meter around refrigerant or cleaning systems where Freon is typically used. The instrument can be used to obtain continuous output or average readings for 1, 3, or 15 min. The Model RI-413 utilizes NDIR absorption for detection. The Model RI-413 contains a microprocessor for control operations and a durable miniature diaphragm pump to draw in the samples. Other features include a choice of alkaline or Ni-Cd batteries, an adaptor for 115-VAC operation, low battery and high gas level alarms, six detection ranges, self-illuminating digital display, and a 3-ft sampling probe. Response time: 10 seconds to 90%. Operating time: 4 hrs.

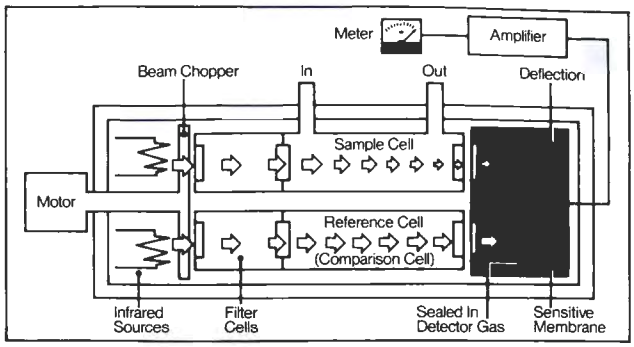
19-5-10. IR-702 Infrared Analyzer

Infrared Industries, Inc.

The IR-702 Infrared Analyzer has the capability of detecting two gases simultaneously. Its internal standardization eliminates the need for span gases, and solid-state circuitry allow fast response with low vibration sensitivity. 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 is a measure of the optical absorption. Speed of response: 90% of reading in 1 second. Accuracy: (specification depends on certified calibrations gas) ± 1% of full scale. Noise level: <1% of full scale. Zero and span drift: <1%/24 hrs. Temperature range: 0 to 20°C. Detector type: solid-state (PbSe). Output: 1–100 mV or 0–1 V. Warm-up time: 15 min.



INSTRUMENT 19-5-10. IR-702 Infrared Analyzer.



INSTRUMENT 19-5-12. LIRA Model 3000 Nondispersive Infrared Analyzer.

The sampling system is constructed of 316 stainless steel, windows of silicon, and tubing of Teflon. Calibration: internal optical attenuator.

19-5-11. IR-711 Portable Hydrocarbon Analyzer

Infrared Industries, Inc.

The IR-711 Portable Hydrocarbon Analyzer is used for the instantaneous detection and measurement of percent LEL and ppm levels of the alkane family of hydrocarbons in and around fuel tanks and other enclosures. Because of its design, the IR-711 is particularly useful in the monitoring of JP-5 and other kerosene-type fuels. This instrument is an NDIR analyzer for continuously monitoring the concentration of a specific gas in a gas sample stream. Standard recorder outputs (0–100 mV) are provided. The analyzer features a single infrared energy source that eliminates the complex alignment problems associated with dual infrared energy sources. 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, thereby reducing maintenance, cleaning, and replacement costs. 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 hrs — high range (<5% LEL), low range (<50 ppm). Warm-up time: 5 min. Response time for temperature compensation: 2 min.

19-5-12. LIRA Model 3000 Nondispersive Infrared Analyzer

Mine Safety Appliances Company

The LIRA Model 3000 Nondispersive Infrared Analyzer is designed for fixed station use in the detection of any gas or vapor that absorbs infrared energy. Its sample cells and windows are application dependent. Inlet, outlet, and purge fittings are 1/8-in. NPT, and the tubing is made of nylon. Least detectable quantity, sensitivity, and specificity are all application dependent. Response time: 90% in 5 seconds; optional 90% in 3 seconds. Zero and span drift: <1% full scale/day,

typically <2% full scale/week. Span check: electrical circuit simulates presence of sample gas when activated by push-button on front panel.

19-5-13. OTOX® Model CO_2 Monitor

Neotronics

The OTOX® can be used as a hand-held and/or wall-mounted CO_2 monitor. The instrument utilizes a nondispersive infrared sensor, which is protected from dust, smoke, and other particulate contaminants by a membrane filter. The OTOX® has a warm-up stabilization time of 5 min and a response time of 20 seconds. The instrument can operate in temperatures from 0 to 50°C and relative humidities between 5% and 95%. A 12-V battery operates the monitor for 1.5–2 hrs.

19-5-14. Series 800 Infrared Analyzers

Rosemount Analytical, Inc.

The Series 800 nondispersive infrared analyzers are designed to monitor CO, CO_2, NO, and hydrocarbons in pollution control, automotive exhaust, or process gas emission applications. Series 800 analyzers produce infrared radiation from one or two separate energy sources. This radiation is modulated by a chopper into pulses. The infrared beam then passes through a flowing sample cell or both sample and reference cells. Based on sample stream characteristics, the reference call may be sealed or flowing. The signal from the infrared detection device(s) is amplified, displayed, and/or transmitted to data acquisition devices. Repeatability: 1% of full scale. Zero/span drift: 1% of full scale/24 hrs.

19-5-15. Model 765-203 Infrared Analyzers

SKC West, Inc.

The Model 765-203 Infrared Analyzer is a wall-mounted/tabletop CO_2 data recorder that can be used to evaluate the efficiency of ventilation systems. The 765-203 has internal memory for storage of time-based data, with the sampling frequency varying from 8 seconds to 30 min. A software package is available to download data to any IBM compatible computer. The software package is menu-driven and allows the user to display, print, and store useful graphs and reports. Power source: 12-V battery with 4.5-hr duration or 12-V, 400-mA AC power adapter. Operating temperature: 10 to 40°C.

Ultraviolet (UV) and Visible Light Photometers

19-6-1. J-W Mercury Vapor SNIFFER®

Bacharach, Inc.

The J-W Model MV-2 Mercury Vapor SNIFFER® is a dual-range, hand-held instrument for the detection and measurement of mercury vapors in working areas. The sample is drawn into the detector and through the UV absorption chamber by a small motor-driven suction fan powered by a battery. To operate the detector, the user turns the control knob to the bias position, adjusts the zero, sets the air knob to sampling position, and reads the vapor concentration on the meter. The vapors of some organic compounds, such as benzene and its compounds, halogenated hydrocarbons, and particulates, absorb UV light at the lamp frequency. Normally, this slight interference does not present a problem. The detector has an efficient built-in filter that permits the meter to be zeroed in a contaminated atmosphere and then switched immediately to read the vapor concentration. The Model MV-2 is a self-contained, battery-powered instrument housed in a lightweight steel case. The indicating meter is calibrated in mg/m^3 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 photoelectric cell, and all other operating components. A slip-on connection is provided in the end of the case for an extension probe when used.

19-6-2. AISI Sulfur Dioxide Monitor

Barringer Research, Ltd.

The Barringer AISI Sulfur Dioxide Monitor is used to quantitatively determine the amount of SO_2 emitted by a source such as a stack without physically procuring a sample of the gas. Operation is based on correlation with the absorption spectra of SO_2 in the UV. Hence, normal skylight may be used as the UV source and measurement obtained with the instrument located several hundred feet from the source. In operation, the viewing unit is first sighted on the target plume near the stack mouth. The vertical aperture 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 is 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, yield the SO_2 concentration in ppm. The instrument is comprised of three units: the electronic unit, the viewing unit, and the tripod. Sensitivity of Option 1 is 2 ppm-m; Option 2, 40 ppm-m. Field of view: 0.15° horizontal; vertical is adjustable from 0 to 1.5°. Meter and chart recorder are located on the front panel. Option 1 is a high-sensitivity instrument designed for such applications as plume tracing. Option 2 is designed specifically for remote stack monitoring. The units cannot be converted in the field.

19-6-3. Model K-23B Mercury Vapor Meter

Beckman Instruments, Inc.

The Beckman Model K-23B Mercury Vapor Meter is designed to provide an instantaneous reading of mer-

cury 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. The Beckman Model K-23B is a portable, UV filter photometer tuned to a wavelength of 253.7 nm (the wavelength at which mercury vapor absorbs light). To ensure optimum accuracy at all times, a calibration filter assembly is built into the meter. Filters with known absorption factors can be switched into the optical path of the meter to provide standard references for calibration. Output: 0–100 mV plus meter. Noise: 0–0.1 scale, ±1.5% full scale; 0–1.0 scale, ±0.5% full scale.

19-6-4. Model TGM555 Portable Toxic Gas Monitor

CEA Instruments, Inc.

The TGM555 is a portable, ambient air monitor that can be used for continuous colorimetric analysis of numerous compounds. The TGM555 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 that 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. A recorder output is also provided.

Operating period: 20 hrs, fully charged internal batteries. Signal output: 0–1.0 V at 0–2.0 mA. Calibration: <1% drift/72 hrs. Sensitivity: 1% of full scale. Nonlinearity: <2%. Zero and span drive: <2%/72 hrs. Air flow drift: <1%/72 hours. Noise: 0.75% of full scale. Lag time: 4 min. Rise time to 90%: 4 min. Fall time 90%: 2.5 min. Temperature range: 4.5 to 49°C. Temperature drift: at laboratory conditions ±3°C, ±1%; from 15 to 30°C, ±2%; from 30 to 50°C, ±4%; from 14 to 50°C, ±8%. Relative humidity range: 5% to 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).

INSTRUMENT 19-6-4. Model TGM555 Portable Toxic Gas Monitor.

INSTRUMENT 19-6-5. Model 1003 Ozone Monitor.

19-6-5. Model 1003 Ozone Monitor

Dasibi Environmental Corporation

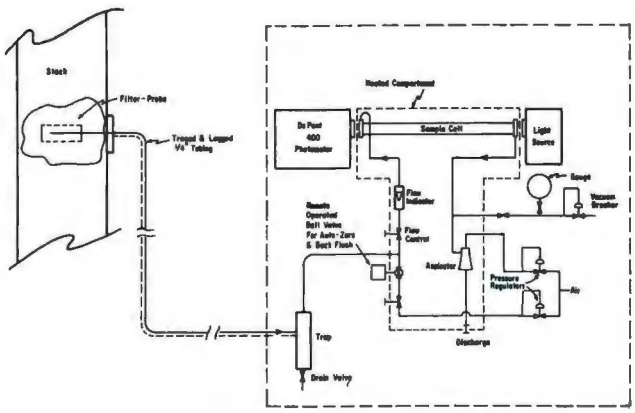
The Model 1003 Ozone Monitor continuously monitors the concentration of ozone in the air in ppm. An analog output is available for continuous strip-chart recording, and a binary-coded decimal (BCD) output enables direct interfacing with a computer or a printer. Ozone concentration is measured by detecting the absorption level of UV light within a sample volume of air. Accuracy: ±3%. Scale factor: adjustable to any standard. Drift: <0.001 ppm/week noncumulative. Zero span: ±0.4%/°C, corresponding to much less than 0.001 ppm. Interval: 8 or 30 seconds. Flow rate: 7 L/min at 8-second intervals; 1.0 L/min at 30-second intervals. Zero return: 1 interval from 1.0 ppm. Temperature: 0 to 49°C. Meets vibration and shock constraints typically encountered in shipping, aircraft, and mobile vans; maintenance, 1000-hr mean time between maintenance under typical conditions.

19-6-6. Stack Gas Analyzers for SO_2, NO_2, and NO_x

DuPont Company

The DuPont 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.

The analyses are based on the strong UV absorption of SO_2 and the visible absorption of NO_2. The DuPont 460 Photometric Analyzer, using a split beam configuration, measures the difference in light absorption at two different wavelengths. Either manual- or automat-



INSTRUMENT 19-6-6. Stack Gas Analyzers for SO_2, NO_2, and NO_x.

ic-operated filter switching mechanisms can be provided to allow one analyzer to be used for both SO_2 and NO_2 measurements. Because NO is essentially transparent in the visible and ultraviolet, quantitative conversion to NO_2 is required for its measurement. Speed of response: 15 seconds or less (5-min cycle for Model 461). Analyzer output: linear, 0- to 10-mV standard; 4–20 mA and 10–50 mA available. Integrally mounted recorder optional. Accuracy: ±2% of full scale. Linearity: better than 2%. An optional calibration filter corresponding to a fixed SO_2 concentration is provided. Compressed air at 30–80 psig.

19-6-7. Autostep Plus

GMD Systems, Inc.

The Autostep Plus is a microprocessor-controlled portable toxic gas detector. The Autostep Plus utilizes a removable, gas-specific ranging or gas-type module to monitor for TDI, MDI, hydrazines, Phosgene "A," Phosgene "B," or acid gas. Multigas modules are available to monitor for TDI, MDI, and HDI or chlorine, hydrides, and acid gas. The detection principle is colorimetric paper tape and reflected light, level measurement controlled by the microprocessor. Other features of the Autostep Plus include 2,000-point data logging capability, built-in audible alarm, and external battery and data connectors. The precision depends on gas and model: 15% of reading or 1 ppb/0.1 ppm, whichever is greater. The Autostep Plus can operate from –10 to 40°C and in 5% to 95% relative humidity, noncondensing.

19-6-8. Model 727-3 UV Ozone Monitor

Mast Development Company

The Model 727-3 UV Ozone Monitor utilizes the technique of UV absorption for fast and specific ozone detection. The monitor is suitable for use in ozone chamber work, environmental chamber work, safety monitoring near ozone generators in industrial or wastewater treatment operations, OSHA-regulated monitoring, quality control for ozone-producing appliances, and plant pathology studies. No expendable reagents of any kind are required. The instrument is portable and designed for both long-term, unattended use and intermittent operation. Off-the-shelf warm-up is less than 20 min. Flow rate: 2 L/min. Ambient temperature range: 0 to 50°C. Relative humidity range: 5% to 95%. Unattended period: up to 30 days. Digital display: 0.00–9.99 ppm. Analog: 1V per 10 ppm. Accuracy: ±4% (based on Beer's law). Lag time: 5 seconds. Rise time: 1 measurement cycle. Fall time: 1 measurement cycle. Zero drift: none. Span drift: 1% of calibration level/24 hrs. Measurement cycle: 20 seconds.

19-6-9. Model 890 SO_2 Analyzer

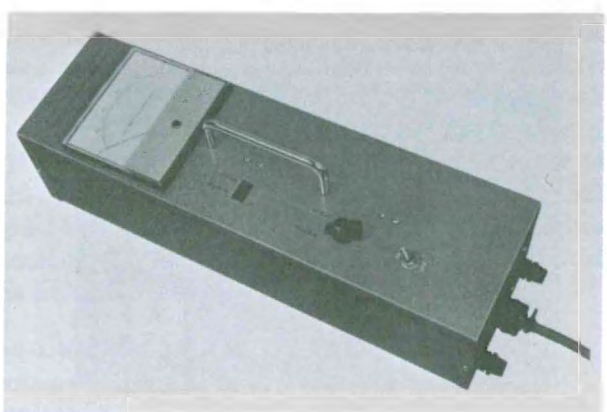
Rosemount Analytical, Inc.

The Model 890 SO_2 Analyzer uses a nondispersive UV "transflectance" analysis bench to monitor for SO_2. Radiation from a pulsed UV source is collimated and directed onto two multidetector blocks, located before and after the single sample cell. Wavelength isolation is achieved by means of a spectrally selective cold mirror in the detector block. Response time: variable, 90% of full scale in 0.5–20 seconds. Repeatability: ≤1% of full scale. Zero/span drift: ±2% of full scale/week.

19-6-10. Instantaneous Vapor Detector

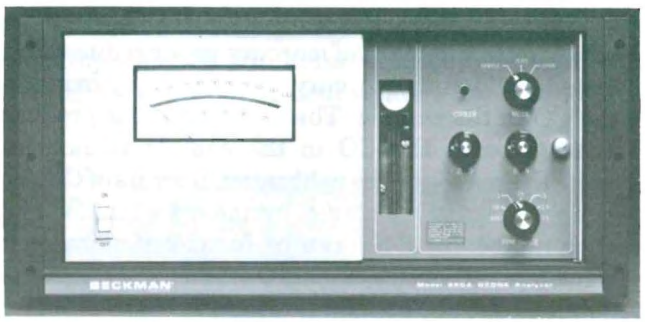
Sunshine Scientific Instruments

The Instantaneous Vapor Detector is intended primarily for the detection of mercury vapor but can be used for the detection of other vapors in specified ranges of concentration. Applications include the manufacture of electrical apparatus, instruments, bulbs, glassware, fur, and salt; use in the chemical, metal mining, and smelting industries; and use by insurance companies and laboratories. Operation of the detector is based on UV light absorption by mercury vapor. This same principle is also used for the detection of certain other vapors that have selective absorption characteristics for UV radiation. For this reason, the identity of the vapor under test must be known and the vapor must be



INSTRUMENT 19-6-10. Instantaneous Vapor Detector.

free from other substances which will absorb or obstruct UV light. In addition, the vapor should be relatively uncontaminated by extraneous substances such as fog, dust, or smoke. Features: warm-up 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/visible alarms, and systems for monitoring multiple locations.



