

United States
Environmental Protection
Agency

Office of Emergency and
Remedial Response
Emergency Response Division

Environmental
Response
Team



Air Monitoring for Hazardous Materials

Environmental Response
Training Program



FOREWORD

This manual is for reference use of students enrolled in scheduled training courses of the U.S. Environmental Protection Agency (EPA). While it will be useful to anyone who needs information on the subjects covered, it will have its greatest value as an adjunct to classroom presentations involving discussions among the students and the instructional staff.

This manual has been developed with a goal of providing the best available current information; however, individual instructors may provide additional material to cover special aspects of their presentations.

Because of the limited availability of the manual, it should not be cited in bibliographies or other publications.

References to products and manufacturers are for illustration only; they do not imply endorsement by EPA.

Constructive suggestions for improvement of the content and format of the manual are welcome.

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AIR MONITORING FOR HAZARDOUS MATERIALS

(165.4)

5 Days

This course instructs participants in the practices and procedures for monitoring and sampling airborne hazardous materials. It is designed for personnel who evaluate releases of airborne hazardous materials at hazardous waste sites or accidental hazardous material releases.

Topics that are discussed include air monitoring and sampling programs, air monitoring and sampling techniques, air monitoring and sampling equipment, instrument calibration, exposure guidelines, air dispersion modeling, and health and safety considerations. The course will include operating procedures for specific air monitoring and sampling equipment, as well as strategies for air monitoring and sampling at abandoned hazardous waste sites and for accidental releases of hazardous chemicals.

Instructional methods include a combination of lectures, group discussions, problem-solving sessions, and laboratory and field exercises with hands-on use of instruments.

After completing the course, participants will be able to:

- Properly use the following types of air monitoring and sampling equipment:
 - Combustible gas indicators
 - Oxygen monitors
 - Detector tubes
 - Toxic gas monitors
 - Photoionization detectors
 - Flame ionization detectors
 - Gas chromatographs
 - Sampling pumps
 - Direct-reading aerosol monitors.
- Identify the operational parameters, limitations, and data interpretation requirements for the instruments listed above.
- Identify the factors to be considered in the development of air monitoring and sampling plans.
- Discuss the use of air monitoring data for the establishment of personnel and operations health and safety requirements.

U.S. Environmental Protection Agency
Office of Emergency and Remedial Response
Environmental Response Team

ACRONYMS AND ABBREVIATIONS

ACGIH	American Conference of Governmental Industrial Hygienists
AID	argon ionization detector
AIHA	American Industrial Hygiene Association
ALOHA	areal locations of hazardous atmospheres
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
BEI	biological exposure indices
C	ceiling (precedes exposure limit)
cc/min	cubic centimeters per minute
cfm	cubic feet per minute
CFR	Code of Federal Regulations
CGI	combustible gas indicator
Cl	chlorine
CO	carbon monoxide
DNPH	2,4-dinitrophenylhydrazine
DQO	data quality objective
ECD	electron capture detector
EPA	U.S. Environmental Protection Agency
ERT	Environmental Response Team (EPA)
eV	electron volt
FID	flame ionization detector
FM	Factory Mutual Research Corporation
GC	gas chromatography
HCl	hydrogen chloride
ICS	incident command system
IDLH	immediately dangerous to life or health
IP	ionization potential
KOH	potassium hydroxide
LCD	liquid crystal display
LED	light-emitting diode
LEL	lower explosive limit
LFL	lower flammable limit
lpm	liters per minute

MACs	maximum allowable concentrations
MAKs	maximum concentrations at the workplace (Federal Republic of Germany)
MCE	mixed cellulose ester
mg/m ³	milligrams per cubic meter
ml	milliliter
mm	millimeter
MOS	metal-oxide semiconductor
MSDS	material safety data sheets
MSHA	Mine Safety and Health Administration
NaOH	sodium hydroxide
NEC	National Electrical Code
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
NRC	Nuclear Regulatory Commission
OH	hydroxide
OSHA	Occupational Safety and Health Administration
OVA	organic vapor analyzer (Foxboro®)
OVM	organic vapor meter
PAH	polycyclic (or polynuclear) aromatic hydrocarbon
PBK	playback
PCB	polychlorinated biphenyl
PEL	permissible exposure limit
PID	photoionization detector
ppb	parts per billion
PPE	personal protective equipment
ppm	parts per million
ppt	parts per trillion
PUF	polyurethane foam
PVC	polyvinyl chloride
REL	recommended exposure limits
SA	shift average
SCBA	self-contained breathing apparatus
SEI	Safety Equipment Institute
SOP	standard operating procedure
SOSG	Standard Operating Safety Guides
SS	chemical-specific sensor
STEL	short-term exposure limit
TCD	thermal conductivity detector
TLV	threshold limit values
TWA	time-weighted average

UEL	upper explosive limit
UL	Underwriters' Laboratory, Inc.
UV	ultraviolet light
VDC	volts DC
WEEL®	workplace environmental exposure level

AIR MONITORING PLANS AND STRATEGIES

PERFORMANCE OBJECTIVES

At the end of this lesson, participants will be able to:

- List six objectives of air monitoring specified by the EPA *Standard Operating Safety Guides*
- Identify the OSHA standard and EPA standard that cover hazardous waste site operations and emergency response
- List four situations that initial entry monitoring is designed to detect
- Differentiate between "personal monitoring" and "area monitoring"
- Define, per 1910.120, when personnel monitoring is required
- List documents that EPA has developed as guidance for compliance with 1910.120
- Given the *Personal Air Sampling and Air Monitoring Requirements Under 29 CFR 1910.120* fact sheet, define air monitoring and air sampling
- List three uses of meteorological data.

AIR MONITORING PLANS AND STRATEGIES

AIR MONITORING EPA Objectives

- Identify and quantify airborne contaminants onsite and offsite
- Track changes in air contaminants that occur over the lifetime of the incident
- Ensure proper selection of work practices and engineering controls

Source: EPA SOSGs

AIR MONITORING EPA Objectives

- Determine the level of worker protection needed
- Assist in defining work zones
- Identify additional medical monitoring needs in any given area of the site.

Source: EPA SOSGs

NOTES

WORKER PROTECTION STANDARDS (OSHA)

- 29 CFR 1910.120 (HAZWOPER)
- Applies to
 - Federal employees
 - Private industry employees
 - State and local employees in OSHA states

WORKER PROTECTION STANDARDS (EPA)

- 40 CFR Part 311
- Applies to state and local employees in non-OSHA states
- Wording same as 1910.120

MONITORING REQUIREMENTS

NOTES

INITIAL ENTRY

Monitoring for:

- Immediately dangerous to life or health (IDLH) conditions
- Exposures over permissible exposure limits (PELs) or published exposure levels

INITIAL ENTRY

Monitoring for:

- Exposure over a radioactive material's dose limits
- Other dangerous conditions
 - Flammable atmospheres
 - Oxygen-deficient environments

PERIODIC MONITORING

"Periodic monitoring (shall) be done when the possibility of a dangerous condition has developed or when there is reason to believe that exposures may have risen above PELs since prior monitoring was conducted."

Source: EPA SOSGs

NOTES

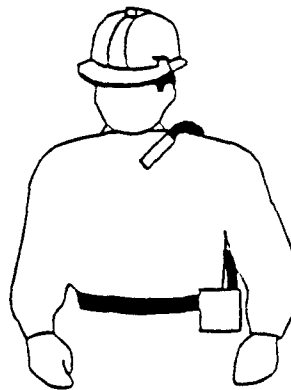
PERSONAL MONITORING

Required

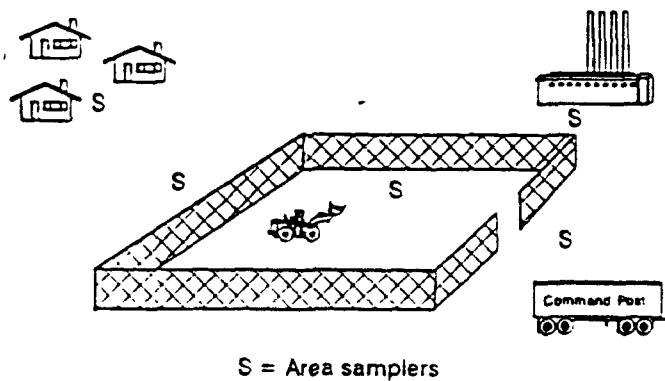
- During actual cleanup phase
- To evaluate high-risk employees (i.e., employees likely to have highest exposures)
- Evaluation of other employees needed if high-risk employees exceed exposure limits

Source: 1910.120(h)(4)

PERSONAL MONITORING



AREA MONITORING



SITE SAFETY AND HEALTH PLAN

Minimum requirement

"Frequency and types of air monitoring, personnel monitoring, and environmental sampling techniques and instrumentation to be used, including methods of maintenance and calibration of monitoring and sampling equipment to be used."