INSTRUMENT 19-7-1. Model 950A Ozone Analyzer.

Chemiluminescence

19-7-1. Model 950A Ozone Analyzer

Beckman Instruments, Inc.

The Model 950A provides ozone analysis over a wide selection of full-scale ranges for ambient air monitoring. The Model 950A utilizes a nonhazardous 90% CO_2/10% C_2H_4 mixture as the reactant gas, instead of pure ethylene typically required for chemiluminescent analysis. The chemiluminescent detection method is based on the principle that ozone mixes with ethylene, resulting in a chemiluminescent reaction that provides a light emission directly proportional to the ozone (O_3) concentration in the ambient air sample. Noise: 0%, 0.002 P/10^6; 80% of span, 0.002 P/10^6. Total interference equivalent: <0.005 P/10^6. Zero drift: <0.005 P/10^6 per 12 hrs; 0.001 P/10^6 per 24 hrs. Span drift: ±2% of full scale/24 hrs. Lag time: <20 seconds. Rise and fall time: <90 seconds. Ambient temperature: 4 to 43°C; U.S. EPA designated at 20 to 30°C. Outputs: 10 mV, 100 mV, 1 V, and 5 VDC.

19-7-2. Model 952A NO/NO_x/NO_2 Analyzer

Beckman Instruments, Inc.

The Model 952A ambient NO_2 monitor is designed for field operation. The Model 952A chemiluminescent detector is based on the principle that NO reacts with ozone to produce NO_2, 10% electronically excited NO_2, and O_2. 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. 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 then routed to the reaction chamber for analysis. Noise: 0%, 0.002P/10^6; 80% of span, 0.003 P/10^6. Total interference equivalent: 0.01 P/10^6. Zero drift: <0.02 P/10^6 per 12 hrs; <0.005 P/10^6 per 24 hrs. Span drift ±2% of full scale/24 hrs. Lag time: 0.5 min. Rise and fall time: 1.5 min and 1.0 min, respectively. Ambient temperature: 4 to 43°C; U.S. EPA designated at 20 to 30°C. Outputs: individual memory outputs for NO/NO_x/NO_2, switch selectable for 10 mV, 100 mV, 1 V, or 5 VDC; primary output signal, switch selectable for 10 mV, 100 mV, 1 V, or 5 VDC.

INSTRUMENT 19-7-2. Model 952A NO/NO_x/NO_2 Analyzer.

19-7-3. Model 1100 Ozone Meter

Columbia Scientific Industries Corporation

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. The Model 1100 Ozone Meter operates on the Nederbragt principle of the chemiluminescent reaction between ozone and ethylene. Ethylene consumption: 15 cm^3/min. Time constant: selectable 1.0 second or 10 seconds. Known atmospheric interferences: none. Data display: panel meter, mirrored 4.5-in. scale. Electronic: solid-state except for photomultiplier tube. Operating temperature: 10 to 45°C ambient. An optional portable Chemiluminescent Ozone Meter, Model MEC 2000, is also available. It has ranges of 0–0.1, 0–0.2, 0–0.5, and 0–1.0 ppm.

19-7-4. Nitrogen Oxides Analyzer

Columbia Scientific Industries Corporation

The Model NA530R Nitrogen Oxides Analyzer is designed for both research investigations and environmental monitoring for NO, NO_2, and NO_x. It uses the chemiluminescence reaction of ozone with NO in two independent and simultaneous photometric measure-

ment systems to 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 NO. The signals are subtracted for the NO_2 signal. The chemiluminescence reaction is temperature sensitive, causing a several percent error if allowed to follow ambient temperature. High sensitivity and accuracy are obtained by controlling the temperature of the reaction chamber. Noise (RMS): 0% URL, 0.002 ppm; 80% URL, 0.004 ppm. Interference equivalent: 0.005 ppm each interferent; 0.015 ppm total interferent. Zero drift: ±0.007 ppm/24 hrs; ±0.01 ppm/7 days. Span drift: ± 0.013 ppm/24 hrs; ±0.020 ppm/7 days. Lag time: <5 seconds. Rise and fall time (95%): 0.5–6 min depending on range and TC position. Linearity: ±1%. Unattended operations: 7 days (no adjustment of flow or electrical systems). Sample air flow rate: 1.2 L/min (max). Dry air flow rate: ozone generator, approximately 200 ml/min. Outputs: meter, with selector switch to read NO, NO_2, or NO_x; recorder, each channel has separate outputs of 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.

19-7-5. Ozone Analyzers

Columbia Scientific Industries Corporation

The Model OA 325-2R and OA 350-2R Ozone Analyzers have been designed to provide real-time, continuous monitoring of ozone in ambient air. Operation of the Ozone Analyzers 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 gases present in ambient air. The analyzers are identical, except the OA350-2R has an internal UV ozone source to produce a span point and also a zero air source. Noise: 0% URL, 0.003 ppm; 80% URL, 0.002 ppm. Each interferent, ±0.002 ppm or better; total interferents, 0.002 ppm or better. Zero drift: ±0.002 ppm, 12 or 24 hrs. 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: 20 to 30°C.

19-7-6. Series 900 Analyzers

Rosemount Analytical, Inc.

The Series 900 Analyzers use chemiluminescence detection technology to monitor for oxides of nitrogen. The Model 951A is designed for light-duty engine and source monitoring as well as process applications. The Model 955 is designed for similar applications, but on a wet basis commonly used in heavy-duty engine exhaust monitoring. The Model 951C was specifically designed to meet the requirements of an integrated continuous emissions monitoring system. Zero/span drift: less than ±0.1 ppm or ±1% of full scale/24 hrs at constant temperature or ±0.2 ppm or ±2% of full scale over any 10°C from 4 to 40°C. Repeatability: ±0.1 ppm or 1% of full scale, whichever is greater.

Photometric Analyzers

19-8-1. Model US400 Carbon Monoxide Analyzer

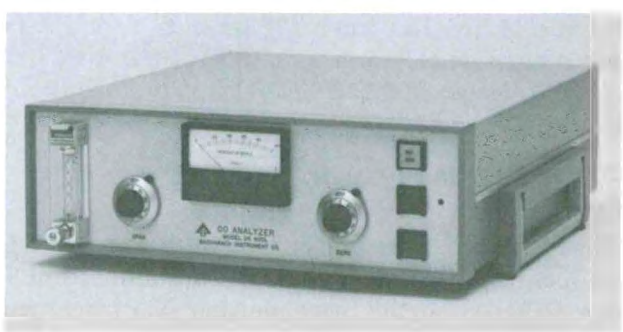
Bacharach, Inc.

The Model US400 is designed for the continuous measurement of low CO concentrations in the field of pollution monitoring and control and when monitoring work areas, garages, ventilation systems, and industrial process streams. Determination of CO is based on the direct measurement of mercury vapor reduced from a heated, solid-state mercury oxide pellet 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 CO. The mercury vapor is measured by means of a UV filter photometer. The US400 can be furnished suitable for bench mounting or installed in a standard 19-in. panel, suitable for rack or panel mounting. The sample-drawing pump and remotely operated flow control valves are enclosed in a separate housing. Ambient temperatures: 4 to 43°C. Altitude range: sea level to 1500 m. Warm-up time: 15 min. Sample flow rate: 4.7 L/min. Span drift: ±2% of full scale/day. Lag time: 5 seconds. Response time: <10 seconds for 90% full scale/day. Sensitivity: 0.1 ppm/mV. Recorder outputs: floating or ground reference.

19-8-2. Carbon Monoxide Analyzer DIF 7000

Beckman Instruments, Inc.

The dual-isotope fluorescence (DIF) technique can detect changes in CO concentrations as small as 0.1 ppm and involves producing infrared radiation spectra to match those of two CO 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 that are then sensed by a solid-state photodiode detector. Accuracy is ±1% of reading, ±1% of full



INSTRUMENT 19-8-1. Model US400 Carbon Monoxide Analyzer.

scale (accuracy is relative to calibration source), and linearity is ±1%, 0200 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: 1% of reading/month (at constant temp.) Zero drift: 1 ppm/week (at constant temp.) Span and zero temperature coefficient: 0.2% of reading/°C 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 V available on special order). Impedance: <400 ohms. Warm-up time: 30 min to full accuracy. Ambient temperature: 0 to 50°C. Ambient relative humidity: 90%.

INSTRUMENT 19-8-3. Model 953 Fluorescent Ambient SO_2 Analyzer.

19-8-3. Model 953 Fluorescent Ambient SO_2 Analyzer

Beckman Instruments, Inc.

Utilizing the fluorescent measurement technique, the Model 953 requires no support gases and reagents typically used with flame photometric or coulometric SO_2 analyzers. An internal zero gas scrubber permits ambient air to be used as the zero gas, eliminating the need for zero air cylinders. An added feature is an interferent reactor that eliminates interference due to polycylic aromatic hydrocarbons (PAHs) typically found in samples where dense automotive traffic prevails. Beckman's fluorescent monitoring methodology is based on the principle that SO_2 molecules fluoresce when irradiated by 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.

Noise: 0.5 $P/10^6$ range, 0.001 $P/10^6$. Lower detectable limit: 0.5 $P/10^6$ range, 0.004 $P/10^6$. Zero drift: 0.5 $P/10^6$ range, less than ± 0.005 $P/10^6$ per 24 hrs. Span drift: 0.5 $P/10^6$ range, less than ± 0.006 $P/10^6$ per 24 hrs. Total interference equivalent: 0.5 $P/10^6$ range, <0.025 $P/10^6$. Lag time: 7 seconds. Fall time: 3 min. Ambient temperature: 20 to 30°C. Output: 10 mV, 100 mV, 1 V, or 5 VDC.

19-8-4. Sulfur Analyzer Model SA285

Columbia Scientific Industries Corporation

The Model SA285 Sulfur Analyzer provides continuous, real-time monitoring of sulfur compounds in the ppb range. It utilizes the Meloy-patented Flame Photometric Detector (FPD) to provide dry analysis of sulfur in air samples. The operating principle of the FPD utilizes the photometric detection of the 394-nm centered band emitted by sulfur-containing compounds in a hydrogen-rich air flame. Its specificity arises from a geometric arrangement that optically shields the photomultiplier tube from the primary flame and the employment of a narrow band-pass interference filter. Noise (RMS): ±0.5% of full scale maximum. Zero drift: ±1% full scale/24 hrs. Span drift: ±2% full scale/24 hrs. Lag time: 10 seconds maximum. Rise and fall time: 90%, 25 seconds maximum. Linearity in ppb: ±1% of full scale. Available outputs: a) meter, b) 10-VDC full scale, c) 100-mVDC full scale (adjustable from 10-mV to 5-V full scale). Unattended operation: 14 to 28 days (no adjustment of flow or electrical system). Sample flow rate: approximately 200 ml/min. Hydrogen flow rate: approximately 140 ml/min. Ambient operating temperature range: 10 to 40°C.

19-8-5. Fluorescence SO_2 Analyzer

Columbia Scientific Industries Corporation

The Model SA700 is built for direct ambient air monitoring of SO_2 using a continuous UV source of high intensity and stability. The low noise characteristics provide rapid response and accuracy to better than ±2%, even on the most sensitive ranges. Sample flow rates are less than 500 cm^3/min. Noise (RMS): ±0.5% on 0- to 500-ppb scale. Zero and span drift: meets U.S. EPA specifications. Lag time: 10 seconds maximum. Rise and fall times: to 95%, 2 min maximum. Linearity: ±1% full scale. Operating temperature range: 20 to 30°C to U.S. EPA specifications. Sample flow: <500 cm^3/min. Interferences: meets U.S. EPA specifications. Output: a) 0–10 V; b) 0–100 mV, adjustable to 0–5 V. This instrument is suitable for bench mounting; rack mounting is available.

19-8-6. Phosphorus Gas Detectors/Analyzers

Columbia Scientific Industries Corporation

Columbia Scientific 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 portable, lightweight unit with 12-V battery supply). Rise time for Model PA 460 is 2–3 seconds (nominal), <10 seconds maximum; for the PA 465, it is 10 seconds to 90% of full response. Fall time: <7 seconds for the PA 460 and 3 seconds for the PA 465.

Photometric Analyzers of Surface Deposit

19-8-7. Hydrogen Sulphide Monitor

Fleming Instruments, Ltd.

The Fleming Hydrogen Sulphide Monitor was developed to meet requirements of underground sewer testing or be used in areas where there is a possibility of encountering toxic gases. The basic principle used in the Type 533 Monitor is the continuous elevation, by a sensitive phototransistor, of the intensity of the brown stain produced by the action of H_2S gas on a lead acetate-treated 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. Paper tape: Whatman B.D.H. No. 1 lead acetate filter paper, 1 cm wide × 5 m long (at least 6 working days supply). Paper tape drive mechanism: clockwork motor with drive mechanism that also indicates the remaining operating time. Pump: miniature axial flow. Distilled water is the "wetting" agent. Sampling period to initiate warning signals is approximately 2 min (i.e., when set to 10 ppm sensitivity, the device will trigger after 2 min sampling in a 10-ppm atmosphere).

19-8-8. Halide Detector

GasTech, Inc.

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 UV region is directly proportional to the halogen content of the gas sampled. Its primary field of application is by industrial hygienists in industrial solvent cleaning and fine chemical production facilities. It has also proven useful as a process monitor. Interpretation of this reading is made by relating the meter reading to a calibration curve based on the specific gas being tested. Sampling rate: continuous. Readout mode: panel meter. Recorder output adjustable from 0–10 to 0–50 mV. Detection limits: threshold limit concentrations of most halogen-containing compounds. The instrument also has a range adjust in arithmetic ratios of 1, 3, and 10, permitting expanded readings up to 10,000 ppm. The instrument is generally not subject to interference from nonhalogenated 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 3–5 seconds with an accuracy of ±5%. Line voltage changes will have an effect on readings; otherwise stability is in the neighborhood of ±5% per day.

19-8-9. Model 722AEX-A Gas and Vapor Analyzer

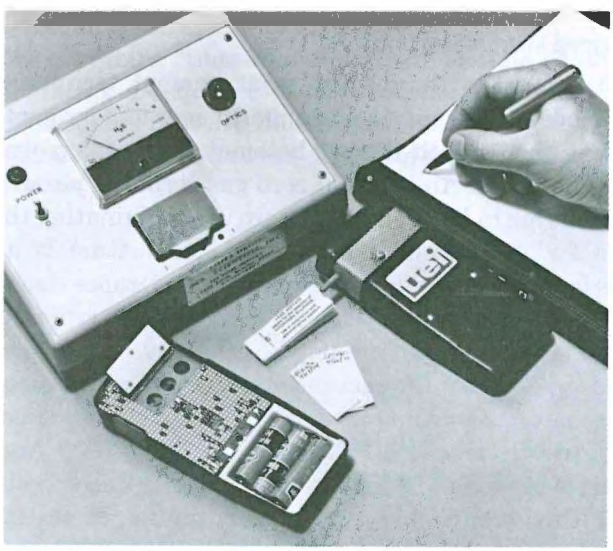
Houston Atlas, Inc.

The 722AEX-A is a fixed monitor that 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 operates by the photometric method. The air sample enters the instrument 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. It is accurate to ±2%. Accurate sample readings are ready in 3 min. Zero drift is 5% of full-scale calibration.

19-8-10. Miniguard Personal Alarm Dosimeter

MDA Scientific, Inc.

The Miniguard is designed to function as a personal dosimeter for toxic chemical gases and vapors. The Miniguard uses a dry, chemically impregnated, paper-tape system, specifically sensitive to the substance being sampled. A piece of tape is inserted into the dosimeter, then the dosimeter is put in a shirt pocket, worn on a belt, etc. The tape is exposed either by diffusion or aspiration, depending on the system in-



INSTRUMENT 19-8-10. Miniguard Personal Alarm Dosimeter.

volved. The exposed tape section and an unexposed reference section of the tape are continually evaluated by two balanced Cd-S photocells. 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. The sampling rate is by diffusion or 0–250 cm^3/min, depending on system and range. Readout is directly in ppm/hrs. Specificity: no significant interference. Response time: variable, depends on alarm setting.