Source: 1910.120(b)(4)(ii)(E)

GUIDANCE DOCUMENTS OSHA

- Technical manual
- Analytical methods manual

GUIDANCE DOCUMENTS EPA

- EPA-ERT *Standard Operating Safety Guides (SOSGs)*, Publication 9285.1-03, June 1992
- *Personal Air Sampling and Air Monitoring Requirements (PASAMR)* Under 29 CFR 1910.120 fact sheet, Publication 9360.8-17FS, May 1993

NOTES

AIR MONITORING vs. AIR SAMPLING

- Air monitoring refers to the use of direct-reading instruments producing instantaneous data
- Air sampling refers to the use of a sampling pump and collection media that produce samples that must be sent to a laboratory for analysis

AIR MONITORING Features

- "Real time" (direct reading)
- Rapid response
- Generally not compound specific
- Limited detection levels
- May not detect certain classes of compounds

AIR SAMPLING Features

- Compound or class specific
- Greater accuracy
- Requires more time for results
- Requires additional pumps, media, and analytical support

NOTES

PERSONNEL AIR SAMPLING Elements in Sampling Strategy

- Employee sampled
- Tasks performed
- Duration
- Hazardous substances
- Equipment to be used

Source: PASAMR fact sheet

AREA SAMPLING Locations

- Upwind
 - Establish background
- Support zone
 - Ensure support area is clean and remains clean

Source: EPA SOSGs

AREA SAMPLING Locations

- Contamination reduction zone
 - Ensure that personnel in zone are properly protected
 - Ensure that onsite workers are not removing PPE in a contaminated area

Source: EPA SOSGs

NOTES

AREA SAMPLING Locations

- Exclusion zone
 - Represents greatest risk of exposure
 - Requires most sampling
 - Use data to set boundaries
 - Use data to select proper levels of PPE
 - Provide a record of air contaminants

Source: EPA SOSGs

AREA SAMPLING Locations

- Fenceline/downwind
 - Determine whether air contaminants are migrating from site

Source: EPA SOSGs

AREA SAMPLING Elements in Sampling Strategy

- Locations where air sampling will be performed
- Hazardous substances that will be sampled during the task
- Duration of the sample

Source: PASAMR fact sheet

AREA SAMPLING

Elements in Sampling Strategy

- Equipment that will be used to sample for the different hazardous substances
- Collection of meteorological data

Source: PASAMR fact sheet

METEOROLOGICAL CONSIDERATIONS

- Data needed
 - Wind speed and direction
 - Temperature
 - Barometric pressure
 - Humidity

METEOROLOGICAL CONSIDERATIONS

- Data uses
 - Placement of samplers
 - Input for air models
 - Calibration adjustments
- Data sources
 - Onsite meteorological stations
 - Government or private organizations

NOTES

AIR DISPERSION MODELS

- Public exposure assessment
- Air monitoring and air modeling should interact

LONG-TERM AIR MONITORING PROGRAMS

Considerations

- Type of equipment
- Cost
- Personnel
- Accuracy of analysis
- Time to obtain results
- Availability of analytical laboratories

Source: EPA SOSGs

LONG-TERM AIR MONITORING PROGRAMS

ERT Approach

- Use total vapor survey instruments for organic vapors and gases
 - Initial detection
 - Periodic site surveys
 - Area monitors to track changes

Source: EPA SOSGs

LONG-TERM AIR MONITORING PROGRAMS

ERT Approach

- Collect air samples
 - Analyze with field gas chromatographs
 - Send selected samples to laboratories
- Use survey instruments or gas chromatographs to screen samples for laboratory analysis

Source: EPA SOSGs

LONG-TERM AIR MONITORING PROGRAMS

ERT Approach

- When they are known to be present or when there are indications that they may be a problem, sample for
 - Particulates
 - Inorganic acids
 - Aromatic amines
 - Halogenated pesticides

Source: EPA SOSGs

ADDITIONAL READING

- Air/Superfund Technical Guidance Study Series
 - Volume IV - *Guidance for Ambient Air Monitoring at Superfund Sites* (revised), EPA-451/R-93-007, May 1993
 - *Compilation of Information on Real-Time Monitoring for Use at Superfund Sites*, EPA-451/R-93-008, May 1993

NOTES

INSTRUMENT CHARACTERISTICS

SELECTIVITY

- Selectivity is an instrument's ability to differentiate a chemical from others in a mixture
- Chemicals that affect an instrument's selectivity are called interferences

SENSITIVITY

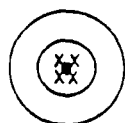
Sensitivity is the least change in concentration that will register an altered reading of the instrument

Source: Air Sampling and Analysis for Contaminants: An Overview

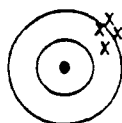
ACCURACY AND PRECISION

- Accuracy refers to the difference between the instrument reading and the true or correct value.
- Precision is the grouping of the data points around a calculated average. Precision measures the repeatability of data.

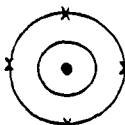
ACCURACY AND PRECISION



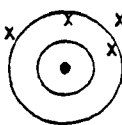
Accurate and Precise



Precise but Inaccurate



Accurate but Imprecise



Inaccurate and Imprecise

Source: *The Industrial Environment - Its Evaluation and Control*

RELATIVE RESPONSE

- Relative response is the relationship between an instrument's reading and the actual concentration
- Calculation

$$\text{Relative Response} = \frac{\text{Instrument Reading}}{\text{Actual Concentration}}$$

NOTES

CALIBRATION

- Process of checking an instrument to see if it gives the proper response and making any necessary adjustments.
- Direct-reading instruments generally are calibrated to one chemical (the standard).

RESPONSE TIME

- Response time is the time between initial sample contact and readout of the full chemical concentration (usually seconds to minutes)
- Turnaround time is the time from sample collection to receipt of results (days to weeks)

MOBILITY

- Portable
 - Hand held
 - No external power supply
- Fieldable
 - Particularly rugged
 - Easily transported by vehicle
 - Limited external power supply
- Mobile
 - Small enough to carry in a mobile lab

Source: Field Screening Methods Catalog, EPA/540/2-88/005, September 1988

NOTES

EASE OF OPERATION

- How easy is it to operate the controls?
- How easy is it to learn to operate?
- How many steps must be performed before an answer is obtained?
- How easy is it to repair?

INHERENT SAFETY



APPROVED



32L6

LISTED

INTRINSICALLY SAFE COMBINATION
COMBUSTIBLE GAS AND OXYGEN INDICATING
DETECTOR FOR HAZARDOUS LOCATIONS
CLASS I, DIVISION 1, GROUPS A, B, C & D

Source: Scott Model S-105 Certification Label

AIR MONITORING PLANS AND STRATEGIES

INTRODUCTION

Airborne contaminants present at a hazardous waste site or a hazardous materials release can present a risk to human health and the environment. One way to assess that risk is to identify and quantify these contaminants by air monitoring. The U.S. Environmental Protection Agency's (EPA) *Standard Operating Safety Guides* (SOSGs) state that the objectives of air monitoring during response operations are to:

- Identify and quantify airborne contaminants onsite and offsite
- Track changes in air contaminants that occur over the lifetime of the incident
- Ensure proper selection of work practices and engineering controls
- Determine the level of worker protection needed
- Assist in defining work zones
- Identify additional medical monitoring needs in any given area of the site.

Several questions should be addressed when you develop an air monitoring plan. *Why* is the air monitoring being done? *How* will the monitoring be done? *Who* will do the monitoring? *When* and *where* will the air monitoring be done? *What* equipment will be used?

The above list gives several reasons why air monitoring is done. Some organizations have developed guidelines on the why, how, who, where, when, and what of air monitoring. Some organizations have procedures that are legal requirements. These organizations will be discussed. Also, general equipment characteristics will be covered in the latter part of this section.

STANDARDS AND GUIDELINES

U.S. Department of Labor - Occupational Safety and Health Administration (OSHA)

Since 1971, OSHA has regulated exposure to chemicals in industry. 29 CFR Part 1910.1000 specifies limits on exposure to airborne concentrations of chemicals. See the section on *Exposure Limits and Action Levels* for further information.

On March 6, 1990, OSHA's *Hazardous Waste Operations and Emergency Response* standard (29 CFR Part 1910.120) went into effect. This standard addressed the legal requirements for protecting workers involved with hazardous waste or emergency responses to hazardous materials. Air monitoring is one of the many activities regulated by this standard.

The standard requires the site-specific safety and health plan to address:

Frequency and types of air monitoring, personnel monitoring, and environmental sampling techniques and instrumentation to be used, including methods of maintenance and calibration of monitoring and sampling equipment to be used. {1910.120(b)(4)(ii)(e)}.

Under section (c) *Site characterization and analysis* is:

(6) *Monitoring.* The following monitoring shall be conducted during initial site entry when the site evaluation produces information that shows the potential for ionizing radiation or IDLH (*Immediately Dangerous to Life or Health*) conditions, or when the site information is not sufficient reasonably to eliminate these possible conditions:

(i) Monitoring with direct-reading instruments for hazardous levels of radiation.

(ii) Monitoring the air with appropriate direct-reading test equipment (e.g., combustible gas meter, detector tubes) for IDLH and other conditions that may cause death or serious harm (combustible or explosive atmospheres, oxygen deficiency, toxic substances).

(iii) Visually observing for signs of actual or potential IDLH or other dangerous conditions.

(iv) An ongoing air monitoring program in accordance with paragraph (h) of this section shall be implemented after site characterization has determined the site is safe for the startup of operations.

This section states when monitoring should be done (site entry), why it is done (to identify IDLH conditions), and what kind of equipment to use. Additional requirements are found under (h) *Monitoring*.

(1) *General*

(i) Monitoring shall be performed in accordance with this paragraph where there may be a question of employee exposure to hazardous concentrations of hazardous substances in order to assure proper selection of engineering controls, work practices and personal protective equipment so that employees are not exposed to levels which exceed permissible exposure limits or published exposure levels for hazardous substances.

(ii) Air monitoring shall be used to identify and quantify airborne levels of hazardous substances and safety and health hazards in order to determine the appropriate level of employee protection needed on site.

Here the purpose (why) is to identify and quantify hazardous substances so that proper exposure controls are used. The substances are identified and quantified so that the concentrations can be compared to an exposure limit. See the *Exposure Limits and Action Levels* section for further information on exposure limits.

(2) *Initial entry.* Upon initial entry, representative air monitoring shall be conducted to identify any IDLH condition, exposure over permissible exposure limits or published exposure levels, exposure over a radioactive material's dose limits or other dangerous condition such as the presence of flammable atmospheres or oxygen-deficient environments.

This paragraph expands on site characterization and analysis paragraph (c)(6) by including exposure limits along with IDLH conditions to monitor.

(3) *Periodic monitoring.* Periodic monitoring shall be conducted when the possibility of an IDLH condition or flammable atmosphere has developed or when there is indication that exposures may have risen over permissible exposure limits or published exposure levels since prior monitoring. Situations where it shall be considered whether the possibility that exposures have risen are as follows:

- (i) When work begins on a different portion of the site.
- (ii) When contaminants other than those previously identified are being handled.
- (iii) When a different type of operation is initiated (e.g., drum opening as opposed to exploratory well drilling).
- (iv) When employees are handling leaking drums or containers or working in areas with obvious liquid contamination (e.g., a spill or lagoon).

Again, where, when, and why are covered.

(4) *Monitoring of high-risk employees.* After the actual cleanup phase of any hazardous waste operation commences; for example, when soil, surface water, or containers are moved or disturbed; the employer shall monitor those employees likely to have the highest exposure to hazardous substances and health hazards likely to be present above permissible exposure limits or published exposure levels by using personal sampling frequently enough to characterize employee exposures. If the employees likely to have the highest exposure are over permissible exposure limits or published exposure limits, then monitoring shall continue to determine all employees likely to be above those limits. The employer may utilize a representative sampling approach by documenting that the employees and chemical chosen for monitoring are based on the criteria stated above.

Note to (h): It is not required to monitor employees engaged in site characterization operations covered by paragraph (c) of this section.

These paragraphs state that personal monitoring (how) must be done on high-risk employees (who) during cleanup activities (when).

Section (q) of 1910.120 addresses emergency responses to hazardous substance releases. It states in (q)(3)(ii) that

the individual in charge of the ICS (*Incident Command System*) shall identify, to the extent possible, all hazardous substances or conditions present and shall address as appropriate site analysis, use of engineering controls, maximum exposure limits, hazardous substances handling procedures, and use of any new technologies.

Air monitoring is not specifically mentioned in section (q), but would be a useful, if not necessary, tool for assessment.

29 CFR 1910.120 is a federal regulation. In states where there is an approved state OSHA (state-plan state), requirements at least as stringent as 1910.120 must be developed. Thus, in some states the air monitoring requirements may be more detailed.

U.S. Environmental Protection Agency (EPA)

On June 23, 1989, EPA adopted 40 CFR Part 311, *Worker Protection Standards for Hazardous Waste Operations and Emergency Response*. This standard is a duplicate of 1910.120. The difference in the standards is to whom they apply. The OSHA standard applies to federal agencies, private industries, and public employees in OSHA state-plan states. The EPA standard applies to public employees in states that have no OSHA state-plan.

As noted in the previous paragraph, EPA has regulations for monitoring for worker protection. There are also requirements for monitoring for public protection. However, this subject will not be discussed here in detail. Additional information is mentioned in this manual in the *Exposure Limits and Action Levels* section.

EPA has published guidelines for hazardous material operations which include air monitoring procedures. General guidelines can be found in the SOSGs. The following topics are discussed in the SOSGs:

1. Objectives of air monitoring
2. Identifying airborne contaminants
3. Air sampling equipment and media
4. Sample collection and analysis
5. General monitoring practices
6. Meteorological considerations
7. Long-term air monitoring programs
8. Variables in hazardous waste site air monitoring
9. Using vapor/gas concentrations to determine level of protection.

Other EPA guidance documents are:

- *Personal Air Sampling and Air Monitoring Requirements Under 29 CFR 1910.120* fact sheet
- *Guidance for Ambient Air Monitoring at Superfund Sites*, Volume IV in the Air/Superfund National Technical Guidance Series
- *Compilation of Information on Real-Time Monitoring for use at Superfund Sites*
- *Removal Program Representative Sampling: Air*
- *A Compendium of Superfund Field Operations Methods*.

EPA's Environmental Response Team (ERT) has developed standard operating procedures for their air monitoring equipment and strategies. These documents provide information on the why, how, when, where, and what of air monitoring. Because EPA is concerned with offsite migration and public exposure along with worker protection, their sampling requirements are broader than OSHA's. Air monitoring is done onsite to determine the type and quantity of chemicals being released. Downwind monitoring is done to determine offsite migration. Upwind sampling is done to determine what background concentrations may be contributing to the downwind and onsite measurements. This helps determine what the site is contributing to the environment.

Some of the methods use air monitoring equipment to monitor for the presence of chemicals in media other than air (e.g., soil gas sampling and water headspace).

Other Organizations

The National Institute for Occupational Safety and Health (NIOSH), the American Conference of Governmental Industrial Hygienists (ACGIH), the American Industrial Hygiene Association (AIHA), and the American Society for Testing and Materials (ASTM) have publications about air monitoring strategies. See the *References* section of this manual for more information.

CHARACTERISTICS OF AIR MONITORING INSTRUMENTS

The selection of equipment to be used must be part of the air monitoring plan. There are many factors to consider when determining the proper equipment to use. Specific instrument characteristics related to the following factors can be found in later sections of this manual.

Hazard

The proper equipment must be selected to monitor the hazard or chemical at hand.

Selectivity

Selectivity is the ability of an instrument to detect and measure a specific chemical. If other chemicals are detected, they are called interferences. Interferences can affect the accuracy of the instrument reading. In some situations, an instrument (like the combustible gas indicator [CGI]) that

responds to more than one chemical is desired. Again, the purpose of the monitoring must be considered.

Sensitivity

Sensitivity is important when slight concentration changes can be dangerous. Sensitivity is defined as the ability of an instrument to accurately measure changes in concentration. Therefore, "sensitive" instruments can detect small changes in concentration.

Accuracy

Accuracy is the measure of how close readings are to true values. It is expressed as % bias. For example, if an instrument is tested and the average results are 15% higher than the true concentration, then the instrument is said to have a bias of +15%. NIOSH recommends that a portable direct-reading instrument be within 25% of the true value 95% of the time.

Precision

Precision is the grouping of the data points. It is a quantitative measure of the variability of a group of measurements compared to their average value. It is defined by the standard deviation. This value is a \pm qualifier when a value is reported (e.g., 10 ± 1 ppm).

Accuracy and precision are affected by factors such as the instrument's calibration and relative response.

Calibration

An instrument must be properly calibrated, prior to use, in order to function properly in the field. Calibration is the process of adjusting the instrument readout so that it corresponds to an actual concentration. Calibration involves checking the instrument results with a known concentration of a gas or vapor to see that the instrument gives the proper response. For example, if a combustible gas meter is checked with a calibration gas that is 20% of the lower explosive limit (LEL), then the instrument should read 20% of the LEL. If it does not read accurately, it is out of calibration and should be adjusted until an accurate reading is obtained.

Although an instrument is calibrated to give a one-to-one response for a specific chemical (the calibration gas), its response to other chemicals is usually different (see *Relative Response* below). If the calibration is changed for an instrument, its relative responses will also change. Also, the instrument may not give a one-to-one response to the chemical for the full range of detection (see detection range).

Instruments come from the manufacturer calibrated to a specific chemical. The manufacturer supplies information about how to maintain that calibration. If the user wants to change the calibration gas, the manufacturer can supply information on how to do so.

Relative Response

Whereas some instruments may detect more than one chemical, equal concentrations may not give equal response. The relationship between the instrument's response and the actual concentration of the chemical is termed the "relative response." Relative response can be calculated by using the following formula:

$$\text{Relative Response} = \frac{\text{Instrument Reading}}{\text{Actual Concentration}} (\times 100\% \text{ for } \% \text{ Relative Response}).$$

For example, if an instrument reading for a 100 ppm concentration of acetone is 63, then the relative response for that instrument and acetone is 0.63 or 63%. **Table 1** gives relative response information for a particular CGI.

**TABLE 1. RELATIVE RESPONSE OF SELECTED CHEMICALS
FOR A CGI CALIBRATED TO PENTANE**

Chemical	Concentration (% LEL)	Meter Response (% LEL)	Relative Response (%)
Methane	50	85	170
Acetylene	50	60	120
Pentane	50	50	100
1,4-Dioxane	50	37	74
Xylene	50	27	54

Source: *Portable Gas Indicator, Model 250 and 260, Response Curves*,
Mine Safety Appliances Company, Pittsburgh, PA.

Relative responses vary with chemical and instrument. The same chemical may have a relative response of 63% for one instrument and 120% response for another. Calibration also affects relative response.

Instruments come from the manufacturer calibrated to a specific chemical. If the instrument is being used for a chemical that is not the calibration standard, then it may be possible to look at the manufacturer's information to get the relative response of that instrument for the chemical. Then the actual concentration can be calculated. For example, if the instrument's relative response for xylene is 0.27 (27%) and the reading is 100 ppm (parts per million), then the actual concentration is 370 ppm ($0.27 \times \text{actual concentration} = 100 \text{ ppm}$; $\text{actual concentration} = 100/0.27 = 370 \text{ ppm}$).

If there is no relative response data for the chemical in question, it may be possible to recalibrate the instrument. If the instrument has adjustable settings and a known concentration is available, the instrument may be adjusted to read directly for the chemical. Because recalibration takes time, this is usually done only if the instrument is going to be used for many measurements of the special chemical.