19-8-11. TLD-1 Toxic Gas Detector

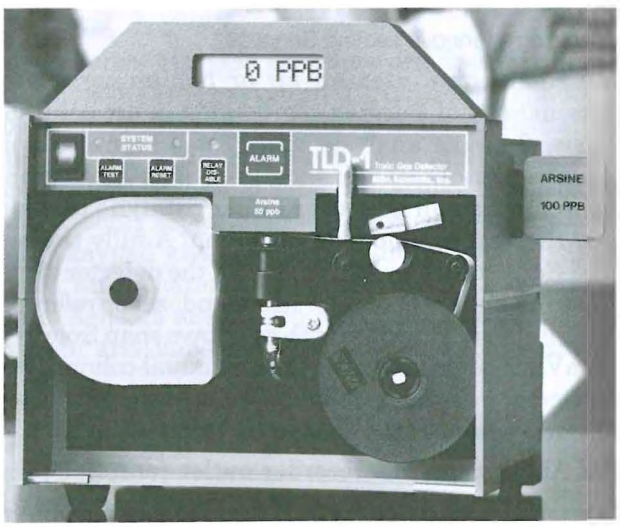
MDA Scientific, Inc.

The TLD-1/ChemKey System is a portable, direct-reading instrument capable of measuring over 40 different toxic, corrosive, or pyrophoric gases. This system is designed for use by emergency response teams, industrial hygienists, or anyone who needs to monitor for different hazardous gases. The ChemKey Gas Selection System allows the operator to switch monitoring modes from one gas to another. All that is needed is a simple change of key and interference-free Chemcassette™ sensor. The system detects NH_3, arsine, Cl_2, diisocyanates, diborane, hydrazines, HF, HCl, HCN, H_2S, PH_3, silane, and phosgene.

19-8-12. Series 7100 Continuous Toxic Gas Monitors

MDA Scientific, Inc.

The MDA Series 7100 Monitor can detect ultra-low levels of over 40 hazardous gases in the workplace. Using MDA's Chemcassette™ paper tape detection system, the 7100 can accurately measure gas concentrations without cross-interference to other substances present. The on-board printer reports ppb levels in minute-by-minute, 8-hr average, and alarm-level formats. Other features include digital LCD readout, user-programmability, dual-alarms, alarm relays, serial output, up to 4 weeks unattended operation, and easy calibration.



INSTRUMENT 19-8-11. TLD-1 Toxic Gas Detector.

INSTRUMENT 19-8-12. Series 7100 Continuous Toxic Gas Monitors.

19-8-13. Halide Meter

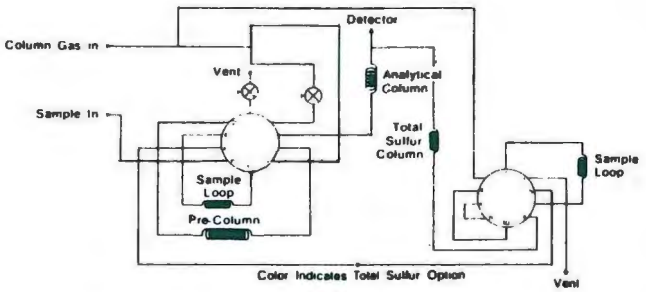
Scott Aviation

The Halide Meter is a portable instrument designed for field determinations of halogenated hydrocarbons in air. The Halide Meter is most often used for determining perchloroethylene, trichloroethylene, carbon tetrachloride, methylene chloride, and similar chlorinated hydrocarbons in air. 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 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. The meter readings are converted to ppm using calibration curves. A 20-ft Tygon® sampling hose is also provided with the instrument. Any halogenated material in the air being sampled will cause the instrument to give a reading and, in this sense, the instrument is nonspecific. It cannot, for example, differentiate carbon tetrachloride from trichloroethylene when the vapors are mixed. Nonhalogenated materials, such as hydrocarbons, do not interfere, however, and mixtures of halogenated vapors with other vapors may be evaluated.

19-8-14. Model 271 HA Sulfur Analyzer

Tracor, Inc.

The Model 271 HA was designed primarily as an automated monitor for low-level H_2S and SO_2 (the two common sulfur air pollutants); however, the 270 HA can be used in a variety of other analytical applications simply by changing the column, sample loop size, and/or operating conditions. Operating on gas chromatograph principles and utilizing the Tracor sulfur-specific flame photometric detector, the 270 HA chromatographically separates and independently quantitates vapor-state sulfur compounds in gaseous media. Precise sample volumes, reproducible to within ±0.2 cm^3, are injected via fixed F.E.P. Teflon sample



INSTRUMENT 19-8-14. Model 271 HA Sulfur Analyzer.

loops (9 cm^3 standard). The 6-ft analytical column 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-cm^3 sample loop) without interference. Sampling rate: cyclic (225 seconds). Readout mode: dual output 0–10 mVFS (chromatographic) and 0–5 VFS (computer or datalogger) for each of two ranges (0–100 ppb and 0–1 ppm). Specificity: sulfur compound specific; possible interferences include high concentrations of CO_2 and/or hydrocarbons (1000 ppm). Response time: sampling is cyclic, maximum response time 225 seconds. Stability: 1%/24 hrs; 2%/week.

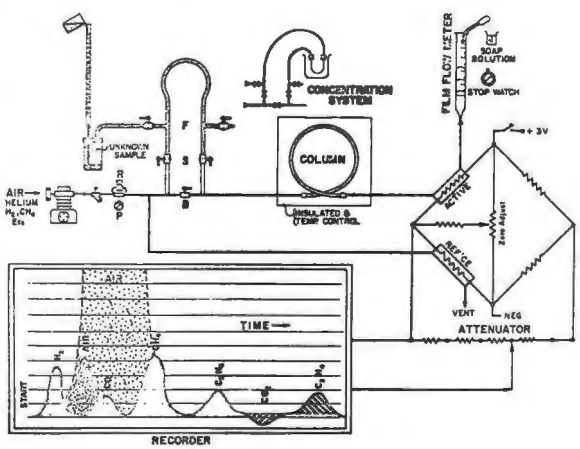
Thermal Conductivity Detectors

19-9-.1. Model 7-C Thermal Conductivity Analyzers

Beckman Instruments, Inc.

The Beckman 7-C Series Analyzers utilize the thermal conductivity principle of measurement to analyze the concentration of one component in a mixture of gases. These analyzers may be used in 1) power generating plants to detect hydrogen in generator cooling systems; 2) ammonia plants to measure hydrogen in NO, ammonia, argon, CO, or O_2; 3) petroleum refineries to measure hydrogen in C through C_6 hydrocarbons; or 4) air liquefaction plants to measure argon in O_2 and NO or measure O_2 with argon impurities. The Beckman instruments use heated TC filaments in a Wheatstone bridge to detect gases. Cell response time: 95% of change in 30 seconds at a sample flow rate of 250 cm^3/min. Sample flow rate: nominally 50–350 cm^3/min. Reference gas flow rate: 5–10 cm^3/min; at these flow rates, a cylinder containing 200 ft^3 of gas will last longer than 1 year. Sample pressure is 0–50 psig (69–345 kPa). An indicating meter is available for most ranges. Ambient temperature limits: 4.4 to 38°C. Explosion-proof enclosures are available for use in Class 1, Division 1, Group D, hazardous locations.

INSTRUMENT 19-9-1. Model 7-C Thermal Conductivity Analyzers.



INSTRUMENT 19-9-2. Analograph and Servocorder.

19-9-2. Analograph and Servocorder

Deutsch Engineering & Testing Services

The Analograph uses an air or helium carrier for determinations of selected compounds in air pollution analysis, flue gas analysis, utility gas identification, toxic gases, and breath gas analysis. The Analograph is a chromatograph that uses either catalytic combustion or thermal conductivity detection. A fully transistorized Servocorder is used to handle the detector signal and has full-scale response of 1/8 second, zener reference voltage, multirange switch with an octave span from 1- to 1024-mV full-scale response. Optional dual-column, hot-cold detector in a top-opening metal case permits sharp peaks for fixed gases to C_{15} components.

The Analograph has recorder outlet terminals, fine and coarse zero adjust, and bridge voltmeter. It is supplied with partition column, carrier gas regulator, flowmeter, operating manual, and technical papers

complete with built-in thermal conductivity and catalytic combustion detector, three 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.

The Servocorder is portable in a two-tone black and gray case with carrying handle. 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 3/4 in./min (chart speed selector optional). Maximum source impedance: 100,000 ohms. Zero adjust: full scale.

19-9-3. Leak Hunter Model 8065

Matheson Gas Products

The Matheson Model 8065 Leak Hunter is a portable, hand-held unit designed for leak detection of nonflammable gases. Leak detection is achieved by a microvolume, thermisterized, thermal conductivity detector cell mounted in the front end of the hand unit. Self-diagnostics are included to determine the status of the detection circuitry, current, and low battery conditions (displayed as visual and audible warnings). For noisy environments, earphones are supplied. Gases detected: any gas with a different thermal conductivity to reference ambient air. Response time: <1 second. Recovery time: 1 second. Audio: fixed volume, variable frequency audio generator mounted in gun housing. Diagnostics: low battery indication, detector cell failure alarm. Operating time: maximum 14 hrs from rechargeable batteries. Operating temperature: 0 to 50°C. Storage temperature: –20 to 70°C.

Heat of Combustion Detectors

19-10-1. Series 100 Gas Detectors

AIM USA

The Series 100 Gas Detectors are designed to detect combustible gases, oxygen, and toxic gases in applications that include confined space survey work, industrial safety and hygiene, and fugitive emissions and leak detection. Instruments in the 100 Series are available to detect one, two, or three separate gases. Features include a data entry keypad and alarm incident, time-interval sampling, and location-survey testing data logging formats. Sensors are electrochemical for toxic gases and oxygen, and nonspecific metal oxide for combustible gases.

19-10-2. GasPointer® Combustible Gas Detectors

Bacharach, Inc.

The GasPointer® detectors are intrinsically safe, battery-powered portable instruments designed to measure concentrations of methane and carbon monoxide in ambient air and flue gas. The instrument is particularly designed for locating gas leaks and testing gas appliance installations in residential, commercial, and industrial applications. The GasPointer® operates with three sensors: a capillary diffusion electrochemical CO sensor; a temperature-compensated, catalytic bead, combustible gas sensor for low concentrations of natural gas; and a temperature-compensated, electrochemical oxygen sensor for higher concentrations of natural gas. The GasPointer® can operate in a temperature range of –5 to 50°C and a relative humidity range of 5% to 99%, noncondensing.

19-10-3. Gastron Combustible Gas Detectors

Bacharach, Inc.

The Gastron is a portable instrument used to detect and locate combustible gas leaks. The Model 310 is identical to the Model 282 except that it will detect hydrogen. A continuous sample of air is drawn through a sensing element where controlled catalytic combustion occurs, causing a signal to be generated that 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. 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. The probe contains a humidity controlling filter. Response time: <2 seconds. Warm-up time: 2 min. Dust discrimination: filters down to 1 mm. Temperature: operating –34 to 54°C; storage –51 to 66°C. Drift rate: 100% of scale/hr in "Search" range (approximate). Detector cell life: 40 hrs (normal operation) average.

19-10-4. SNIFFER® 500 Series Portable Area Monitors

Bacharach, Inc.

The SNIFFER® 500 Series Portable Area Monitors are instruments designed to alert personnel to the hazards of O_2 deficiency and the presence of dangerous concentrations of combustible gases, CO, and H_2S. The SNIFFER 500 Series combines sensors for two or three different contaminants. The sensors include a heated catalytic bead for combustible gases and electrochemical cells for O_2, H_2S, and CO. Any combination of these contaminants, up to three, is available. Various visual (steady or pulsing LEDs) and audible alarms (using steady, alternating, or pulsed tones) are used for different instruments. In addition to the various alarm options, the 500 Series includes an integral sampling pump, a variety of concentration ranges for combustibles, analog displays, low flow and battery alarms, and use in hazardous areas. Operating temperature: 20 to 50°C. Response time: variable from 5 seconds to 60 seconds (90% response). Operating time: 10 hrs.

INSTRUMENT 19-10-5. Super Sensitive Indicator.

19-10-5. Super Sensitive Indicator

Bacharach, Inc.

The Super Sensitive Indicator uses a catalytic combustion sensor comprised of two identical platinum elements incorporated as opposite arms of a 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. Batteries provide up to 8 hrs of continuous operation. Sampling rate: approximately 1.0 L/min. Readout mode: meter. Response time: initial response within 1–2 seconds of exposure. Instrument stability is in keeping with battery-operated instruments of this general design.

19-10-6. TLV SNIFFER®

Bacharach, Inc.

This instrument operates on the principle of catalytic combustion (a process of oxidizing a combustible gas/air mixture on the surface of a heated catalytic bead element). Eight-hour continuous operation is possible with six size D, Ni-Cd batteries or approximately 3 hrs with six size D, carbon-zinc batteries. Sampling rate: 1.65 L/min, nominal. Readout mode: meter, audible alarm, earphone output, and recorder output. Response time: initial response within 12 seconds of exposure. Its stability is in keeping with instruments of similar sensitivity and construction.

19-10-7. Ultra I and Ultra II

Bacharach, Inc.

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 that indicates both percent LEL and the actual quantity of combustible gas in the sample. 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. Both units use methane as the calibration gas; have span and zero adjustments through holes in the lower housing; are powered by four size D batteries; and have temperature ranges from –10 to 50°C (limited by battery specifications).

19-10-8. Model 12 Combustible Gas Detector

Chestec, Inc.

The Model 12 is a solid-state detector for all combustible gases. The unit can be worn as a safety monitor for gas meter readers, gas appliance servicemen, petroleum workers, and laboratory workers. The Model 12 utilizes a solid-state semiconductor detector. The detector is silenced by nulling (zeroing) using the sensitivity knob. Any additional combustible gas will start the instrument clicking within seconds. Like a Geiger counter, the click rate increases with combustible gas concentration. The detector can be nulled to silence for gas concentrations up to about 1000 ppm. Any additional gas concentration will cause the instrument to start clicking. The knob pointer and dial scale indicates the approximate concentration in ppm at null. Other features include 12-VDC to 6-VDC charger, belt clip, earphone for noise operations, and rechargeable Ni-Cd batteries. Temperature range: –29 to 66°C. Operating time: 10 hrs.

19-10-9. Model XP-316 High Sensitivity Gas Indicator

COSMOS Gas Detection Systems

The XP-316 employs the principle of solid-thermal conductivity on a semiconductor/platinum filament for the detection of combustible gases and Freons, and for

INSTRUMENT 19-10-6. TLV SNIFFER®.

replacement Freons applications such as safety/compliance monitoring or locating small leaks. The instrument is graduated with a low range (0–1000 ppm) and a high range (0–10,000 ppm). Warm-up time is a maximum of 60 seconds and response time is 3 seconds to start of meter pointer deflection. Battery life: 10 hrs with alkaline cells. Standard accessories include standard AT-3A probe with DF-4 moisture trap and FE-2 filter, standard 1-m hose, carrying case with shoulder strap, four AA dry cell batteries, and FE-2 filter refills.

19-10-10. Model XP-704 Freon Detector

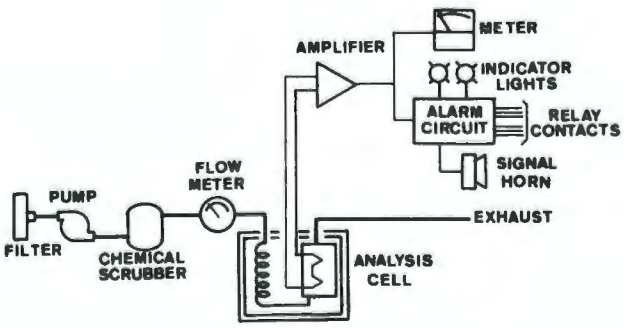
COSMOS Gas Detection Systems

The XP-704 is an intrinsically safe, high sensitivity leak detector for HCFC replacement freons. The minimum detectable leak rate is 3.3×10^{-5} atm-cm^3/sec. and the minimum detectable concentration is 5 ppm. Gas intake is automatic sampling by built-in micropump. The alarm system is an intermittent tone and flashing lamp with frequency proportional to gas concentration. Power is supplied by four AA batteries operate the instrument for 3 hrs continuously. Response time: 3 seconds maximum. Standard accessories include rubber search probe (AT-2), carrying case with shoulder strap, filter/moisture trap, two spare filter refills, and a set of four AA batteries.

19-10-11. Carbon Monoxide Detection System

Devco Engineering, Inc.

The Devco Engineering Carbon Monoxide Detection System is used in air pollution monitoring and to detect the presence of CO in parking garages, vehicle tunnels, steel mills, industrial plants, and warehouses. Devco Series 1000 Carbon Monoxide Detection Systems utilize the "Heat of Reaction" method for the measurement of CO in air. A schematic of the flow system is shown below. The air sample is passed through a heated chamber containing a catalyst bed, which promotes the oxidation of CO. Heat generated by this reaction is proportional to the concentration of CO in the air sample. A solid-state, time-proportioning temperature controller maintains the constant temperature within the analysis cell and cell chamber. All Series 1000 instruments 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 temperature. Zero drift: less than ±2% with voltage fluctuations of ±15%. Response to reading: 30 seconds. Error: none due to hydrogen or hydrocarbon gases. Catalyst life: 1–2 years average. Calibration drift: due to relative humidity, error <2% of full-scale reading for relative humidity 50% ± 20%.



INSTRUMENT 19-10-11. Carbon Monoxide Detection System.

INSTRUMENT 19-10-13. LCD Combo Monitor.

19-10-12. Combustible Gas/Vapor Detection System

Devco Engineering, Inc.

Devco Engineering Series 5000 Combustible Gas and Vapor Detection Systems are designed for continuous monitoring of combustible gases. These systems employ a pair of catalytic hot wire elements forming two legs of a balance Wheatstone bridge. 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. 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 suction pump to maintain a continuous flow of the sample through the analysis cell. Speed of response: <1.0 second. Analog signal output for recorders, controllers, or digital display. Solid-state single and dual alarm circuits available. Ambient temperature limits: instrument, 0 to 57°C; detector head, to 93°C standard; to 121°C for high-temperature head.

19-10-13. LCD Combo Monitor

Dynamation, Inc.

The LCD Combo may be used to measure the level of combustible gas and O_2 deficiency. Applications include confined space entry and use as a personal warning device. The unit uses catalytic hot wire sensors for detection of combustible gas and a chemical cell for O_2 detection. The twin combustible sensors are electrically

INSTRUMENT 19-10-14. Respiratory Airline CO Monitor/Alarm.

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 O_2 level and has up to 18 months of life before replacement. The O_2 cell is temperature compensated with a thermistor that is embedded inside the sensor. The cell can be easily changed and operated from 9 to 49°C. The instrument batteries provide up to 9 hrs of operation. Response time: combustible gas, 90% of maximum reading within 30 seconds. Warm-up time: 3 seconds for combustible gas; 10 seconds for O_2.

19-10-14. Respiratory Airline CO Monitor/Alarm

Dynamation, Inc.

The Model ABL-50 is a CO monitor/alarm specifically designed for respiratory airline 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. The Model ABL-50 is connected to a tee fitting in the airline that bleeds off a small, continuous sample of air flowing between the compressor and the user. This sample is filtered for particulate matter, has the oil mist removed, and is regulated to 10 psig before passing over the solid-state, catalytic semiconductor sensor. Enclosure: polyester fiberglass NEMA 4 with cover latch. Controls: calibration and alarm threshold internal. Meter size: 2.5 in. Response: 90% of maximum reading within 2 min with 20 ppm CO concentration; faster at higher concentrations. Alarm adjustment range: 2–50 ppm CO. Recorder output: 0–1 mA. Interferences: other types of organic vapors will be detected if present in high concentrations or at their TLV. Sensor purge period: 1 min nominal. Sensor stabilization period: 10 min nominal.

19-10-15. Combustible Gas/Vapor Detectors

ERDCO Engineering Corporation

The ERDCO Engineering Corporation line of TOX/EX portable combustion gas/vapor indicators are used in 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 sewage treatment plants. They are widely used in utilities, refineries, laboratories, and combustible storage areas. 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 in a Wheatstone bridge circuit. Accessories available for most models include hose sampling attachment with a 5-ft hose or additional lengths optional, 30-in. semirigid nylon tubing probe, calibrator, and adapter and tank with 25% LEL methane. All models have a response time of less than 3 seconds using 25 ft of sample hose; approximately 5 seconds with 50 ft 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.

19-10-16. Model EX-10 Personal Combustible Gas Detector

ENMET Corp.

The EX-10 is a pocket-sized combustible gas detector designed for personal protection of workers in hazardous areas or for confined space entry. The catalytic sensor in this instrument has a typical life expectancy of 3–5 years. Alarms are audible and visual, and are adjustable over the full scale. Response time: less than 10 seconds when exposed to 50% LEL methane. Operating temperature range: –10 to 55°C for intermittent exposures. Rechargeable 3.6-V Ni-Cd batteries provide 45 hrs of continuous operation.

19-10-17. Portable Dual Range Combination Combustibles/Oxygen Deficiency Detector and Alarm

GasTech, Inc.

The GX-3A detects combustible gas and O_2 deficiency simultaneously and gives both an audible and a visual alarm whenever either hazardous condition is encountered. It uses a resistive catalytic combustion sensor for combustible gases and an electrochemical cell to measure O_2. The sample is drawn into the instrument by means of an integral pump, and continuous operation of up to 6 hrs is assured by the use of Ni-Cd rechargeable batteries. Solid-state alarm circuits for O_2 and combustibles actuate independent alarm lights and a common audible signal that continues until manually reset. Standard calibration is based on methane. In the ppm range, the detector is calibrated to read directly in

ppm of a specific hydrocarbon vapor, normally calibrated on toluene. Calibration curves can be supplied for interpretation of readings of other vapors of interest. Detection limits for O_2 are direct readings from 0% to 25% O_2. Alarms 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/4-hr period.

19-10-18. Exotector® Combustible Gas Meter

GfG Gas Electronics, Inc.

The Exotector® series of combustible gas meters covers three models for confined space entry, gas survey work, and leak detection. The Exotector has two modes of operation: pump operation for sampling from confined spaces and diffusion operation for continuous operation in combustible atmospheres. The different models offer ranges of combustible/methane detection from 0% to 10% LEL for leak detection to 0% to 100% LEL for full-range monitoring. The Exotector uses two sensors: catalytic combustion for 0% to 100% LEL and a hybrid thermal conductivity cell for 0% to 100% by volume detection even in the absence of O_2. Both sensors are mounted in a voltage- and temperature-balanced bridge configuration. Standard features include an analog display, an optical/acoustical alarm, a dual operation mode, 16 hrs of operation on one battery charge, sensor life of 1–3 years, and an intrinsically safe design. The three models (G614/G615, G624/G625, and G634/G635) are housed in antistatic, high-impact Polyamid 12. Response time: T_{90} = 10 seconds; warm-up time <15 seconds.

INSTRUMENT 19-10-17. Portable Dual Range Combination Combustibles/ Oxygen Deficiency Detector and Alarm.

INSTRUMENT 19-10-20. Combustible Gas Detectors.

19-10-19. Combustibles Analyzer, Model 647

Hays-Republic Division Corp.

The Hays-Republic Model 647 Heavy-duty Industrial Combustibles Analyzer effectively monitors combustibles levels in flue gases. Other applications include coating ovens and dyers, controlled-atmosphere furnaces, crude-oil handling facilities, distilling operations, engine test cells, electrolytic generators, explosives and fumigant manufacturing, sewage treatment plants, and combustion processes. The Model 647 operates on the principle of catalytic combustion, utilizing a balanced Wheatstone bridge circuit. The sensor consists of two flame arrestors, five layers of fine mesh of woven Monel wire, and a porous metal cup for a double margin of ignition safety. The sensor is further protected by a selective, molecular barrier that reduces catalytic poisoning from tetraethyl lead and silicone compounds. Contaminants: silicone vapors, tetraethyl lead. Integral indications: meter for percent combustibles or LEL; alarms and failure and pilot lights. Output: 0–100 mV. Accuracy: ±5% full scale/day (FSD). Linearity: ±4% FSD. Hysteresis: <1% FSD. Zero drift: 1% FSD/30 days maximum. Speed of response: 90% in 10 seconds. Alarm outputs: isolated NO and NC contacts for warning, alarm, and 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. Temperature range: 0 to 66°C.

19-10-20. Combustible Gas Detectors

Houston Atlas, Inc.

All of these instruments are capable of detecting the presence of any gas or vapor which, when combined with O_2 in free air, presents a potential explosion hazard. These instruments use the hot wire platinum

element for detection. Model 510: portable type in aluminum case with batteries and built-in charger. Its probe is on a 2-m cable. Model 520: a multiunit instrument composed of two to six channels, each similar in operation to the Model 510 above. Either rack- or panel-type mountings. The sensing element is housed in a probe and safety shielded by a Monel metal screen. Up to 100 ft of extension cable may be used with this probe. Response: full scale in 4 seconds.

19-10-21. Model CD212 Methane Gas Monitor

Industrial Scientific Corporation

The CD212 Methane Gas Monitor is designed for use in mines and other work environments to assure optimum protection against hazardous levels of methane gas (CH_4). This monitor is suitable for use by face bosses and equipment operators where continuous monitoring of CH_4 is essential. It also is ideal for maintenance crews performing welding or cutting operations by the last open crosscut. The CD212 and CD210 (High Sensitivity) Methane Monitors utilize diffusion-type catalytic bead sensors in a Wheatstone bridge. The sensor detects methane over the range of 0% to 5% (by volume) and can run continuously for up to 9 hrs on a charge. Other features include an audible alarm for rising methane levels, low battery condition, and malfunction in the sensor; on–off switch that prevents accidental shutoff; digital LCD with illumination; and a rugged stainless steel case. Temperature range: 10 to 50°C.

10-10-22. GASPONDER® Multiple Gas Monitors

Lumidor Safety Products

The GASPONDER® Models (I–IV) offer the capability of monitoring combustibles, percent O_2, CO, and H_2S in any desired combination or all together. These monitors are designed for a wide variety of applications including telecommunications, industrial processes, water and waste treatment plants, sewer and manhole areas, construction, and oil and gas refineries. The GASPONDERs employ a wide variety of sensors, including a poison-resistant catalytic sensor for combustibles, galvanic cell for O_2, and electrochemical cell for CO and H_2S. The monitors use an internal pump at flows of up to 375 cm^3/min for fast instrument response. The monitors also incorporate audible and visual alarms for high or low concentrations, low battery condition, and low flow; charge indicator; automatic battery cutoff circuit; and back-lighted LCD. MSHA approved for mining and methane atmospheres. Temperature range: –5 to 45°C. Operating time: 10 to 12 hrs per charge.

10-10-23. Rechargeable RCM/REM Carbon Monoxide and Ethylene Oxide (EtO) Meters

Macurco, Inc.

The RCM and REM are miniature (shirt pocket-sized) meters specific to CO and EtO, respectively, that are powered by rechargeable Ni-Cd batteries. The units may be plugged into 120 VAC for continuous use or operated on batteries as a portable meter. The RCM and REM use low maintenance, solid-state semiconductor sensors. The readouts are composed of 10 LEDs for display of the concentrations. Other features include special warm-up circuits, low-voltage battery protection, simple operation, and interference-free measurements. Accuracy: continuous use, 10%; intermittent use, 25%. Warranty: 1 year, including batteries.

10-10-24. RGM Flammable Gas Meter

Macurco, Inc.

The RGM is a miniature (shirt-pocket-sized) flammable gas (CH_x) meter that is powered by Ni-Cd rechargeable batteries. The CH_x semiconductor sensor features low maintenance and long life. An electronic meter, composed of 10 LEDs, displays the 0% to 1% or 0% to 5% range of methane gas in air. Other features include special warm-up circuits, low-voltage battery protection, easy calibration, and simple operation. Accuracy: in normal use, 25%; after calibration, 10%. Warranty: 1 year, including batteries.

19-10-25. Gasurveyor 1000 Hydrocarbon Gas Detector

McNeill International

The Gasurveyor is designed to detect combustible gases, O_2, and toxic gases from leaks around pipes, pumps, flanges, and underground tanks in ppm or % LEL. Features include audible and visual alarms, automatic calibration, analogue and digital display, and intrinsically safe BASEEFA and CERCHAR certification. The instrument can operate >12 hrs on alkaline batteries. Operating temperature: –20 to 50°C. Relative humidity range: 20% to 95%, noncondensing.

19-10-26. Model 8057 Hazardous Gas Leak Detector

Matheson Gas Products

The Model 8057 Hazardous Gas Leak Detector monitors laboratory, plant, and process areas; instrumentation; tubing; fittings; storage containers; and production equipment for potentially dangerous leaks of gases and vapors at TLV levels. The Model 8057 uses a solid-state gas sensor with a sintered metallic block. An air sample from the suspected leak-source area is drawn into the unit and over the sensors by the internal, low-power-drain micropump. At intermittent tone sounds, an LED lamp flashes if a gas leak is detected. The tone frequency is proportional to the detected gas concentration; i.e., slow beep for low concentration and a faster beep for higher gas concentrations. The alarm can be silenced by means of a switch on the back of the unit. In this mode, the LED continues to flash in the event of gas detection. Detection time: 10–20 seconds, depending on gas and sensitivity setting. Approximately 6-hr continuous operating time with full charge

(charger included). Operating temperature: 0 to 40°C. Warranty: 1 year from date of purchase.

19-10-27. Portable Combustible Gas and Oxygen Alarm, Models 260 and 100

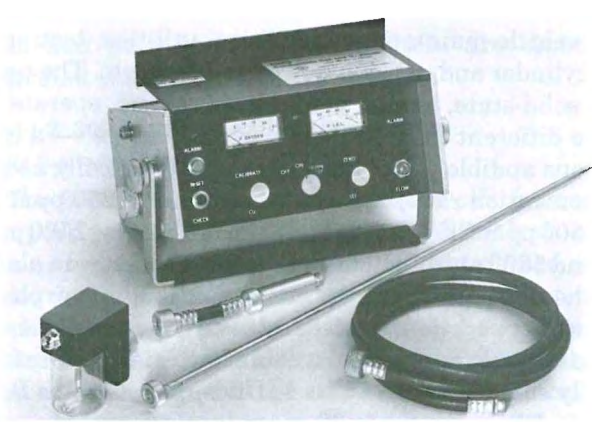
Mine Safety Appliances Company

The Portable Combustible Gas and Oxygen Alarm, Model 260, is a dual-purpose instrument designed to monitor areas for combustible gases and/or O_2 deficiency. 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. The combustible gas portion of the instrument uses a catalytically activated Pelement™ filament in a Wheatstone bridge. The O_2 portion of the instrument operates by means of a diffusion galvanic sensor cell. Sampling rate is 1.6 L/min. Other accessories include standard MSA probe rods, tubes, carrying harness, and sampling lines when used for remote sampling. The combustible gas alarm is factory set to trigger at 50% LEL and the O_2 alarm at 19.5% O_2. Both alarm points are field adjustable. Compounds containing silicon and leaded gasoline vapors may seriously impair instrument response. An inhibitor filter should be used to nullify the effect of leaded gasoline vapors. Response: 90% in <20 seconds. Accuracy: ±5% of full scale for combustibles and ±2% for O_2.

19-10-28. Explosimeter® Combustible Gas Indicator, Model 2A

Mine Safety Appliances Company

The MSA Explosimeter®, Model 2A, measures combustible gases and vapors in concentrations up to 100% of LEL. The instrument operates by the catalytic action of a heated platinum filament in contact with combustible gases. External accessories: sampling line available in length multiples of 5 ft for remote testing; 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 an aid in distinguishing between gases and condensable vapors in sample. 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. When testing other combustible gases, readings are generally on the high or safe side.



INSTRUMENT 19-10-27. Portable Combustible Gas and Oxygen Alarm, Models 260 and 100.

INSTRUMENT 19-10-28. Explosimeter® Combustible Gas Indicator, Model 2A.