Detection Range

The operating range is the lower and upper use limits of the instrument. It is defined by the lower detection limit at one end and the saturation concentration at the other end. The lower detection limit is the lowest concentration to which an instrument will respond. It is important to use an instrument with an operating range that will accurately measure the concentration in the range of concern. For example, a CGI could be used to monitor for methane because methane is combustible. However, the upper limit of the CGI is the lower explosive limit (LEL) of the chemical. LEL is the lowest concentration of gas or vapor (in air) that will burn or explode if an ignition source is present at ambient temperatures. In this case, that would be 5% methane. If higher concentrations of methane need to be quantified, another type of instrument would be needed. Also, most CGIs are not sensitive to ppm concentrations. A different instrument would be needed to measure that range.

Some instruments may respond to the chemical for a range of concentrations but not give a consistent response throughout the range. The linear range is the range of concentrations over which the instrument gives response proportional to the chemical concentration.

Response Time

Response time is the time between initial sample contact and readout of the full chemical concentration. In direct-reading instruments, a rapid response time is desired. Response time for direct-reading instruments can be from seconds to minutes. The HNU PI-101 gives 90% of full-scale concentration in 3 seconds. Some hydrogen cyanide detectors may take 90 seconds to give a full concentration reading. Factors that affect response time are temperature, type of detector, and sample hose length.

For methods that require air sample collection and analysis, the response time is referred to as the turnaround time. In other words, how long was the period of time between collection of the sample and receipt of results from the laboratory?

Mobility

EPA's Field Screening Methods Catalog uses the following terms:

- **Portable**—Hand-held devices that can be easily carried by one person and require no external power source.
- **Fieldable**—Easily transported in a van, pick-up, or four-wheel drive. Particularly rugged and limited external power required.
- **Mobile**—Small enough to carry in a mobile lab. Power consideration may limit the use of many instruments in mobile laboratories. (Size, durability, and power supply are the main considerations in determining the mobility of an instrument.)

Ease of Operation

Because many of these instruments were designed for industrial use, allowances may not have been made for using the instrument while wearing protective equipment. One must consider how easy it is to use the instrument while wearing gloves or how difficult it is to read the meter while wearing a respirator. Also, how quickly a user can learn to operate the instrument correctly should be considered.

Preparation time for use of the instrument should be short. Rapid warm-up, easy attachment of accessories, and quick instrument checks shorten preparation time.

Direct-Reading vs. Sample Analysis

Direct-reading instruments are those that give a response to a chemical within seconds or minutes of contact. They are also meant to be taken to the location that is to be evaluated. Sample analysis, however, involves collecting an air sample on a media or in a container and then sending it to an analytical laboratory. This type of analysis involves much more time—sometimes days longer—than using a direct-reading instrument.

Personal vs. Area Monitor/Sampler

A personal monitor/sampler is one that can be worn by the worker with the intent of obtaining the exposure for the wearer. An area monitor/sampler obtains information for the area in which it is placed. A personal monitor/sampler must be small enough to be worn by the worker and also must have a battery supply if it is electronic. A personal monitor/sampler is the ultimate in portability. They range in size from pocket size to a size that can be clipped to a belt without hindering the wearer. Area samplers can be much larger and can use AC power. Many of the personal monitors are equipped with warning alarms and with dataloggers to store and calculate exposures.

Inherent Safety

Many of the instruments used for air monitoring will be used in the atmosphere being monitored. Therefore, they must be safe to use in that environment. Electrical devices, including instruments, must be constructed to prevent the ignition of a combustible atmosphere. The sources of this ignition could be an arc generated by the power source itself or the associated electronics, or a flame or heat source necessary for function of the instrument. The National Fire Protection Association (NFPA) publishes the National Electrical Code (NEC), which spells out types of areas in which hazardous atmospheres can be generated and the types of materials that generate these atmospheres. It also lists design safeguards acceptable for use in hazardous atmospheres.

Hazardous Atmospheres

The term "hazardous atmosphere" causes response workers, depending on their backgrounds, to imagine situations ranging from toxic air contaminants to flammable atmospheres. For NEC purposes, an atmosphere is hazardous if it meets the following criteria:

- It is a mixture of any flammable material in air whose concentration is within the material's flammable range (i.e., between the material's lower flammable limit and its upper flammable limit).
- There is the potential for an ignition source to be present.
- The resulting exothermic reaction could propagate beyond where it started.

To adequately describe hazardous atmospheres, the NEC categorizes them according to their class, group, and division. Class is a category describing the type of flammable material that produces the hazardous atmosphere:

- Class I is flammable vapors and gases, such as gasoline and hydrogen. Class I is further divided into Groups A, B, C, and D on the basis of similar flammability characteristics (Table 2).
- Class II consists of combustible dusts like coal or grain and is divided into groups E, F, and G (Table 3).
- Class III is ignitable fibers such as those produced by cotton milling.

TABLE 2. SELECTED CLASS I CHEMICALS BY GROUP

Group	Examples of Chemicals Within Group		
Group A Atmospheres	acetylene		
Group B Atmospheres	1,3-butadiene	ethylene oxide	hydrogen
Group C Atmospheres	carbon monoxide diethyl ether dicyclopentadiene ethyl mercaptan	ethylene hydrazine hydrogen sulfide methyl ether	nitropropane tetrahydrofuran tetramethyl lead triethylamine
Group D Atmospheres	acetone ammonia benzene ethanol	fuel oils gasoline liquified petroleum gas methane	methyl ethyl ketone propane vinyl chloride xylenes

Source: NFPA. 1991. *Classification of Gases, Vapors, and Dusts for Electrical Equipment in Hazardous (classified) Locations*. National Fire Protection Association, ANSI/NFPA 497M.

TABLE 3. SELECTED CLASS II CHEMICALS BY GROUP

Group	Characteristics of Group
Group E Conductive Dusts	Atmospheres containing metal dusts, including aluminum, magnesium, and their commercial alloys, and other metals of similarly hazardous characteristics
Group F Semivolatile Dusts	Atmospheres containing carbon black, coal, or coke dust with more than 8% volatile material
Group G Nonconductive Dusts	Atmospheres containing flour, starch, grain, carbonaceous, chemical thermoplastic, thermosetting and molding compounds.

Source: NFPA. 1991. *Classification of Gases, Vapors, and Dusts for Electrical Equipment in Hazardous (classified) Locations*. National Fire Protection Association, ANSI/NFPA 497M.

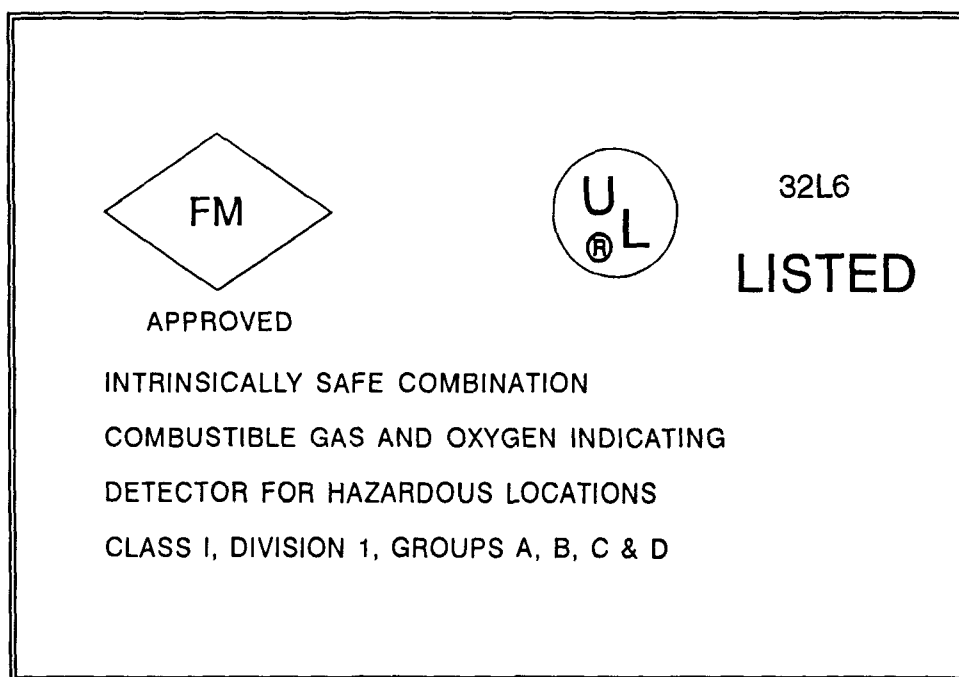
Division is the term describing the "location" of generation and release of the flammable material.

- Division 1 is a location where the generation and release are continuous, intermittent, or periodic into an open, unconfined area under normal conditions. Instruments certified for Division 1 locations are also called "intrinsically safe."
- Division 2 is a location where the generation and release are only from ruptures, leaks, or other failures from closed systems or containers.

Using this system, a hazardous atmosphere can be routinely and adequately defined. As an example, an abandoned waste site containing intact closed drums of methyl ethyl ketone, toluene and xylene would be considered a Class I, Division 2, Group D environment. However, when transfer of the flammable liquids takes place at the site, or if releases of flammable gases/vapors are considered normal, those areas would be considered Class I, Division 1.

Certification

If a device is certified for a given class, division, and group, and it is used, maintained, and serviced according to the manufacturer's instructions, it will not contribute to ignition. The device is not, however, certified for use in atmospheres other than those indicated. All certified devices must be marked to show class, division, and group (**Figure 1**). Any manufacturer wishing to have an electrical device certified must submit a prototype to a recognized laboratory for testing. If the unit passes, it is certified as submitted. However, the manufacturer agrees to allow the testing laboratory to randomly check the manufacturing plant at any time, as well as any marketed units. Furthermore, any change in the unit requires the manufacturer to notify the test laboratory, which can continue the certification or withdraw it until the modified unit can be retested. NFPA does not do certification testing. Testing and certification is done by such organizations as Underwriters' Laboratory, Inc. (UL) or Factory Mutual Research Corporation (FM).