19-10-29. Combustible Gas Detection System, Series 5000

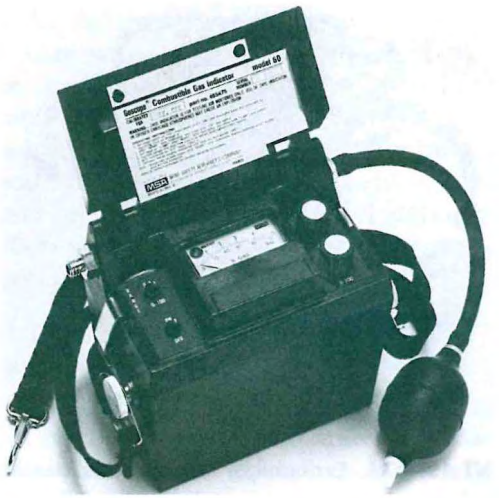
Mine Safety Appliances Company

Series 5000 instruments are designed to display gas concentrations from any number of the MSA combustible, toxic, and O_2 gas sensors. These instruments have a high density, yet are reliable and easy to install, start up, and maintain. All Series 5000 instruments provide a three-digit LED readout, three alarm levels, a malfunction indicator, and 4- to 20-mA outputs for each sensor. Sensors may be located up to 5000 ft from the instrument. Different models are available that will accept up to 2, 6, 12, or 24 sensors with NEMA 12 or NEMA 4X enclosures.

19-10-30. Gascope® Combustible Gas Indicator, Models 60 and 62

Mine Safety Appliances Company

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% to 5% and a high range of 0% to 100%. Model 62 is calibrated on pentane in air in a low range of 0% to 100% LEL and a high range of 0% to 100% by volume. 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. Sampling rate: 1.5 L/min. The Gascope may be used with MSA 3-ft probe tubes and rods. An external holder for charcoal cartridges at-



INSTRUMENT 19-10-30. Gascope® Combustible Gas Indicator, Models 60 and 62.

taches to sample line connection of the instrument. Gascope indicators can operate continuously for over 8 hrs on batteries. Silicon compounds may seriously impair response of the instruments. Leaded gasoline vapors can also poison the catalytic combustion filament; an inhibitor filter should be used to nullify this effect. Constant voltage power supply to filaments minimizes zero drift. Calibration: separate adjustment knobs for each measuring circuit of the changings of zero settings.

19-10-31. Methanometer

National Mine Service Company

The G-2000 Methanometer is a pocket-sized, handheld instrument for measuring the concentration of methane in air. The G-2000 is a diffusion-type methanometer. Gas is admitted to the sensor through two screened ports in the top of the instrument. An LED 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. The G-2000 is housed in a stainless steel case. MSHA certification: 8C–43. Display: LED chain (0% to 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.

10-10-32. D-Series Combustible Gas Systems

Scott Aviation

The D-Series are portable instruments that can detect most combustible gases or vapors in air. Two-scale instruments are available. One meter scale range employs catalytic filaments to indicate combustible gas concentration from zero to the LEL. The second scale operates on the thermal conductivity principle and indicates combustible gas or vapor concentration directly from 0% to 100% gas. The D-Series are equipped with aspirator bulb, neck strap, and eight D-cell batteries.

19-10-33. Hydrogen Sulfide Monitor, Model 10HS

Sierra Monitor Corporation

The Sierra Model 10HS monitor continuously measures the concentration of H_2S in the ambient air. Incorporated in the Model 10HS is a solid-state H_2S sensor, microprocessor, concentration display, operating controls, audible alarm, and rechargeable battery or AC power supply. Displays include present concentration, time-weighted average value for exposure on a single shift, or maximum concentration value sensed during a work period. Accessories supplied: earphone for high noise area, instruction manual, and instrument case. Battery gives 8- to 10-hr operation per charge. Device and alarm are intrinsically safe for use in hazardous locations. Operating temperature range: –20 to 40°C. Response time: 80% of full scale in 2 min. Zero drift: <3% of full scale in 8 hrs. Warm-up time: <5 min. 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, 4) time unit has been in operation, 5) test for checking operation function and audible alarm, 6) zero screw adjustment to display zero present concentration in fresh air (interior adjustment), and 7) calibration screw adjustment 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.

19-10-34. Model 2000 Portable Combustible Gas Detectors

Sierra Monitor Corporation

The Series 2000 detectors are ideal for gas detection in mines, manholes, tanks, natural gas fields, garages and vehicle maintenance facilities, utilities, testing of gas cylinder and new piping connections, etc. The units use solid-state, metal oxide sensors and operate in three different modes: 1) proportional mode — a continuous audible "tick" increases logarithmically as gas concentration rises, 2) low alarm mode — 250 ppm H_2 and 500 ppm CH_4, and 3) high alarm mode — 2500 ppm H_2 and 5000 ppm CH_4. Other features include an alarm for the upper range of gas concentration, an earphone for noisy operation, a 15-ft, 120-VAC power cable, an 18-in. flexible probe, replaceable batteries, and intrinsically safe for use in Class 1, Division 1, Groups B, C, and D. Warm-up time: 30 seconds. Response time: <1 second. Temperature range: –5 to 50°C. Battery life: 8-hrs continuous.

19-10-35. Model 102 Combustible Gas Analyzer

Teledyne Analytical Instruments

The Model 102 uses a catalytic bead sensor. Combustible gases present in the air burn in the presence of O_2, producing a signal proportional to the concentration of the combustible gases. Sample rate: diffusion when placed in air. Readout mode: integral meter with recorder output signal. 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.

INSTRUMENT 19-10-35. Model 102 Combustible Gas Analyzer.

Gas Chromatographic (GC) Analyzers

19-11-1. Organic Vapor Analyzer

Foxboro Company

Foxboro's Organic Vapor Analyzer is designed to measure trace quantities of organic materials in air using a hydrogen flame ionization detection system. It has a single logarithmically scaled readout from 1 to 100,000 ppm or with a 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. The instrument response is read on a hand-held meter assembly or can be read utilizing the external monitor signal. An audible detection alarm is provided; it can be preset to any desired level and has a frequency modulated tone that varies as a function of the signal level. The standard instrument includes an audible flame-out alarm, battery test indicator, and internal electronic calibration.

Standard accessories include instrument carrying and storage case, high pressure fuel filling hose assembly, and AC battery charger. Response time: <2 seconds. Sample flow rate: nominally 2 L/min. Fuel supply: 75-cm^3 tank of pure hydrogen at maximum pressure of 2300 psig, fillable while in case. Service life: hydrogen supply and battery power — 8 hrs operating time, minimum. The umbilical cord is 5 ft long with connectors for electrical cable and sample hose. In-line disposable and permanent particle filters are standard; activated charcoal filters are optional.

19-11-2. 300 Series Gas Chromatographs

HNU Systems, Inc.

The 300 Series gas chromatographs offer a range of compact versatility for environmental analysis of organic compounds. Five different detectors are available, including two detectors operational at once. Packed or capillary columns can be used, as well as a a wide range of isothermal or programmed temperatures. The units feature all the extras of a laboratory gas chromatograph, but in a rugged, compact package. Other options include a built-in printer and a choice of injectors.

19-11-3. MSI-301 Organic Vapor Monitor

Microsensor Systems, Inc.

The MS-301 Series Analyzers are designed for high sensitivity, onsite, continuous monitoring of organic vapors. The system contains an isothermal gas chromatograph, a sensitive solid-state sensor, and an onboard microcomputer for control and analysis. Carrier gas is generated by scrubbing ambient air through filters into a pressurized tank. Ambient air samples are collected on concentrator tubes and thermally heated and injected into the column. The system can be remotely controlled via a direct cable or a modem connection. The unit can be operated from 120 VAC or from an optional 12-VDC battery. Other features include ppb sensitivity, multicomponent analysis, self diagnosis, and a simple calibration procedure.

19-11-4. 10S Series Portable Gas Chromatographs

Photovac International, Inc.

The self-contained model 10S air analyzer can be used as a portable or fixed station monitor to provide multicomponent air analyses to the ppb level. The 10S utilizes a photoionization detector that can measure compounds not usually detected by photoionization such as chloromethanes, fluorochloromethanes, and ethane. Automatic sampling is accomplished using a miniature, printed circuit card upon which are mounted very small, three-way solenoid valves, chosen for their extreme reliability and long life. These valves are all under independent computer control and can be interconnected to produce a wide range of different chromatographies. The computer also handles the timing of different valve arrangements, controlling, calibrating, identifying, and quantifying chromatograms; runs the tiny printer/plotter; monitors temperature and battery charge; and provides an auto-zero function at the beginning of each analysis. Chromatography: dual-column, manual injection standard. Multifunction, 6-value (18-ports) option provides variety of gas chromatography arrangements; "quick-scan" and "analytical" columns and "precolumn backflush" are software selectable. A wide range of interchangeable columns is available. Sampling: manual injection or optional automatic injection, computer-controlled in-

ternal sampling pump with provision for connection of sampling line. Injection volumes can be software selectable. Carrier gas: normally, air is used but can use other carriers including NO, He, and CO_2. Rechargeable internal reservoir will last about 2 days. Calibration: manual or fully automatic (from portable standard vessel), depending on option chosen. Analysis time: depends on compound sought and any potential interferences. Display mode: internal or external chart recorder shows chromatograph trace and name compounds with concentrations and time-weighted averages (depending on which option is chosen). LCD gives 32 characters, alpha-numeric or bar graph for 10S10. Warm-up time: 5–10 min for most tasks.

19-11-5. SnapShot™ Hand-held Gas Chromatograph

Photovac International, Inc.

The SnapShot™ is designed for specific industrial and environmental monitoring tasks (e.g., benzene, C1–C5 hydrocarbons, and acrylonitrile). Weighing only 8.5 lbs and totally self-contained, the unit is truly hand-held. Single button operation with specific modules means little or no prior training is required. Features include a PID detector, isothermal capillary column, internal software for species identification, LCD readout, internal data logger, automatic injection and backflush, and direct downloading to a PC. A single snap-on lead acid battery allows for 8 hrs of operation and can be easily changed.

19-11-6. Scentograph "Plus II" Portable Gas Chromatograph

Sentex Systems, Inc.

The Scentograph is a portable gas chromatograph designed to provide onsite field analysis with laboratory gas chromatographic quality. Five detector options are available, along with a choice of commercially available columns, either capillary or packed. The units can be heated isothermally or ramped to temperatures up to 180°C. The unit has an internal battery and gas supply for total portability or can be connected to AC power for prolonged use. A detachable lap-top PC with applicable software controls the system and conducts the sample analysis, storing the results on disk for future recall.

19-11-7. Scentoscreen Portable Gas Chromatograph

Sentex Systems, Inc.

The Scentoscreen is a lighter, smaller version of the Scentograph (see Instrument No. 19-11.6) portable gas chromatograph. Not all options available on the Scentograph are available for the Scentoscreen.

TABLE 19-I-1. Electrical Conductivity Analyzers

Instrument No.	Mfg./ Supp.*	Model	Analytes	Range (ppm)	Detection Limit (ppm)	Precision (±)	Dimensions (cm) H	W	L	Weight (kg)	Power	Alarms Aud.	Vis.	Comments
19-1-1	AIC	411	Hg	0.001–1.999	0.001	5%	5.1	2.4	1.6	2.3	7.2 VDC or 110 VAC	—	—	F
19-1-2	BAC	MHO	H_2S, SO_2, NH_3	0–5, 10, 20 0–50, 100	—	—	3.9	4.7	2.4	6.8	115 VAC	X	X	A, B
19-1-3	CAL	U3S	SO_2		0.005	—	6.3	5.5	8.3	27.3	115 VAC	—	—	C, D
19-1-4	DVC	Series 9000	H_2S, Cl_2, CO_2, NH_3, SO_2, halogenated hydrocarbons	0–1	variable	2–5%	NEMA type wall enclosures			—	115 VAC	—	—	A, E

*Manufacturer codes given in Table 19-I-12.

A. H_2S converted to SO_2 in inlet.

B. Absorbs sample in distilled H_2O.

C. Absorbs sample in acidified H_2O_2 solution.

D. Converts SO_2 to H_2SO_4; temperature compensated.

E. Pyrolysis train on inlet for some analytes.

F. Collects a 1- or 10-second sample on a gold film sensor.

TABLE 19-I-2. Potentiometric Analyzers

Instrument No.	Mfg./ Supp.*	Model	Analytes	Range (ppm)	Detection Limit (ppm)	Precision (±)	Dimensions (cm) H	W	L	Weight (kg)	Power	Alarms Aud.	Vis.	Comments
19-2-1	AIM	200 Series 300 Series	O_2, CO, H_2S, SO_2, NO, NO_2, Cl_2, H, HCN, HCl, explosives	—	—	—	39.9 long × 6.4 diameter			1.0	battery	X	X	A, C, N
19-2-2	AIM	500 Series	O_2 H_2S CO combustible gases	0–25% 0–200 0–500 0–100% LEL	—	2.5% FS** 3% FS	19	10.2	6.4	1.4	Pb-acid battery	X	X	A, E, N, O
19-2-3	BAC	Sentinel® 44	O_2 combustibles CO H_2S	0-25% 0–100% LEL 0–999 0–200	—	—	19.7	11.4	5.1	1.1	Pb-acid battery	X	X	C, E
19-2-4	CAL	Mikrogas® Series	SO_2, HCl, H_2S, NH_3, Cl_2, $COCl_2$, COS, CS_2, HCN, etc.	0–1.0 and up	0.04	3% FS		—		—	VAC	X	—	A
19-2-5	CAL	Ultragas® Series	CO, CO_2, CH_4, NH_3, H_2S, SO_2, HCl, $COCl_2$, CKW, COS, CS_2, HCN	0–10 0–5000	0.1	1% FS		—		—	VAC	X	—	A
19-2-6	CEA	Gasman	O_2, H_2S, CO, SO_2, Cl_2, NO_2, NO, HCl, HCN, NH_3, combustibles	variable	variable	—	11.5	6.6	3.9	0.3	4 AA cells	X	X	A, N
19-2-7	CEA	Series U	CO, NH_3, organics, combustibles, Freons	0–250, 500, 100 or %LEL	variable	—	1.7	2.9	1.1	< 0.09	Ni–Cd	X	X	A, D
19-2-8.	CEA	TG-BA Series	Cl_2, H_2S, HCN, HCl, SO_2, $COCl_2$, halogens, NO_x, amines, NH_3, Freons	variable	variable	5%	3.1	3.1	5.1	5.9	110 or Ni–Cd	X	X	A
19-2-9	CEA	Triple Plus	same as Gasman	variable	variable	—	17	8	2	0.9	110 or Pb-acid	X	X	A, C, E, O
19-2-10	COS	XP-302IIE	O_2 combustibles H_2S CO	0–25% 0–100% LEL 0–30 0–100	—	0.7% 5% LEL 1.5 10	23	10.5	17.5	5.0	4-AA	X	X	A, C, M
19-2-11	DYM	O_2-25H	O_2	0–25%	0.5%	1%	1.0	2.0	0.8	0.4	—	X		A
19-2-12	DYM	Monoguard/ dynaMite	CO, H_2S, O_2, SO_2, NO	0–100, 500 100% (O_2)	—	1 ppm	2.0 1.3	1.2 0.9	0.4 0.6	0.3 0.2	9-V lithium 250 hr	X	X	A, B, E

TABLE 19-I-2 (con't.). Potentiometric Analyzers

Instrument No.	Mfg./ Supp.*	Model	Analytes	Range (ppm)	Detection Limit (ppm)	Precision (±)	Dimensions (cm) H	W	L	Weight (kg)	Power	Alarms Aud.	Vis.	Comments
19-2-13	EIT	Series 300	SO_2, NO_2, NO_x, H_2S	0–1, 10,000 analyte dependent	0.001 variable	1%	2.6	4.8	5.1	5.5	115–220 VAC	—	—	F
19-2-14	ENM	CGS Series	combustible gases O_2 deficiency	%LEL %vol	—	—	19.2	11.1	6.1	1.6	9.6-V battery	X	X	G
		Omni 4000	CO, H_2S, NH_3, SO_2, Cl_2, HCN, HCl, NO, NO_2, combustible gases, O_2 deficiency	—	—	—		—		—	battery	X	X	C, E
		Quad-400	CO H_2S CH_4 O_2	0–100 5–30 0–60% LEL 0–99.9%	—	—	19.7	14.0	6.6	1.7	7.2-V battery	X	X	A, C, M, O
19-2-15	ENM	Toximet Series	O_2, CO, H_2S, NO, H_2, NO_2, HCl, HCN, SO_2, Cl_2, NH_3	varies by analyte	—	1%	13	6.3	2.8	0.2	9-V alkaline	X	X	A
19-2-16	ENS	Ethylene Oxide Meter	ethylene oxide	0–100	0.1	—	11.4	6.1	2.5	0.1	9-V battery	X	—	A, B
19-2-17	GFG	Series G3000	CO, H_2S	0–200, 50	—	2–3%	1.5	0.9	0.6	0.2	Ni–Cd 100 hr	X	X	A, B
19-2-18	GFG	Polytector	CO O_2 combustibles	0–200, 5000 0–25% 0–5%, 100%	2 0.2% 0.1%	2 ppm 0.2% 1%	3.3	1.4	0.9	0.9	—	—	—	A, B, E
19-2-19	ISC	CO260	CO	0–1999	1		1.9	1.1	0.6	0.4 2.0	4 AA cells	X	X	A, B
19-2-20	ISC	TMX 410	combustibles CH_4, O_2, CO, H_2S NO_2, SO_2, Cl_2	0–100% LEL 0–5% vol 0–30% vol 0–999 0–99.9	0.1% 0.1% 0.1% 1, 0.1 0.1		12.1	7.0	5.0	0.7	Ni–Cd	X	X	A
19-2-21	ITS	Series 1000 & 4000	CO, SO_2, H_2S, Cl_2, NO, NO_2, hydrazines ClO_2, HCN, E_4O, HCHO	0.1–10 × TLV	2% FS	1% FS	2.9 17.8	2.4 10.2	4.5 22.5	3.6 2.0	Ni–Cd	X	X	A, C, E
19-2-22	ITS	Series 5000	CO, NO_2, H_2S, SO_2, Cl_2	0.1–10 times TLV	0.5%	2%	2.4	1.2	0.8	0.7	9V 125 hr	X	X	A, B, E

TABLE 19-I-2 (con't.). Potentiometric Analyzers

Instrument No.	Mfg./ Supp.*	Model	Analytes	Range (ppm)	Detection Limit (ppm)	Precision (±)	Dimensions (cm) H	W	L	Weight (kg)	Power	Alarms Aud.	Vis.	Comments
19-2-23	MCN	PhD Cannonball®	O_2, combustible gases, CO, H_2S, Cl_2, SO_2, NO_2, HCN	—	—	—	5.6	10.9	18.3	0.6	Pb-acid gel	X	X	E, N
19-2-24	MCN	Toxilog	CO, H_2S, SO_2, Cl_2, NO_2, NO, HCN, NH_3, HCl	vary by analyte	—	0.1 ppm	2.2	6.0	10.2	0.2	3-AAA alkaline	X	X	B, N
19-2-25	MDA	Formalde-meter	formaldehyde	0.3–99.9	—	15%	3.0	6.3	12	0.1	9V	X	X	A
19-2-26	MDA	Monitox	CO, Cl_2, N_2H_4, HCN, H_2S, $COCl_2$, SO_2	0–300 analyte dependent	variable	10%	10.5	6.2	2.4	0.15	Px-23 or Px-14 battery	X	X	A
19-2-27	MET	60	CO	0–1999	—	1%	15.0	7.8	4.8	0.9	AA Ni–Cd 120 VAC	X	X	A, B
		70	SO_2	0–1000, 50, 200, 400										
		80	NO_x	0–100, 50, 200, 400										
		90	H_2S	0–400, 5, 10, 25										
19-2-28	MET	PM-7000 Series	CO H_2S, SO_2, NO Cl_2, NO_2	0–1999 0–199.9 0–19.9	—	1%	7.6	10.2	2.3	0.3	9-V battery	X	X	A, E, G
19-2-29	MSA	MiniCO IV	CO	0–100, 250, 500	2	2%	—	—	—	—	—	X	X	A, B
19-2-30	MSA	Cricket	O_2, CO, H_2S, Cl_2	0–25% analyte dependent	2% FS	—	3.2	7.6	5	—	Ni–Cd	X	X	B, M
19-2-31	MST	MSTox 8600	AsH_3, CO, Cl_2, B_2H_6, H_2, HCl, HCN, H_2S, NO_2, O_2, $COCl_2$, PH_3, SiH_4	analyte dependent	—	—	9.3	4.7	2.1	0.1	battery	X	X	A, C
19-2-32	NDR	Ecolyzer Series 2000	CO	0–50, 100, 500, 600, 3000	0.5%	1%	2.8	5.1	2.8	4	Ni–Cd	—	—	A
19-2-33	NDR	210	CO	0–1999	1.0	1 ppm	2.1	1.3	0.5	0.34	9V	X	X	A, B
19-2-34	NDR	7100	NO NO_2	0–10, 50 0–2, 10		1–2%					Ni–Cd	X	X	A

TABLE 19-I-2 (con't.). Potentiometric Analyzers

Instrument No.	Mfg./ Supp.*	Model	Analytes	Range (ppm)	Detection Limit (ppm)	Precision (±)	Dimensions (cm) H	W	L	Weight (kg)	Power	Alarms Aud.	Vis.	Comments
19-2-35	NDR	Dualarm	combustible gases	0–99% LEL	—	5% LEL	18	8.5	4.5	0.7	Ni–Cd	X	X	A, C,
		Trialarm	O_2	0–25% vol		3%								E, N,
		Quadalarm	CO	0–999		3%								O
		Multi-Pac	H_2S	0–199		3%								
19-2-36	NEO	Exotox	O_2	0–25%	0.5%	2.5%	6	3.5	2.1	2	Ni–Cd	X	X	A, M
			CO	0–999	1									
			H_2S	0–999	1									
19-2-37	NEO	Neotox	O_2, CO, H_2S	0–35% O_2	0.1% O_2	1–2.5%	1.6	0.9	0.7	2.4	9V	X	X	A, C
				0–999	1						200–300 hr			
19-2-38	NEO	Minigas	flammable gases	0–99% LEL	—	2% LEL	4.2	7.2	16.2	0.8	Ni–Cd or	X	X	C
			O_2	0–25% vol		0.3%					4-AAA			
			CO	0–999		5								
			H_2S	0–499		2								
19-2-39	NEO	OTOX®												
		2002	CO	0–100	—	2.5%	23	13	7	2.0	12 VDC	X	X	A
		2003	H_2S, SO_2, Cl_2	0–2000		2.5%	20	13	9	1.3	120 VAC			
19-2-40	ORE	O3T	O_3	1–100 pph/vol	3 pphm/vol	3%	9.4	5.9	5.1	32	110 VAC	X	—	H
19-2-41	ORE	MSA-3	O_3	5 pphm–0.1% (v)	—	—	6.7	4.7	3.9	21	115 VAC	—	—	H, I
19-2-42	PRA	Titrilog II	oxidizable sulfur compounds (e.g. SO_2, H_2S)		0.01–0.02	—	5.6	5.6	8.3	30	115 VAC	—	—	J, K
19-2-43	SCA	S100 Series	combustibles	0–100% LEL	—	0–50%: 3% >50%: 10%	15.9	4.1	7.9	—	Ni–Cd	X	X	C
			O_2	0–25%		0.8%								
			H_2S	0–199		0–50: 5 >51: 5% FS								
19-2-44	SEN	Mini Monitor	H_2S, CO, O_2, NO_2, SO_2	0–10, 20, 100, 400, 40%	—	5%	11.8	2.4	7.6	0.2	AA (2) 100 hr	X	X	A, B, C
19-2-45	TEL	990	O_2, CO in flue gas	0–500, 100, 5, 25%	2%	5%	4.8	5.1	2.7	5	Ni–Cd	—	—	A, L, M

*Manufacturer codes given in Table 19-I-12.
**FS = full scale.
A. Electrochemical sensor.
B. Diffusion sampling.
C. Intrinsically safe.
D. Explosion-proof units available.
E. Data logger capabilities.
F. Uses temperature-compensated Faristor sensor.
G. Available in variety of fixed units.
H. Absorbing solution is potassium iodine.
I. Endpoint is a titration with sodium thiosulfate.
J. Cell reagent is KBr, where Br_2 is generated.
K. Liquid prefilters are required for some analytes.
L. Designed for combustion process measurements.
M. Separate sensors for CO and O_2.
N. A variety of sensors available.
O. Designed for confined space entry.

TABLE 19-I-3. Coulometric Analyzers

Instrument No.	Mfg./ Supp.*	Model	Analytes	Range (ppm)	Detection Limit (ppm)	Precision (±)	Dimensions (cm) H	W	L	Weight (kg)	Power	Alarms Aud.	Vis.	Comments
19-3-1	ADS	EA-1	Flammable toxic gases	ppm & % LEL	small concentrations	% of LEL	3.2	4.1	2.2	<4.5	90–120 VAC 190–240 VAC	—	—	A
19-3-2	BAC	Sentox	H_2S	0–50	3	3–10 ppm	4.1	2.7	2.6	3.2	Ni–Cd	X	X	B
19-3-3	BAC	K Series	O_2 combustibles	0–5, 25% O_2 0–1, 4, 100% LEL	0.5% O_2 0.01% LEL	0.1% —	1.2 1.6	1.7 2.2	2.3 3.0	1.3 2.6	battery	X	X	C, D
19-3-4	BAC	Sniffer® 103	O_2 combustibles	0–25% O_2 0–100% LEL	—	—	2.4	1.4	0.9	0.7	9V	X	X	C, D
19-3-5	BEC	946	trace acid base concentration	0–1, 10, 100	0.05	5%	11.8	11.8	4.7	wall mount	107–207 VAC 214–254 VAC	—	—	E
19-3-6	BEC	OM-11EA OM-11	O_2	0-5, 10, 25%	0.05%	1%	—	—	—	wall mount	115/230 VAC	—	—	F
19-3-7	BEC	950	O_3	0–0.025, 0.05, 0.1, 0.25, 0.5, 1.0, 2.5	0.001	1%	—	—	—	wall mount	115/230 VAC	X	—	G
19-3-8	BEC	952	NO, NO_2, NO_x	0.25, 0.5, 1.0, 2.5, 5, 10, 25	0.005	1%	—	—	—	wall mount	115/230 VAC	X	—	H
19-3-9	ESD	OX630	O_2	0–100%	—	1% FS**	15.3	8.9	3.8	—	9V		—	C, J
19-3-10	GAT	OX-80	O_2	0–50%	0.1%	—	2.2	1.2	0.4	0.4	Ni–Cd	X	—	C, J
19-3-11	GFG	G 3000 Microox®	O_2	0–25%	0.1%	0.5%	1.5	0.9	0.6	0.2	Ni–Cd	X	X	C, J
19-3-12	ISC	OX 231	O_2	variable	0.1%	—	1.9	1.1	0.6	0.5	4 AA cells	X	X	B, C, D, J
19-3-13	LSP	Scen-Trio	O_2, toxic gases, combustibles	variable	—	0.5%	3.1	0.8	2.0	1.4	Ni–Cd	X	X	C, J
19-3-14	LSP	LP-COM-19GR	O_2	0–50%	—	0.5%	0.5	1.4	2.4	0.5	Alkaline	X	X	
19-3-15	MDC	724-2 725-11 725-21	O_3 NO_2 Cl_2, F_2	0–100 pphm O_3 0–30 0–1.5	0.003 0.1 0.05					4.8	115 VAC			

TABLE 19-I-3 (con't.). Coulometric Analyzers

Instrument No.	Mfg./ Supp.*	Model	Analytes	Range (ppm)	Detection Limit (ppm)	Precision (±)	Dimensions (cm) H	W	L	Weight (kg)	Power	Alarms Aud.	Vis.	Comments
19-3-16	MDA	3300	O_2	0–100% 0–25%	—	2% FS	6 3.0	13 2.4	13 4.5	0.5	9V (2)	X	X	C K
19-3-17	MGP	8060/ 8061	O_2	0–40% vol	—	3%	12	6.6	2.9	0.3	2-AA Ni–Cd	X	—	C
19-3-18	MSA	245 245R 245RA	O_2	0–25%	2% O_2	1% FS	0.8 0.8 0.8	1.0 1.0 1.0	2.0 2.0 2.0	0.3 0.4 0.5	— — 2V alk.	— — X	— — —	C
19-3-19	MSA	Passport	CO, H_2S, SO_2, NO, NO_2, HCN, HCl, Cl_2	variable	variable	—	—	—	—	—	Ni–Cd	X X	X X	C, D, J
19-3-20	MSA	C	H_2S, HCN CO	0–50 0–100	— —	2% FS	3.1	2.4	1.4	3.6	120 VAC	— X	— X	L
19-3-21	PEI	PW 9700	SO_2, NO_2, NO, CO, H_2S, O_3	variable	0.005 NO_2, NO, SO_2, O_3 0.1 CO	2% FS	wall mount			22	110, 125, 200, 220, 240 VAC	—	—	M
19-3-22	TEL	Series 330	O_2	0–25%	—	0.25% O_2	4.0	2.4	1.5	1.7	4 C cells	—	—	C

* Manufacturer codes given in Table 19-I-12.
** FS = full scale.
A. Uses Cold Sensor™.
B. Metal oxide semiconductor sensor.
C. Electrolytic cell for oxygen.
D. Catalytic (platinum) sensor for combustibles.
E. Measures pH shifts and converts to ppm.
F. Designed to measure oxygen in vehicle emissions.
G. Uses chemiluminescent method based on reaction with ozone and ethylene.
H. Measures chemiluminescence of reaction of ozone with NO.
I. Uses electrochemical cell covered with SO_2 permeable membrane.
J. Diffusion sensor.
K. Nonspecific electrochemical sensors for oxidants.
L. Amperometric-type, two-electrode sensor.
M. Measuring modules are electrochemical but are specific for each pollutant of interest.
N. Electrochemical sensors for ambient and stack sampling.

TABLE 19-I-4. Ionization Detectors

Instrument No.	Mfg./ Supp.*	Model	Analytes	Range (ppm)	Detection Limit (ppm)	Precision (±)	Dimensions (cm) H	W	L	Weight (kg)	Power	Alarms Aud.	Vis.	Comments
19-4-1	CSI	HC5000	hydrocarbons	0–10, 50, 100, 500, 1000	0.1 CH_4	0.1 ppm CH_4	4.8	7.5	7.9	18.2	110 VAC	—	—	B
19-4-2	FOX	OVA	organic vapor	1–10^5	1		3.4	4.6	1.7	5.0	12 VDC batt. pack	X	—	A, B, D
19-4-3	GRI	OVA	many toxic vapors	1–80 ppb	1 ppb	—	14.5.	8	39	2.6	Ni–Cd	—	—	E, J, K
19-4-4	HNU	PI-101	organic vapor	0–20, 200, 2000	0.2 (benzene)	1% FS**	4.3	2.1	3.2	4.1	Ni–Cd 12 VDC	X	—	E, F
19-4-5	ITI	505 Leakmeter	SF_6, CCl_4, Freons	—	0.1 (Freons) 0.01 ppb (SF_6)	— 1%	43 45	39 40	23 75	14 10	110 VAC	X	—	H
19-4-6	MSA	Gas Corder	Volatile organic compounds	wide	variable	—	—	—	—	—	battery	—	—	E, F, I
19-4-7	PII	TIP™	organic vapor	0–2000	0.05 (benzene)	vary by element	45 long × 6.3 diameter			1.4	Ni–Cd	X	—	E, F
19-4-8	RAI	Series 400	total hydrocarbons	8 ranges 1–1000	0–4@ 10% scale US CH_4	1% FS	7.4	3.4	6.2	29.5	120 VAC	–	X	A, D
19-4-9	SCA	11-654	hydrocarbons	ppm-vol. % by element	< 2 benzene	1% FS	3.9	4.3	7.1	13.6	110 VAC	—	—	A, B
19-4-10	TEL	TAI 400	total hydrocarbons	10–1000	2 CH_4		6.3	6.7	3.5	—	110 VAC	—	—	A
19-4-11	TEI	580	organic vapors	0–2000	0.1 (benzene)	0.1 ppm (benzene)	7.6	22.8	25.4	3.75	—	X	X	A, B, E
		585		0–10000										
19-4-12	TEI	710	total hydrocarbons	0–20000	0.1	0.1 ppm	25	37	35	6.4	Ni–Cd	—	—	A, B, E
		712			1.0							X	—	
19-4-13	TEI	910	organic vapors	0–1000	0.1 (benzene)	—	23	43	46	11.8	110 VAC	X	X	F, G
19-4-14	THE	680	organic vapors	0–100 0–20000	0.5	0.1 ppm 1.0 ppm	31.8	29.2	6.6	5.1	battery 115/220 VAC	—	—	B, E
19-4-15	TRA	350F	total hydrocarbons	0.01–200	0.01	—	—	3.5	7.5	—	115 VAC	—	—	A, D

* Manufacturer codes given in Table 19-I-12.
** FS = full scale.
A. Temperature controlled.
B. Processor controlled.
C. Explosion proof.
D. Gas shutoff.
E. Portable units.
F. PID.
G. Designed for bench mounting.
H. Electon capture detector.
I. FID.
J. Detector uses ^{63}Ni radioactive source.
K. Designed as a leak detector.