**FIGURE 1. CERTIFICATION LABEL FROM SCOTT® MODEL S-105
COMBUSTIBLE GAS AND O₂ INDICATOR**

To ensure personnel safety, only approved instruments can be used onsite and only in atmospheres for which they have been certified. When investigating incidents involving unknown hazards, the monitoring instruments should be rated for use in the most hazardous locations. The following points will assist in selection of equipment that will not contribute to ignition of a hazardous atmosphere:

- The mention of a certifying group in the manufacturer's equipment literature does not guarantee certification.
- Some organizations test and certify instruments for locations different from the NEC classifications. The Mine Safety and Health Administration (MSHA) tests instruments only for use in methane-air atmospheres and in atmospheres containing coal dust.
- In an area designated Division 1, there is a greater probability of generating a hazardous atmosphere than in Division 2. Therefore, the test protocols for Division 1 certification are more stringent than those for Division 2. Thus, a device approved for Division 1 is also permitted for use in Division 2, but not vice versa. For most response work, this means that devices approved for Class 1 (vapors and gases), Division 1 (areas of ignitable concentrations), Groups A, B, C, and D should be chosen whenever possible. At a minimum, an instrument should be approved for use in Division 2 locations.
- There are so many groups, classes, and divisions that it may not be possible to certify an all-inclusive instrument. Therefore, select a certified device based on the chemicals and conditions most likely to be encountered. For example, a device certified for a Class II, Division 1, Group E (combustible metal dust) would offer little protection around a flammable vapor or gas.

Accessories or Options

Many manufacturers offer accessories or options for their instruments. A useful option is an alarm to alert the user that a concentration level has been exceeded. This is a common feature on CGIs and oxygen meters.

A recent addition to instruments are microprocessors/dataloggers. This combination can help the operator calibrate the instrument, store calibration information, make adjustments to the instrument, store readings so that a readout of concentrations at specific locations or times can be made at the end of a monitoring period, and report the data. Some units may even do time-weighted averaging of the concentrations. Some instruments can transfer this information into an external computer for storage and data manipulation.

Other accessories and options include special sample probes, special carrying cases, and the ability to change detectors in an instrument.

DATA QUALITY

The *Characteristics of Air Monitoring Instruments* section discussed instrument characteristics (e.g., accuracy, selectivity, and sensitivity) that affect the quality of the data from the air monitoring instruments. Data quality is a concern and EPA has published a document entitled *Data Quality Objectives for Remedial Response Activities* (U.S. EPA 1987) that discusses how to address this concern.

The data quality objectives (DQOs) basically state that the desired quality of data determines the amount of time and effort needed to produce the result. There are different levels of data quality. **Table 4** illustrates this point. The higher the analytical level, the better the quality of data. However, higher analytical levels usually require more time and money.

CONCLUSION

The desired air monitoring instrument is one that is portable, direct-reading, easy to use, and accurate and precise. The instrument should also respond quickly, be capable of detecting ppb and % concentrations, be inherently safe, identify and give concentrations of all the chemicals and hazards in an atmosphere, and do its job while the operator is sitting at a safe distance from the hazardous material site or spill. Unfortunately, no instrument meets these criteria. Thus, a variety of instruments are needed depending on the air monitoring plan.

When preparing an air monitoring plan, the operator must determine why, how, when, and where the monitoring is to be done and what equipment is necessary. In addition, there are legal requirements to comply with. Guidance documents are available to assist in complying with these requirements. Other factors must also be considered when selecting the monitoring equipment. Additional information on why to sample, or what to sample for, will be covered in the *Exposure Limits and Action Levels* section of the course. Characteristics of the various types of equipment will also be discussed in later sections.

TABLE 4. SUMMARY OF ANALYTICAL LEVELS APPROPRIATE TO DATA USES

DATA USES	ANALYTICAL LEVEL	TYPE OF ANALYSIS	LIMITATIONS	DATA QUALITY
SITE CHARACTERIZATION MONITORING DURING IMPLEMENTATION	LEVEL I	<ul style="list-style-type: none"> TOTAL ORGANIC/INORGANIC VAPOR DETECTION USING PORTABLE INSTRUMENTS FIELD TEST KITS 	<ul style="list-style-type: none"> INSTRUMENTS RESPOND TO NATURALLY OCCURRING COMPOUNDS 	<ul style="list-style-type: none"> IF INSTRUMENTS CALIBRATED AND DATA INTERPRETED CORRECTLY, CAN PROVIDE INDICATION OF CONTAMINATION
SITE CHARACTERIZATION EVALUATION OF ALTERNATIVES ENGINEERING DESIGN MONITORING DURING IMPLEMENTATION	LEVEL II	<ul style="list-style-type: none"> VARIETY OF ORGANICS BY GC; INORGANICS BY AA, XRF TENTATIVE ID; ANALYTE-SPECIFIC DETECTION LIMITS VARY FROM LOW ppm TO LOW ppb 	<ul style="list-style-type: none"> TENTATIVE ID TECHNIQUES/INSTRUMENTS LIMITED MOSTLY TO VOLATILES, METALS 	<ul style="list-style-type: none"> DEPENDENT ON QA/QC STEPS EMPLOYED DATA TYPICALLY REPORTED IN CONCENTRATION RANGES
RISK ASSESSMENT PRP DETERMINATION SITE CHARACTERIZATION EVALUATION OF ALTERNATIVES ENGINEERING DESIGN MONITORING DURING IMPLEMENTATION	LEVEL III	<ul style="list-style-type: none"> ORGANICS/INORGANICS USING EPA PROCEDURES OTHER THAN CLP CAN BE ANALYTE-SPECIFIC RCRA CHARACTERISTIC TESTS 	<ul style="list-style-type: none"> TENTATIVE ID IN SOME CASES CAN PROVIDE DATA OF SAME QUALITY AS LEVELS IV, NS 	<ul style="list-style-type: none"> SIMILAR DETECTION LIMITS TO CLP LESS RIGOROUS QA/QC
RISK ASSESSMENT PRP DETERMINATION EVALUATION OF ALTERNATIVES ENGINEERING DESIGN	LEVEL IV	<ul style="list-style-type: none"> HSL ORGANICS/INORGANICS BY GC/MS; AA; ICP LOW ppb DETECTION LIMIT 	<ul style="list-style-type: none"> TENTATIVE IDENTIFICATION OF NON-HSL PARAMETERS SOME TIME MAY BE REQUIRED FOR VALIDATION OF PACKAGES 	<ul style="list-style-type: none"> GOAL IS DATA OF KNOWN QUALITY RIGOROUS QA/QC
RISK ASSESSMENT PRP DETERMINATION	LEVEL V	<ul style="list-style-type: none"> NONCONVENTIONAL PARAMETERS METHOD-SPECIFIC DETECTION LIMITS MODIFICATION OF EXISTING METHODS APPENDIX B PARAMETERS 	<ul style="list-style-type: none"> MAY REQUIRE METHOD DEVELOPMENT/MODIFICATION MECHANISM TO OBTAIN SERVICES REQUIRES SPECIAL LEAD TIME 	<ul style="list-style-type: none"> METHOD-SPECIFIC

Source: U.S. EPA. 1987. *Data Quality Objectives for Remedial Response Activities*. EPA/540/G-87/003.
U.S. Environmental Protection Agency.

EXPOSURE LIMITS AND ACTION LEVELS

PERFORMANCE OBJECTIVES

At the end of this lesson, participants will be able to:

- Identify the three sources of exposure limits specified in OSHA's 29 CFR 1910.120 *Hazardous Waste Operations and Emergency Response* standard
- Define the terms "time-weighted average (TWA) limit," "short-term exposure limit," and "ceiling limit"
- Given the identity and concentration of a chemical exposure, determine whether an exposure limit is exceeded
- Calculate an 8-hour TWA exposure when given a chemical's exposure concentration and the duration of the exposure
- List the three uses mentioned in 1910.120 for exposure limits
- List three of the five applications for which the American Conference of Governmental Industrial Hygienists states the threshold limit values should not be used
- List EPA's action levels for oxygen, combustible gas, and radiation and the actions associated with each level.

EXPOSURE LIMITS AND ACTION LEVELS

EXPOSURE LIMITS (29 CFR Part 1910.120)

- Permissible Exposure Limits (PELs)
 - 29 CFR Part 1910, Subparts G and Z, Occupational Safety and Health Administration (OSHA)

EXPOSURE LIMITS (29 CFR Part 1910.120)

- Published Exposure Levels
 - *NIOSH Recommendations for Occupational Health Standards*, 1986
 - American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs) for 1987-1988

NOTES

EXPOSURE LIMITS Sources

- OSHA
 - PELs
 - Legal requirements
 - 1968 TLVs and American National Standards Institute (ANSI)
 - 29 CFR 1910.1000 (tables)
 - Specific standards - benzene

EXPOSURE LIMITS Sources

- National Institute for Occupational Safety and Health (NIOSH)
 - Recommended exposure limits (RELs)
 - May be legal (1910.120)
 - Rationale in criteria documents
 - Immediately dangerous to life or health (IDLH)

EXPOSURE LIMITS Sources

- ACGIH
 - TLVs
 - Recommendations
 - May be legal (1910.120)
 - Yearly booklet
 - Documentation