TABLE 19-I-5. Infrared Photometers

Instrument No.	Mfg./ Supp.*	Model	Analytes	Range (ppm)	Detection Limit (ppm)	Precision (±)	Dimensions (cm)			Weight (kg)	Power	Alarms		Comments
							H	W	L			Aud.	Vis.	
19-5-1	ASP	5600	combustible gases	0–100% LEL	—	3%	2.8	2.8	2.6	5.5	110/220 VAC 12-VDC back-up	X	—	A
19-5-2	BEC	864/865	vehicle exhaust	0–100, 500, 1000 CO	—	1% FS**	3.4	5.2	8.8	22.7–27.3	110 VAC		—	B
19-5-3	BEC	866	CO	0–50	—	0.2 ppm	7.2	4.8	10.2	25.9	115 VAC		—	B, C
19-5-4	BKJ	1301	IR absorbing gases	4 orders of magnitude	10.1–10	1% FS	20.5	43	15	18	VAC		—	G
19-5-5	BKJ	1302	IR absorbing gases	5 orders of magnitude	0.01–1	1% FS	17.5	39.5	30	9	VAC or battery	X	X	G, H
19-5-6	CEA	RI-411A	CO_2	0–9950	50	2% FS	3.9	3.0	1.8	—	Ni-Cd 6-D cells 115-VAC adapter	X	—	D
19-5-7	CEA	RI-550A	CO, CO_2, CH_4, ethane, propane, butane, ethylene	—	1% FS	2% FS	3.1	3.4	5.0	9.5	110/220 VAC		—	E
19-5-8	FOX	MIRAN-I	gases that absorb between 2.5–14.5 μm	varies by gas <1 ppm–1%v	varies by gas most <1 ppm	2%	70	28	18	11.4	115/230 VAC		—	E
19-5-9	GAT	RI-413	Freon- R-11, 12, 113, 115, 502	0–9990 (R-11, R-12, R-22, R-502) 0–7900 (R-113) 0–4900 (R-114)	—	5% FS	3.9	3.0	1.8	3.0	Ni-Cd 115-VAC adapter	X	—	B, D
19-5-10	IIT	IR-702	many gases	—	—	1% FS		—		—	90–130 VAC		—	B
19-5-11	IIT	IR-711	hydrocarbons	0–100% LEL (JP-5) 0–1000 ppm	—	2%		—		4.1	—		—	B
19-5-12	MSA	3000	CO, CO_2, SO_2, fluorocarbons, hydrocarbons, etc.	application dependent	application dependent	0.5% FS	8.4	3.7	2.7	20.0	105/220 VAC		—	B

TABLE 19-I-5 (con't.). Infrared Photometers

Instrument No.	Mfg./ Supp.*	Model	Analytes	Range (ppm)	Detection Limit (ppm)	Precision (±)	Dimensions (cm) H	W	L	Weight (kg)	Power	Alarms Aud.	Vis.	Comments
19-5-13	NEO	OTOX® CO_2 Monitor	CO_2	0–1999	—	5% FS	19	9.5	17	0.4	12 VDC 120 VAC	X	X	
19-5-14	RAI	800 Series	CO, CO_2, NO hydrocarbons	—	—	1% FS		—		—	150/230 VAC	—		
19-5-15	SKC	765-203	CO_2	0–40%	—	5% FS	9.5	18.4	7.6	0.6	4-D batteries	—		D

*Manufacturer codes given in Table 19-I-12.
**FS = full scale.
A. Dual wavelength.
B. Dual beam.
C. Model available for vehicle exhaust and bag sampling.
D. Microprocessor controlled.
E. Specified vapor analyzer available.
F. MOD202X suitable for Class I, Groups B, C, D.
G. Utilizes FTIR photoacoustic spectroscopy.
H. Measures up to five gases simultaneously.

TABLE 19-I-6. Ultraviolet and Visible Light Photometers

Instrument No.	Mfg./ Supp.*	Model	Analytes	Range (ppm)	Detection Limit (ppm)	Precision (±)	Dimensions (cm)			Weight (kg)	Power	Alarms		Comments
							H	W	L			Aud.	Vis.	
19-6-1	BAC	MV-2	Hg vapor	0.02, 1.0 mg/m^3	0.01 mg/m^3	5% FS**	4.5	1.9	1.7	2.7	12 V Ni-Cd			A, B
19-6-2	BAR	AISI	SO_2	1.0–500, 2000, 40,000	2 or 40 ppm meters	—		—		45.5	battery or 115 VAC		—	B
19-6-3	BEC	K-23B	Hg vapor	0–0.1, 1.0 mg/m^3	0.2% FS	10%	5.1	3.3	1.8	7	115 VAC		—	B
19-6-4	CEA	TGM 555	SO_2, NO_2, NO_x, NH_3, Cl_2, TDI, HCHO, HCN, halides, oxidants	variable 0–0.25, 10	0.025–SO_2	1%	4.7	7.9	2.2	11.4	12 VDC		—	G
19-6-5	DEC	1003	O_3	0.01–9.99	0.01	2%	2.0	5.9	7.3	20.5	115–130 VAC		—	B
19-6-6	DUP	460 461	SO_2, NO_2, NO_x NO_x	0–200, 100% SO_2 or NO_2 0–150, 100% NO_x	4 SO_2/NO_2	1% FS		—		—	115 VAC		—	B, C, E
19-6-7	GMD	Autostep® plus	TDI, MDI, HDI, Cl_2, hydrides, HF, HCl, IPDI, hydrazines, phosgene	varies by analyte	—	15%	21.7	9.8	24.4	2.2	—	X	—	H
19-6-8	MDC	727-3	O_3	0–9.99	0.02	1%	4.3	2.4	9.1	6.8	115 VAC		—	B
19-6-9	RAI	890	SO_2	0–50, 50000	—	≤ 0.1		—		—	115/230 VAC		—	
19-6-10	SSI	38	Hg and organic vapors	0–0.1 mg/m^3	0.01 mg/m^3	5%	1.2	1.6	6.7	3.6	120 VAC		—	A, B, D

*Manufacturer codes given in Table 19-I-12.
**FS = full scale.
A. Organic vapors may interfere.
C. Designed for Class I, Group D.
D. Dual beam.
E. Visible absorption.
F. Utilizes second-derivative spectroscopy in UV and visible spectrum.
G. Liquid reagents required.

TABLE 19-I-7. Chemiluminescent Detectors

Instrument No.	Mfg./ Supp.*	Model	Analytes	Range (ppm)	Detection Limit (ppm)	Precision (±)	Dimensions (cm)			Weight (kg)	Power	Alarms		Comments
							H	W	L			Aud.	Vis.	
19-7-1	BEC	950A	O_3	0–0.025 to 25 (7 ranges)	0.01	2% FS**	3.4	7.5	8.4	—	105–125V		—	A, B
19-7-2	BEC	952A	NO, NO_2, NO_x	0–0.25 to 25 (7 ranges)	0.01	0.005 ppm	3.4	7.5	8.4	—	105–125V	X	—	A, C, D
19-7-3	CSI	1100	O_3	0–1, 5, 10	0.01 pphm	1% FS	4.1	6.7	6.9	18.2	105–125 VAC		—	A, B
19-7-4	CSI	530 R	NO, NO_2, NO_x	0–0.1, 0.25, 0.5, 1.0, 5	0.004	0.002 ppm	4.8	6.7	7.9	27.3	105 VAC 130 VAC	X	—	A, C, D
19-7-5	CSI	325-2R 04350-2R	O_3	0–0.1, 0.5, 1.0, 5, 10	0.001	0.001 ppm	4.8	6.7	7.9	18.2	105–125 VAC		—	A, B
19-7-6	RAI	900 Series	NO, NO_2	0–10, 25, 100, 250, 2500, 10,000	—	0.1 ppm		—		—	—		—	

*Manufacturer codes given in Table 19-I-12.
**FS = full scale.
A. Intended for unattended operation.
B. Uses chemiluminescent reactions of O_3 with ethylene as basis for detection.
C. Uses chemiluminescent reaction of NO with ozone as basis for detection.
D. NO_2 converted to NO for analysis.

TABLE 19-I-8. Photometric Analyzers

Instrument No.	Mfg./ Supp.*	Model	Analytes	Range (ppm)	Detection Limit (ppm)	Precision (±)	Dimensions (cm) H	W	L	Weight (kg)	Power	Alarms Aud.	Vis.	Comments
19-8-1	BAC	US400	CO	0–5	0.1 ppm/mv	—	panel mounted			15.9	115V ± 10		—	A, C
19-8-2	BEC	DIF 7000	CO	0–20, 50, 100, 200	0.1	1% FS**	2.2	6.7	6.6	14.5	115 VAC ± 10%		—	B, C
19-8-3	BEC	953	SO_2	0.25, 0.5, 1.0, 2.0	0.004	0.003 ppm	4.8	7.5	8.7	40.9	105–125 VAC		—	C, D
19-8-4	CSI	SA 285	sulfur compounds	0–50, 100, 500, 1000 ppb	1% FS	1% FS	4.8	6.7	7.9	22.7	115 ± 10 VAC	X	—	C
19-8-5	CSI	SA 700	SO_2	0–250, 500, 1000, 5000, 10,000 ppb	5 ppb	2% FS	4.8	6.7	7.9	20.0	105–130 VAC 220 VAC		—	C, F
19-8-6	CSI	PA 460	phosphorus gas	0.001–10	0.001	19 (460)	7.5	4.8	7.9	18.2	115 VAC		—	C
		PA 465				20 (465)	3.5	3.9	6.3	9.1	external 115 VAC internal 12 VDC			E
19-8-7	FLM	533	H_2S	—	0.1	—	3.1	2.4	1.2	1.8	9.6-V battery	X	X	H
19-8-8	GAT	Halide	halogenated compounds	1000–10,000	50–100	3%	4.3	2.8	2.8	5.9	120/130 VAC		—	G
19-8-9	HAI	722AEX-A	H_2S	0–100	1	3%	8.3	5.1	5.1	27.3	—	X	—	H
19-8-10	MDA	Miniguard	H_2S, $COCl_2$, TDI, Cl_2, SO_2, NH_3	variable	variable fraction of TLV	—	2.0	0.5	1.0	0.3	3-AA	X	—	H, I
19-8-11	MDA	TLD-1	amines, halides, CO_2, diisocyanates, hydrazines, hydrides, HCN, H_2O_2, H_2S, mineral acids, NO_2, O_3, $COCl_2$, SO_2	ppb-ppm	analyte dep	± 5%@TLV	16.5	21.2	17.7	3.4	110/220 VAC or Pb-acid battery	X	X	H,J
19-8-12	MDA	Series 7100	ibid	ppb-ppm	analyte dep	± 5%@TLV	16.5	43.2	45.7	20.4	115/230 VAC	X	X	H, C
19-8-13	SCA	Halide	halogenated hydrocarbons	0–500	10	10%	6.3	3.8	5.9	15.9	110 VAC		—	G

TABLE 19-I-8 (con't.). Photometric Analyzers

Instrument No.	Mfg./ Supp.*	Model	Analytes	Range (ppm)	Detection Limit (ppm)	Precision (±)	Dimensions (cm) H	W	L	Weight (kg)	Power	Alarms Aud.	Vis.	Comments
19-8-14	TRA	271 HA	sulfur compounds	0–100 ppb < 0–1	4 ppb	< 1%	3.5	7.5	9.4	27.3	115 V	—		C, H

*Manufacturer codes given in Table 19-I-12.
**FS = full scale.
A. Sensors employ analysis of mercury vapor by UV absorption which is generated by oxidation of CO with mercury oxide.
B. Utilizes dual-isotope fluorescence detection.
C. Intended for unattended operation.
D. Utilizes SO_2 fluorescence reaction with UV light for detection.
E. Uses flame photometric detector.
F. Uses SO_2 absorption of UV light.
G. Utilizes increased spectral enhancement of an AC spark by a halogen for detection.
H. Utilizes automatic paper tape sampler.
I. Designed as personal monitoring system.
J. Portable models.

TABLE 19-I-9. Thermal Conductivity Detectors

Instrument No.	Mfg./ Supp.*	Model	Analytes	Range (ppm)	Detection Limit (ppm)	Precision (±)	Dimensions (cm) H	W	L	Weight (kg)	Power	Alarms Aud.	Vis.	Comments
19-9-1	BEC	7-C Series	H_2, Ar, O_2	vary by analyte 0–500 H_2	vary by analyte	2% FS**	7.2	6.0	4.4	—	220 115 VAC	—	—	A, B
19-9-2	DET	Analograph	H_2, He, O_2, CO, CO_2, CH_4, C_2H_6, C_2–C_6 hydrocarbons	vary by analyte	vary by analyte	—	2.8	5.3	5.7	11.4	110 VAC	—	—	C
19-9-3	MGP	Leak Hunter 8065	nonflammable gases	—	He: 1×10^{-5}; CO_2: 3.5×10^{-5}; Freon 12: 1.2×10^{-5}; cc/sec leak rate	—	1.4	3.9	5.5	2.3	4 × 1.5 V dry cell or Ni-Cd	X	X	D

*Manufacturer codes given in Table 19-I-12.
**FS = full scale.
A. Explosion proof available.
B. Corrosion-resistant cells.
C. A separate Servocorder available.
D. Designed for leak detection, not quantification.

TABLE 19-I-10. Heat of Combustion Detectors

Instrument No.	Mfg./ Supp.*	Model	Analytes	Range (ppm)	Detection Limit (ppm)	Precision (±)	Dimensions (cm) H	W	L	Weight (kg)	Power	Alarms Aud.	Vis.	Comments
19-10-1	AIM	Logic 100 Series	O_2, CO, H_2S, SO_2, NO, NO_2, Cl_2, HCN, HCl, explosive gases	—	—	—	39.9 long 6.4 diameter			1.0	battery	X	X	B, G
19-10-2	BAC	Gas-Pointer® II	combustible gas CO	0–99% LEL 5–99% gas 0–500	—	0.25% 3% 10 ppm	20.6	9.4	5.6	0.9	Ni-Cd	—		A, H, N
19-10-3	BAC	Gastron 282 310	combustible gases	hydrocarbons: 0–500; H_2: 0–25	hydrocarbon: 50; H_2: 10	—	—	—	—	1.9	Ni-Cd	X	X	A
19-10-4	BAC	Sniffer® 500 Series	O_2 deficiency H_2S, CO, combustible gases	O_2: 0–25%; H_2S: 0–100; CO: 0–500; combustibles: 0–10,000	variable	5% FS**	3.0	3.9	2.5	4.3	6 VDC Pb-acid	X	X	A, H
19-10-5	BAC	Super Sniffer®	combustible gases and vapors	0–1000 0–100% LEL	variable	5% FS	1.2	2.4	3.0	3.1	Ni-Cd	—	—	A
19-10-6	BAC	TLV Sniffer®	combustible vapors	0–100, 1000 0–100% LEL	3	5% FS	22.8	9.5	16.8	2.3	Ni-Cd 6 size D	X	—	A
19-10-7	BAC	Ultra I & II	combustible gases and vapors	0–20% LEL 0–100% LEL	—	5% FS	3.3	1.1	2.3	1.4–1.6	4 size D	—	—	A, M
19-10-8	CHI	12	combustible gases	—	1	—	2.3	1.0	0.6	0.5	6 or 12 VDC Ni-Cd	X	—	B, C
19-10-9	COS	XP-316	combustible gases	5 ranges	—	5% FS	19	8.4	4.0	0.7	4-AA	X	X	A, G, N
19-10-10	COS	XP-704	Freon	—	2.1×10^{-5} atm cm^3/sec	—	15.7	6.9	3.3	0.4	4-AA	X	X	I, N
19-10-11	DVC	1000 Series	CO	0–500	—	2% FS	—	—	—	—	115 VAC 220 VAC	—	X	A
19-10-12	DVC	5000 Series	combustible gases and vapors	0–100% LEL	—	3% FS	—	—	—	—	—	—	X	A, D
19-10-13	DYM	LCD combo	combustible gases, O_2 deficiency	0–100% LEL	—		2.8	1.6	1.2	1.4	5 size C	—	—	A, H
19-10-14	DYM	ABL-50	CO	2–50	2	10% FS	5.1	5.5	2.2	7.3	110 VAC 12 VDC	X	X	E, F

TABLE 19-I-10 (con't.). Heat of Combustion Detectors

Instrument No.	Mfg./ Supp.*	Model	Analytes	Range (ppm)	Detection Limit (ppm)	Precision (±)	Dimensions (cm) H	W	L	Weight (kg)	Power	Alarms Aud.	Vis.	Comments
19-10-15	EEC	03 HCS	combustible gases	0–100% LEL	—	—	3.1	0.7	1.2	0.8	2 size D	—	—	A, G
		05 HCS	and vapors	0–10, 100% LEL	—	—	3.5	1.1	1.4	1.1	2 size D	X	—	A, D, G
		06 HCS		0–100%	—	—	2.3	2.5	1.4	1.8	8 size D	—	—	A
		07 HCS		0–1000 0–100% LEL	—	—	3.5	1.1	1.2	—	Ni-Cd or 110 VAC	X	—	A, D
19-10-16	ENM	EX-10	combustible hydrocarbons	0–100% LEL	—	5%	4	6	18	0.5	Ni-Cd or 110/220 VAC	X	X	A
19-10-17	GAT	GX-3A	O_2 deficiency combustible gases	0–25% 0–100% LEL 0–1000	—	5% FS	4.3	2.8	2.2	5.5	6 size D Ni-Cd	X X	X X	A, H
19-10-18	GFG	Exotector®	combustible gases	0–10% LEL 0–100% LEL	variable 0.1–5% LEL	2% LEL	2.0	1.4	0.8	0.6	Ni-Cd	X	X	A, D or F, G, M
19-10-19	HRD	647	combustible gases	0–5% comb. 0–10% comb. 0–100% LEL	0.25% LEL	1% FS	5.0	3.8	3.5	—	115 VAC	—	X	A
19-10-20	HAI	510	combustible gases	0–100%	—	5% FS	2.0	2.8	3.1	5.5	115 VAC	X	—	A, G
19-10-21	ISC	CD212	CH_4	0–5% by volume	0.1% by volume	—	1.9	1.1	0.6	0.5	5 V Ni-Cd	X	—	A, D
19-10-22	LSP	Gasponder® I-IV	combustibles O_2, CO, H_2S	CH_4: 0–100% LEL CO: 0–400 H_2S: 0–100 O_2: 0–30%	variable	CH_4: 5% LEL CO: 2% H_2S: 2% O_2: 0.5%	1.1	2.1	3.0	1.4–1.8	battery	X	X	A, H
19-10-23	MAC	RCM	CO	0–100, 500	10	10–25%	0.6	1.1	2.0	0.5	Ni-Cd or 120 VAC	–	X	B
		REM	EtO	0–50, 250	5									
19-10-24	MAC	RGM	combustible gases	0–1, 5%	100	10–25%	0.5	1.1	2.0	0.5	Ni-Cd			
19-10-25	MCN	Gasurveyor 1000	hydrocarbons	0–1000; 0–10%, 100% LEL; 0–100% vol%	10	5%	18	9.5	10.5	1.6	4-D batteries	X	X	G
19-10-26	MGP	8057	Cl_2, AsH_3, H_2, H_2S, PH_3, etc.	—	vary by analyte	—	1.1	2.4	0.5	0.4	4 size AA Ni-Cd	X	X	B, I

TABLE 19-I-10 (con't.). Heat of Combustion Detectors

Instrument No.	Mfg./ Supp.*	Model	Analytes	Range (ppm)	Detection Limit (ppm)	Precision (±)	Dimensions (cm) H	W	L	Weight (kg)	Power	Alarms Aud.	Vis.	Comments
19-10-27	MSA	260 100	combustible gas and O_2	0–100 LEL O_2 0–20% vol.	—	5% FS comb. 2% FS O_2	2.8	3.9	1.5	3.2	2.4 VDC battery pack	X	X	A, H, J
19-10-28	MSA	Explosi-meter® 2A	combustible gas	0–100% LEL	2% LEL	5% FSD	1.3	2.1	2.2	1.8	6 size D cells	—	—	A
19-10-29	MSA	Series 5000	combustible gas	0–100% LEL	—	2%	2.4	5.6	5.3	—	105, 115, 230 VAC	X	X	A, K
19-10-30	MSA	Gascope; Model 60, 62	combustible gases	0–5, 100% CH_4 (vol) 0–100% LEL	—	15% FC	2.6	2.9	1.6	2.3	8 ZnC	—	—	A, L, M
19-10-31	NMS	G-2000	CH_4	0–2% CH_4	—	—	0.8	1.5	0.5	0.3	3.6 VDC Ni-Cd	—	—	A, D
19-10-32	SCA	D Series	combustible gases	% LEL % gas	—	—		—		—	8 size D cells	—	—	
19-10-33	SMC	10HS	H_2S	0–50	—	—	3.0	1.5	0.7	0.7	Ni-Cd	X	—	B, F, G, N
19-10-34	SMC	2000 Series	combustible gases	H_2: 100–5000 CH_4: 200–20,000	H_2: 80 CH_4: 150	—	10.6 × 8 round			0.7	120 VAC	X	—	B, G
19-10-35	TEL	102	combustible gases	0–100% LEL	—	0.5% FSD	1.4	3.7	2.8	3.2	115 VAC	—	—	A, D

*Manufacturer codes given in Table 19-I-12.
**FS = full scale.
A. Heated catalytic combustion sensor.
B. Metal oxide semiconductor sensor.
C. No meter readout; uses rate of clicking relative to concentration.
D. Diffusion sampler.
E. Airline monitor.
F. Continuous line monitor - auto reset.
G. Intrinsically safe for Class I, Groups B, C, D (GG-groups B & D).
H. Electrochemical cell for O_2 deficiency.
I. Designed as leak detector.
J. Model 100, combustible gas only.
K. Explosion-proof model available.
L. Silicon compounds interfere.
M. Thermal conductivity detector for use in absence of oxygen.
N. Models with multiple sensors contained in Table I-19-2.

TABLE 19-I-11. Gas Chromatograph Analyzers

Instrument No.	Mfg./ Supp.*	Model	Analytes	Range (ppm)	Detection Limit (ppm)	Detectors	Dimensions (cm) H	W	L	Weight (kg)	Power	Alarms Aud.	Vis.	Comments
19-11-1	FOX	OVA 128	Organics	0–10,000, 1000	—	FID	13	23	30.5	5.5	Pb-acid	X	—	A, B
19-11-2	HNU	300 Series	Organics	1, 10, 100 (0–1V)	—	FID, PID, ECD, TCD, FPD	26.7	35	28 (Model 301)	11.3	110/230 VAC	—	—	D
19-11-3	MSI	MSI-301	Organics	1 ppb–100 ppm	1 ppb	Solid State	9	37	33	5.5	110 VAC 12 VDC	—	—	C, F
19-11-4	PII	10S Series	Organics	wide	0.1 ppb (benzene)	PID	16	46	34	11.8	battery 110/220 VAC 10–18 VDC	X		C
19-11-5	PII	Snapshot	Organics	wide	0.1 ppb (benzene)	PID	23	12.7	35.6	3.7	Pb-acid	X		C
19-11-6	SST	Scento/ graph Plus II	Organics	0.1–2000 ppm	0.1 ppm	PID, AID, MAID, ECD, TCD	15.2	52	50.8	24	12 VDC 110 VAC	X	—	A, C, E
19-11-7	SST	Scento/ screen	Organics	0.1–2000 ppm	0.1 ppm	PID, AID, MAID, ECD, TCD	16.5	34.2	49.5	10.7	12 VDC	X	—	C, E

*Manufacturer codes given in Table 19-I-12.

A. Intrinsically safe, Class I, Division I, Groups A, B, C, D.

B. Has continuous, direct-reading capabilities.

C. Designed for portable operation.

D. Designed for mobile and environmental laboratories.

E. Can be remotely operated; contains calibration sequence.

F. 12-V battery optional.

TABLE 19-I-12. List of Instrument Manufacturers

ADS	Adsistor Technology, Inc. Box 51160 Seattle, WA 98115
AIM	AIM USA P.O. Box 720540 Houston, TX 77272-0540
AIC	Arizona Instrument Corp. P.O. Box 1930 Tempe, AZ 85280
ASI	Astro International Corporation 100 Park Avenue League City, TX 77573
BAC	Bacharach, Inc. 625 Alpha Drive Pittsburg, PA 15238 (412)963-2160
BAR	Barringer Research, Ltd. 304 Carlingview Drive Rexdale, Ontario Canada M9W 5G6
BEC	Beckman Instruments, Inc. Process Instruments Division 2500 N. Harbor Boulevard Fullerton, CA 92634
BIO	Biosystems, Inc. 5 Brookside Road Middlefield, CT 06455
BKJ	Bruel & Kjaer Instruments, Inc. 185 Forest Street Marlborough, MA 01752
CEA	CEA Instruments, Inc. 16 Chestnut Street Box 303 Emerson, NJ 07630-0303 (201)967-5660 FAX (201)967-8450
COS	COSMOS Gas Detection Systems P.O. Box 70498 Seattle, WA 98107
CAL	Calibrated Instruments, Inc. 200 Saw Mill River Road Hawthorne, NY 10532 (914)741-5700 or (800)969-2254 FAX (914)741-5711
CAS	Casella London Limited Regent House, Britannia Walk London, N1 7ND, England
CHE	Chestec, Inc. P.O. Box 10362 Santa Ana, CA 92711
CSI	Columbia Scientific P.O. Box 203190 Austin, TX 78720 (512)258-5191
DEC	Dasibi Environmental Corp. 515 W. Colorado Street Glendale, CA 91204
DET	Deutsch Engineering & Testing Services P.O. Box 389 Monsey, NY 10952
DVC	Devco Engineering, Inc. Control Systems Division 36 Pier Lane West Fairfield, NY 07006
DUP	DuPont Company Instrument Products Division Wilmington, DE 19898
DYM	Dynamation Incorporated 3784 Plaza Drive Ann Arbor, MI 48108
ETI	EIT 251 Welsh Pool Road Exton, PA 19341
ENM	ENMET Corp. 2308 S. Industrial Way P.O. Box 979 Ann Arbor, MI 48106-0979 (313)761-1270
EEC	ERDCO Engineering Corp. P.O. Box 1310 Evanston, IL 60204
EDW	Edmont-Wilson Division of Becton Dickinson & Company 1300 Walnut Street Coshocton, OH 43812
EIT	Eitel Manufacturing, Inc. 33208 Paseo Cerveza, Unit G San Juan Capistrano, CA 92675
ESD	Engineering Systems and Design 119A Sandy Drive Newark, DE 19713
ENS	Environmental Sensors Co. 4901 North Dixie Highway Boca Raton, FL 33431
ERI	Ericson Instruments P.O. Box 226 Ossining, NY 10562
FLM	Fleming Instruments, Ltd. Caxton Way, Sevenage Hertfordshire, England
FOX	Foxboro Company Foxboro, MA 02035
GCI	G.C. Industries, Inc. 49050 Milmont Drive Fremont, CA 94538
GFG	GfG Gas Electronics, Inc. 6617 Clayton Rd. Suite 209 Title Bldg. St. Louis, MO 63117
GMD	GMD Systems, Inc. (A Bacharach affiliate) Old Route 519 Hendersonville, PA 15339 (412)746-3600
GAT	GasTech, Inc. 8445 Central Avenue Newark, CA 94560-3431
GMI	General Monitors, Inc. 26776 Simpatica Circle El Toro, CA 92630
GRI	Graseby Ionics Odhams Trading Estate St Albans Road Watford, Herts, UK WD2-5JX
HNU	H-Nu Systems, Inc. 160 Charlemont Street Newton, MA 02161
HRD	Hayes-Republic Division Corp. 3695 Interstate Parkway Riviera Beach, FL 33404
HAI	Houston Atlas, Inc. 9441 Baythorne Drive Houston, TX 77041-7709
ISC	Industrial Scientific 1001 Oakdale Drive Oakdale, PA 15071
ITS	Interscan Corp. P.O. Box 2496 Chatsworth, CA 91313
ITI	Ion Track Instruments, Inc. 340 Fordham Rd. Wilmington, MA 01887
III	Infrared Industries, Inc. 1424 North Central Park Ave. Anaheim, CA 92802

TABLE 19-I-12 (con't.). List of Instrument Manufacturers

LAT	Lagus Applied Technology, Inc. 11760 Sorrento Valley Road, Suite M San Diego, CA 92121
LER	Lear Siegler Environmental Technology Division 74 Inverness Drive East Englewood, CO 80112
LSP	Lumidor Safety Products 11221 Interchange Circle S Miramar, FL 33025
MDA	MDA Scientific, Inc. 405 Barclay Boulevard Lincolnshire, IL 60069 (708)634-2800 or (800)323-2000 FAX (708)634-1371
MST	MST Measurement Systems, Inc. 327 Messner Drive Wheeling, IL 60090
MAC	Macurco, Inc. 3946 S. Mariposa Street Englewood, CO 80110
MDC	Mast Development Company 2212 East 12th Street Davenport, IA 52803
MGP	Matheson Gas Products 30 Seaview Drive P.O. Box 1587 Secaucus, NJ 07096 (201)867-4100
MCN	McNeill International 37914 Euclid Ave. Willoughby, OH 44094
MET	Metrosonics, Inc. General Products Division P.O. Box 23075 Rochester, NY 14692
MSI	Microsensor Systems, Inc. 62 Corporate Court Bowling Green, KY 42103-4147
MSA	Mine Safety Appliances Company P.O. Box 427 Pittsburgh, PA 15230 (412)776-8600 or (800)MSA-INST FAX (412)776-3280
NDR	National Draeger, Inc. 101 Technology Drive P.O. Box 120 Pittsburgh, PA 15230 (412)787-8383/8389 or (800)MSA-INST FAX (412)787-2207 or (800)922-5519
NMS	National Mine Service Company 600 N. Bell Avenue Carnegie, PA 15106
NEO	Neotronics P.O. Box 370 2144 Hilton Drive, S.W. Gainesville, GA 30503
ORE	Ozone Research and Equipment Corp. 3840 North 40th Avenue Phoenix, AZ 85019
PEI	Phillips Electronics Instruments 85 McKee Drive Mahwah, NJ 07430
PII	Photovac International, Inc. 739B Park Avenue Huntington, NY 11743
PRA	Process Analyzer, Inc. 3 Headly Place Fallsington, PA 19054
RAI	Rosemount Analytical, Inc. 600 South Harbor Blvd. La Habra, CA 90631 (310)690-7600 or (800)441-7245 FAX (310)690-7127
SKC	SKC West, Inc. P.O. Box 4133 Fullerton, CA 92634
SCA	Scott Aviation 225 Erie Street Lancaster, NY 14086
SEN	Sensidyne, Inc. 16333 Bay Vista Dr. Clearwater, FL 34620 (813)530-3602 or (800)451-9444
SST	Sentex Sensing Technology 553 Broad Ave. Ridgefield, NJ 07657
SMC	Sierra Monitor Corp. 1991 Tarob Court Milpitas, CA 95035
SSI	Sunshine Scientific Instruments 1810 Grant Avenue Philadelphia, PA 19115
TEL	Teledyne Analytic Instruments 16830 Chestnut Street City of Industry, CA 91749-1580
TEI	Thermo Electron Instruments 108 South Street Hopkinton, MA 01748
THE	Thermo Electron Instruments, Inc. 8 West Forge Parkway Franklin, MA 02038
TRA	Tracor, Inc. Analytical Instruments Division 6600 Tracor Lane, Building 27 Austin, TX 78725
WPD	Western Precipitation Division 4565 Colorado Boulevard Los Angeles, CA 90039
XON	XonTech, Inc. 6862 Hayvenhurst Avenue Van Nuys, CA 91406

Air Sampling Instruments

for evaluation of atmospheric contaminants

8th Edition
1995

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Beverly S. Cohen
Susanne V. Hering

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