NOTES

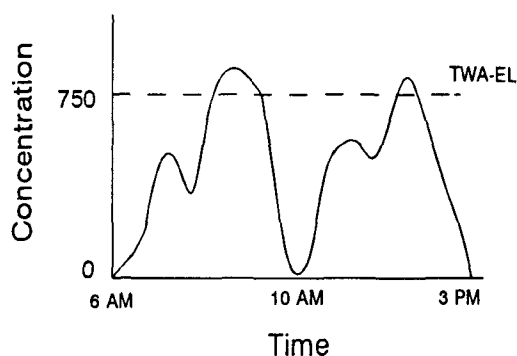
EXPOSURE GUIDELINES Sources

- American Industrial Hygiene Association (AIHA)
 - Workplace environmental exposure levels (WEELs)
 - Recommendations
 - Yearly updates
 - Documentation

EXPOSURE GUIDELINES Sources

- Other
 - U.S. Army and U.S. Air Force
 - Mine Safety and Health Administration (MSHA)
 - Other countries (e.g., Federal Republic of Germany maximum concentration values in the workplace (MAKs))

TIME-WEIGHTED AVERAGE (TWA)



NOTES

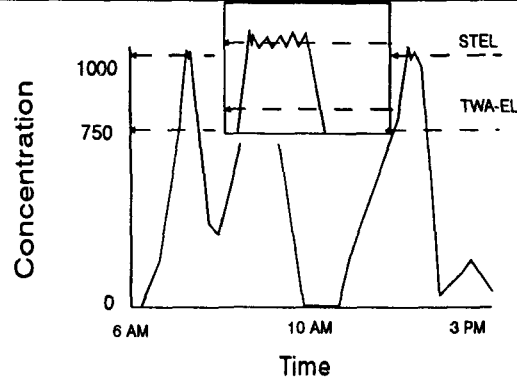
TIME-WEIGHTED AVERAGE CALCULATION

Exposures: 1500 ppm for 1 hour
500 ppm for 3 hours
200 ppm for 4 hours

$$\frac{(1 \text{ hr})(1500 \text{ ppm}) + (3 \text{ hrs})(500 \text{ ppm}) + (4 \text{ hrs})(200 \text{ ppm})}{8 \text{ hrs}} =$$

$$\frac{1500 \text{ ppm} + 1500 \text{ ppm} + 800 \text{ ppm}}{8} = 475 \text{ ppm}$$

SHORT-TERM EXPOSURE LIMIT (STEL)

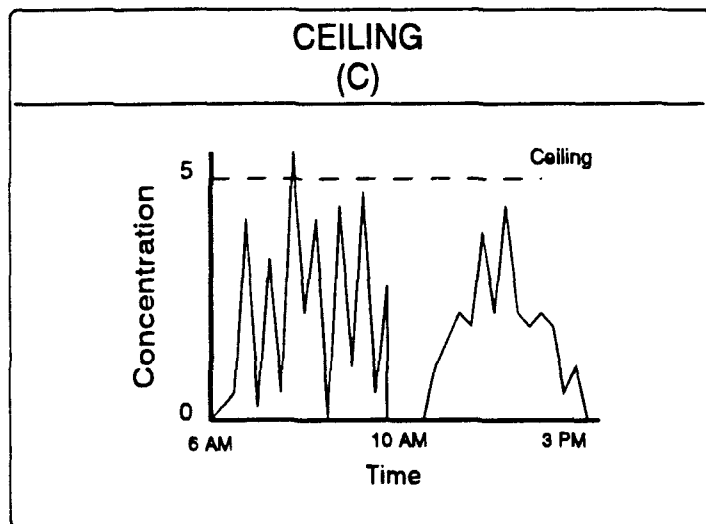


STEL

Excursions to the STEL

- Should not be longer than 15 minutes in duration (OSHA, NIOSH, ACGIH)
- Should be at least 60 minutes apart (ACGIH)
- Should not be repeated more than 4 times per day (ACGIH)
- Supplement TWA

NOTES



CEILING

The exposure that shall not be exceeded during any part of the work day. If instantaneous monitoring is not feasible, the ceiling shall be assessed as a 15-minute TWA exposure (unless otherwise specified) that shall not be exceeded at any time during a work day

Source: NIOSH Recommendations for Occupational Safety and Health. 1992.

COMPARISON OF EXPOSURE LIMITS

Chemical	OSHA	NIOSH	ACGIH
Acetone	1000*	250	750/1000
Benzene	1/5	0.1/C 1	10 (0.1)
Lead (mg/m ³)	0.05	<0.1	0.15 (0.05)
Benzaldehyde	NA	NA	NA

*Note: * units are ppm; TWA/STEL
() indicates intended change*

NOTES

IDLH

"...means an atmospheric concentration of any toxic, corrosive, or asphyxiant substance that poses an immediate threat to life or would cause irreversible or delayed adverse health effects or would interfere with an individual's ability to escape from a dangerous atmosphere."

Source: 29 CFR 1910.120(a)

IDLH

IDLH concentrations represent the maximum concentration from which, in the event of respirator failure, one could escape within 30 minutes without a respirator and without experiencing any escape-impairing or irreversible health effects.

Note: IDLH level defined by the Standards Completion Program - NIOSH/OSHA - only for purposes of respirator selection

IDLH VALUES Examples

Chemical	IDLH
Acetone	20,000 ppm (LEL?)
Benzene	Ca (3000 ppm)
Lead	700 mg/m ³
Tetraethyl lead	40 mg/m ³
Benzaldehyde	Not available

Source: NIOSH Pocket Guide to Chemical Hazards. 1990.

EVALUATION OF A MIXTURE

$$E_m = C_1/L_1 + C_2/L_2 + \dots C_n/L_n$$

E_m = the equivalent exposure for the mixture

C = the concentration of a particular contaminant

L = the exposure limit for that contaminant

EVALUATION OF A MIXTURE Example

Chemical A $C = 500$ ppm $L = 750$ ppm (TWA)

Chemical B $C = 200$ ppm $L = 500$ ppm (TWA)

Chemical C $C = 50$ ppm $L = 200$ ppm (TWA)

$$E_m = (500/750) + (200/500) + (50/200)$$

$$E_m = 0.67 + 0.40 + 0.25$$

$$E_m = 1.3$$

EVALUATION OF A MIXTURE

- E_m should not exceed 1
- The calculation applies to chemicals where the effects are the same and are additive
- Do not mix TWAs, STELs, or ceilings

NOTES

EXPOSURE LIMITS

Used to determine:

- Site characterization
- Medical surveillance
- Exposure controls
 - Engineered controls
 - Work practices
 - Personal protective equipment (PPE)

Source: 29 CFR 1910.120

THRESHOLD LIMIT VALUES

Not intended for use:

- As a relative index of toxicity
- In the evaluation or control of community air pollution nuisances
- In estimating the toxic potential of continuous, uninterrupted exposures or other extended work periods

Source: ACGIH TLVs and BEIs for 1993-1994

THRESHOLD LIMIT VALUES

Not intended for use:

- As proof or disproof of an existing disease or condition
- For adoption by countries whose working conditions differ from those in the United States of America and where substances and processes differ

Source: ACGIH TLVs and BEIs for 1993-1994

NOTES

ENVIRONMENTAL EXPOSURE LIMITS

- U.S. EPA
 - National Ambient Air Quality Standards Program (NAAQS)
- State/Local
 - NAAQS
 - Modified TLVs
 - Risk assessment

ACTION GUIDE

- The chemical concentration or instrument reading at which a specific action should be taken
- Sources:
 - EPA Standard Operating Safety Guides (SOSGs)
 - OSHA standards for specific chemicals may require an action (e.g., medical monitoring) if one-half the PEL is reached (action level)

EPA ACTION GUIDES Combustible Gas Indicator

Level	Action
<10% LEL (<5%)*	Continue monitoring with caution
10-25% LEL	Continue monitoring, but with extreme caution
>25% LEL (>5%)*	Explosion hazard! Withdraw from area immediately.

* Confined space

NOTES

EPA ACTION GUIDES Oxygen Concentration

Level	Action
<19.5%	Monitor wearing SCBA.
19.5-25%	Continue monitoring with caution. SCBA not needed based only on oxygen content.
>25%	Discontinue monitoring. Fire potential! Consult specialist.

EXPOSURE LIMITS AND ACTION LEVELS

INTRODUCTION

It is necessary, for response activities involving hazardous materials, to acknowledge and plan that response personnel may become exposed. Most hazardous materials have levels of exposure that can be tolerated without adverse health effects. However, it is imperative to determine:

- The identity of materials involved
- The type and extent of exposure
- The possible health effects from overexposure
- The exposure limits and/or action levels considered safe for each hazardous material encountered.

SOURCES FOR EXPOSURE LIMITS FOR AIRBORNE CONTAMINANTS

Several organizations have proposed exposure limits for chemicals and other hazards. The Occupational Safety and Health Administration (OSHA) is one such organization. It is charged with protecting the health and safety of workers. In 29 CFR 1910.120, the *Hazardous Waste Operations and Emergency Response* standard, OSHA specifies the use of certain exposure limits. The exposure limits that are specified are OSHA's permissible exposure limits (PELs) and "published exposure levels." The published exposure levels are used when no PEL exists. A published exposure level is defined as:

the exposure limits published in "NIOSH Recommendations for Occupational Health Standards" dated 1986 incorporated by reference. If none is specified, the exposure limits published in the standards specified by the American Conference of Governmental Industrial Hygienists in their publication "Threshold Limit Values and Biological Exposure Indices for 1987-88" dated 1987 incorporated by reference. (29 CFR 1910.120 (a)(3))

Organizations that have developed exposure limits are discussed below. Not all of these groups are specifically mentioned in 1910.120. Many of the following organizations have exposure guidelines for exposures to hazards other than airborne contaminants (e.g. heat stress, noise, radiation). This part will deal only with airborne chemical exposures.

Occupational Safety and Health Administration

In 1971, the OSHA promulgated PELs. These limits were extracted from the 1968 American Conference of Governmental Industrial Hygienists' (ACGIH) threshold limit values (TLVs), the American National Standards Institute (ANSI) standards, and other federal standards. The PELs are found in 29 CFR 1910.1000. Since then, additional PELs have been adopted and a few of the

originals have been changed. These initial changes have been incorporated into specific standards for chemicals (e.g., 29 CFR 1910.1028 - benzene). There are also standards for 13 carcinogens for which there is no allowable inhalation exposure.

OSHA is a regulatory agency. Therefore, its PELs are legally enforceable standards and apply to all private industries and federal agencies. Depending on state or local laws, the PELs may also apply to state and local employees.

National Institute for Occupational Safety and Health

NIOSH was formed at the same time as OSHA. NIOSH conducts scientific research and recommends occupational safety and health standards. The exposure levels NIOSH has researched have been used to develop new OSHA standards. However, many recommended exposure limits (RELs) have not been adopted by OSHA. Unless OSHA adopts NIOSH RELs into a standard (like 1910.120), they are only recommendations. The RELs are found in the *NIOSH Recommendations for Occupational Health Standards*.

NIOSH also publishes criteria documents that provide information on handling specific chemicals. These documents also provide rationale for the chemical's exposure limit. Additionally, NIOSH publishes immediately dangerous to life or health (IDLH) values in its *Pocket Guide to Chemical Hazards*. IDLHs will be discussed later.

American Conference of Governmental Industrial Hygienists

One of the first groups to develop exposure limits was ACGIH. In 1941, ACGIH suggested the development of maximum allowable concentrations (MACs) for use by industry. A list of MACs was compiled by ACGIH and published in 1946. In the early 1960s, ACGIH revised those recommendations and renamed them TLVs.

"Threshold Limit Values (TLVs) refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse health effects." (*Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices*, ACGIH). The publication further states that the TLVs "are developed as guidelines to assist in the control of health hazards. These recommendations or guidelines are intended for use in the practice of industrial hygiene, to be interpreted and applied only by a person trained in this discipline." (Policy Statement on the Uses of TLVs and BEIs).

Along with the TLVs, ACGIH publishes biological exposure indices (BEIs). BEIs are to be used as guides for evaluation of exposure where inhalation is not the only possible route of exposure. Because the TLVs are for inhalation only, they may not be protective if the chemical is ingested or absorbed through the skin. Biological monitoring (e.g., urine samples and breath analysis) can be used to assess the overall exposure. This procedure uses information about what occurs in the body (e.g., metabolism of benzene to phenol) to determine if there has been an unsafe exposure. The BEIs serve as a reference for biological monitoring just as TLVs serve as a reference for air monitoring.

The TLVs are reviewed yearly and are published in ACGIH's *Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices*.

American Industrial Hygiene Association (AIHA)

The AIHA has provided guidance for industrial hygienists for many years. In 1984, AIHA developed exposure guidelines that it calls Workplace Environmental Exposure Level Guides (WEELs®). These are reviewed and updated each year. Although the list is not as large as others, AIHA has chosen chemicals for which other groups have not developed exposure limits. Thus, they are providing information to fill the gaps in information sources.

Other Organizations

In the United States, the Army and Air Force have also developed exposure limits for their purposes. The Mine Safety and Health Administration (MSHA) has health standards for air contaminants that may be encountered during mining activities.

Other countries have also developed exposure limits. An example are the Federal Republic of Germany's maximum concentrations at the workplace (MAKs). They can be found in ACGIH's *Guide to Occupational Exposure Values* along with PELs, RELs, and TLVs.

Even though the other organizations are not part of the list of published exposure limits in 1910.120, they are sources that may be useful. 1910.120 (g) suggests looking at published literature and material safety data sheets (MSDS) if PELs or published exposure limits do not exist.

TYPES OF EXPOSURE GUIDELINES

Although there are different organizations that develop exposure guidelines, the types of guidelines they produce are similar.

Time-Weighted Average (TWA)

A TWA exposure limit is the average concentration of a chemical most workers can be exposed to during a 40-hour work week and a normal 8-hour work day without showing any toxic effects. Some TWA exposure limits (e.g., NIOSH) can also be used to evaluate exposures up to 10 hours. The TWA permits exposure to concentrations above the limit, provided these excursions are compensated by equivalent exposure below the TWA. **Figure 1** shows an example that illustrates this point for a chemical (e.g., acetone) with a TWA exposure limit of 750 ppm.

A TWA exposure is determined by averaging the concentrations during the different exposure periods over an 8-hour period with each concentration weighted based on the duration of exposure. For example, an exposure to acetone at the following concentrations and durations would have an 8-hour TWA exposure of:

- 1500 ppm for 1 hour
- 500 ppm for 3 hours
- 200 ppm for 4 hours

$$\frac{(1 \text{ hr})(1500 \text{ ppm}) + (3 \text{ hrs})(500 \text{ ppm}) + (4 \text{ hrs})(200 \text{ ppm})}{8 \text{ hrs}} =$$

$$\frac{1500 \text{ ppm} + 1500 \text{ ppm} + 800 \text{ ppm}}{8} = 475 \text{ ppm}$$

This exposure would be compared to an 8-hour TWA exposure limit.

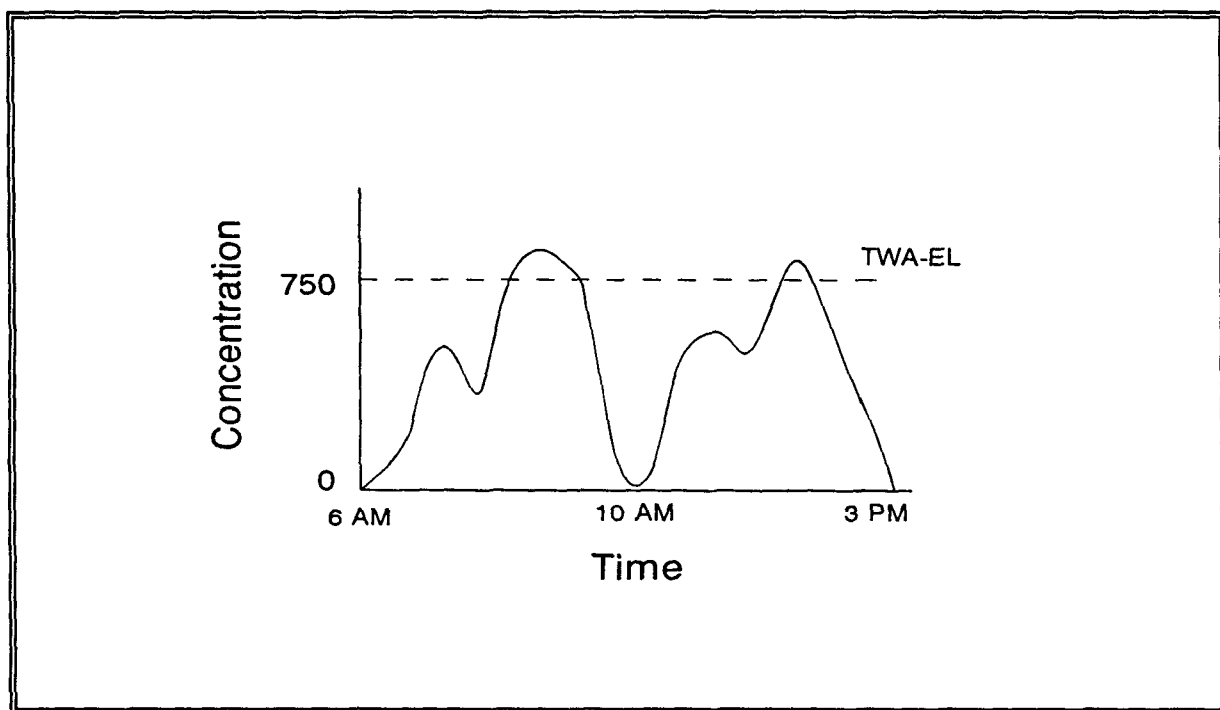


FIGURE 1. EXAMPLE OF AN EXPOSURE COMPARED TO A TWA EXPOSURE LIMIT

Short-Term Exposure Limit (STEL)

The excursions allowed by the TWA exposure could involve very high concentrations. This might cause an adverse effect but still be within the allowable average. Therefore, some organizations felt there was a need to limit these excursions. OSHA, NIOSH, and ACGIH define the STEL as a 15-minute TWA exposure limit. ACGIH has the additional stipulation that excursions to the STEL should not be longer than 15 minutes in duration, should be at least 60 minutes apart, and should not be repeated more than 4 times per day. **Figure 2** illustrates an exposure that does not exceed the

15-minute limit for an STEL of 1000 ppm (note that in the previous example of an 8-hour TWA calculation, the acetone STEL was exceeded but the TWA was not).

The STEL supplements the TWA and does not replace it. Both exposure limits should be used. The STEL reflects an exposure limit protecting against acute effects from a substance which primarily exhibits chronic toxic effects. This concentration is set at a level to protect workers against irritation, narcosis, and irreversible tissue damage.

AIHA has some short-term TWAs that are similar to the STELs. The times used vary from 1 to 30 minutes. These short-term TWAs are used in conjunction with, or in place of, the 8-hour TWA. There is no limitation on the number of these excursions or the rest period between each excursion.

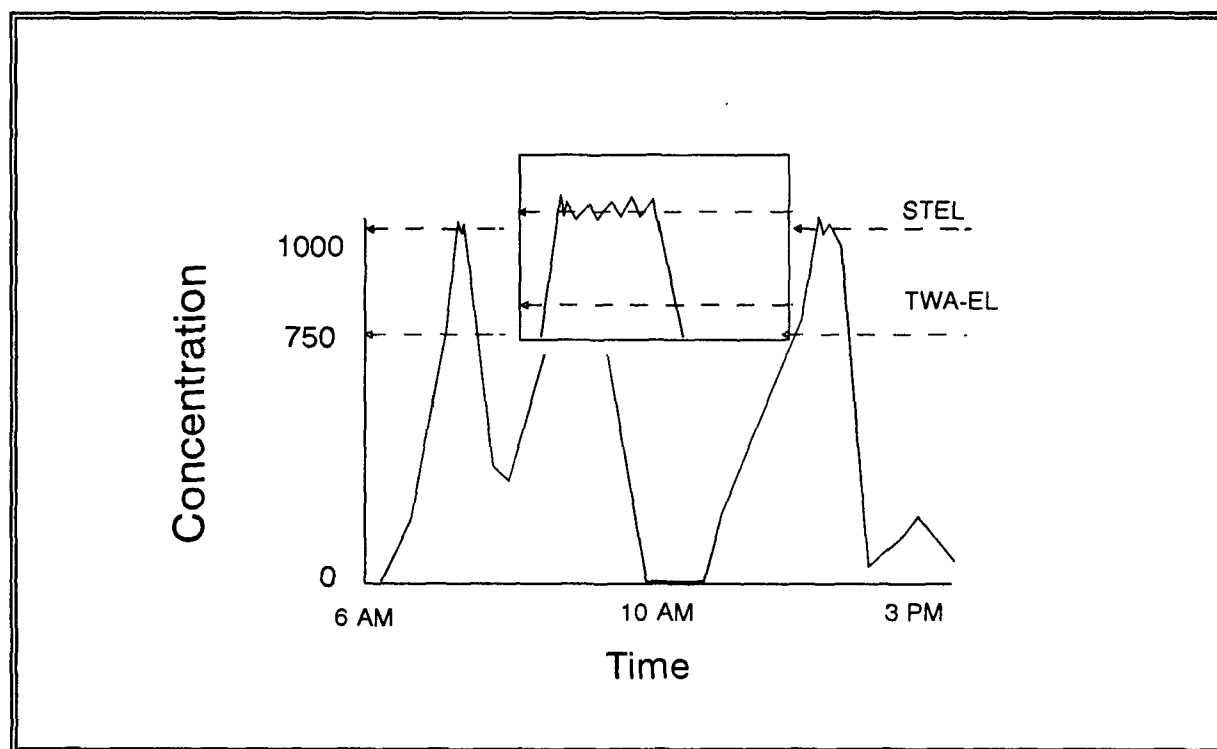


FIGURE 2. EXAMPLE OF AN EXPOSURE COMPARED TO AN STEL AND A TWA

Ceiling (C)

Ceiling values exist for substances for which exposure could result in a rapid and specific response. The ceiling is that concentration that should not be exceeded during any part of the work day. If instantaneous monitoring is not feasible, the ceiling shall be assessed as a 15-minute TWA exposure (unless otherwise specified) that shall not be exceeded at any time during a work day. A ceiling value is denoted by a "C" preceding the exposure limit.

Figure 3 illustrates an exposure that exceeds a ceiling value of 5 ppm.



protection. The inhalation exposure limit is designed for exposures only from inhalation. If additional routes of exposure are added, there can be detrimental effects even if the inhalation exposure limit is not exceeded.

Immediately Dangerous to Life or Health (IDLH)

As defined in the NIOSH *Pocket Guide to Chemical Hazards*, "IDLH concentrations represent the maximum concentration from which, in the event of respirator failure, one could escape within 30 minutes without a respirator and without experiencing any escape-impairing or irreversible health effects." Although 30 minutes is stated in the definition, this is not a 30 minute allowable exposure limit. NIOSH's purpose in developing this IDLH was for respirator selection.

Other organizations, such as ANSI, OSHA, and MSHA, have similar definitions for IDLH, but not always the same application. It is accepted by all of these groups that IDLH conditions include 1) toxic concentrations of contaminants, 2) oxygen-deficient atmospheres, and 3) explosive, or near-explosive (above, at, or near the lower explosive limits), environments.

Guidelines for potentially explosive, oxygen-deficient, or radioactive environments can be found in the EPA's *Standard Operating Safety Guides* and the NIOSH/OSHA/USCG/EPA publication entitled *Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities*.

At hazardous material incidents, IDLH concentrations should be assumed to represent concentrations above which only workers wearing respirators that provide the maximum protection (i.e., a positive-pressure, full-facepiece, self-contained breathing apparatus [SCBA] or a combination positive-pressure, full-facepiece, supplied-air respirator with positive-pressure escape SCBA) are permitted. Specific IDLH concentration values for many substances can be found in the NIOSH *Pocket Guide to Chemical Hazards*. For some chemicals, NIOSH gives a "Ca" designation along with a concentration for IDLH. Ca denotes those chemicals that NIOSH considers to be potential human carcinogens. NIOSH recommends the highest level of respiratory protection for exposure to these substances, even below IDLH. However, carcinogenic effects were not considered when developing the IDLH concentrations.

MIXTURES

The exposure limits that have been discussed are based on exposure to single chemicals. Because many exposures include more than one chemical, values are adjusted to account for the combination. When the effects of the exposure are considered to be additive, a formula can be used to determine whether total exposure exceeds the limits. The following calculation is used:

$$E_m = (C_1 \div L_1) + (C_2 \div L_2) + \dots (C_n \div L_n)$$

where:

- E_m = the equivalent exposure for the mixture
- C = the concentration of a particular contaminant
- L = the exposure limit for that substance.

The value of E_m should not exceed unity (1).

An example using this calculation would be as follows:

Chemical A $C = 500$ ppm; $L = 750$ ppm (TWA)
Chemical B $C = 200$ ppm; $L = 500$ ppm (TWA)
Chemical C $C = 50$ ppm; $L = 200$ ppm (TWA)

$$\begin{aligned} E_m &= (500 \div 750) + (200 \div 500) + (50 \div 200) \\ E_m &= 0.67 + 0.40 + 0.25 \\ E_m &= 1.3 \end{aligned}$$

Because E_m exceeds unity, the exposure combination may be a problem. The next step should be to determine whether exposure limits are based on similar effects. This calculation applies to chemicals where the effects are the same and are additive. If the combination is not additive, the calculation is not appropriate. Also, mixing TWA, STEL, and ceiling limits in this equation is not appropriate.

APPLICATION OF EXPOSURE GUIDELINES

OSHA's *Hazardous Waste Operations and Emergency Response* standard specifies uses for exposure limits.

Site Characterization

29 CFR 1910.120 (c) (3) requires identification of IDLH conditions during site characterization. 29 CFR 1910.120 (h) (3) requires air monitoring upon initial entry to identify IDLH conditions, other dangerous conditions, and exposures over the exposure limits.

Medical Surveillance

29 CFR 1910.120 (f) (2) (i) requires a medical surveillance program for all employees exposed to substances or hazards above the PEL for 30 or more days per year. If there is no PEL, then the published exposure levels are used for evaluation. The exposures are considered even if a respirator was being used at the time of exposure.

Exposure Controls

Engineered Controls and Work Practices

29 CFR 1910.120 (g) (1) (i) states "Engineering controls and work practices shall be instituted to reduce and maintain employee exposure to or below the permissible exposure limits for substances regulated by 29 CFR Part 1910, to the extent required by Subpart Z, except to the extent that such

controls and practices are not feasible." [emphasis added] Whenever engineering controls and work practices are not feasible, personal protective equipment shall be used to reduce and maintain exposures.

For those substances or hazards where there is no PEL, the published exposure levels are used. If there are no PELs or published exposure limits, published literature and MSDS may be used for evaluation. In these circumstances, a combination of engineering controls, work practices, and personal protective equipment (PPE) shall be used to reduce and maintain exposures.

Personal Protective Equipment

Because the selection of PPE must be based on the hazards present at the site, the exposure limits are used to evaluate the appropriate PPE. Comparing the actual or expected exposure to the PEL or other exposure limits gives the wearer information on selection of the proper PPE.

LIMITATIONS AND RESTRICTIONS OF USE

The exposure guidelines discussed in this section are based on industrial experience, experimental human studies, experimental animal studies, or a combination of the three. The guidelines were developed for workers in the industrial environment. Thus, they are not meant to be used for other purposes. ACGIH in its *Threshold Limit Values and Biological Exposure Indices* states:

These limits are intended for use in the practice of industrial hygiene as guidelines or recommendations in the control of potential health hazards and for no other use, e.g., in the evaluation or control of community air pollution nuisances; in estimating the toxic potential of continuous, uninterrupted exposures or other extended work periods; as proof or disproof of an existing disease or physical condition; or adoption by countries whose working conditions differ from those in the United States of America and where substances and processes differ. These limits *are not* fine lines between safe and dangerous concentration nor are they a relative index of toxicity. They *should not* be used by anyone untrained in the discipline of industrial hygiene.

As can be seen from this qualifier, these exposure limits are not intended as exposure limits for exposure to the public.

There is the limitation on the use of the exposure guideline as a relative index of toxicity. This is because the exposure limits are based on different effects for different chemicals. For example, the TLV-TWA for acetone is chosen to prevent irritation to the eyes and respiratory system. The TLV-TWA for acrylonitrile is chosen to reduce the risk to cancer. Exposures to these chemicals at other concentration levels could lead to other effects. Thus, when evaluating the risk of chemical exposure, consult the documentation for the exposure limit along with other toxicological data.

NON-OCCUPATIONAL EXPOSURE LIMITS

As mentioned earlier, the occupational exposure limits are not intended for use in evaluating public health hazards. However, they are often used because there may not be anything else available. In other situations, a group may feel that the exposure may be for a short duration and the occupational exposure limits are adequate. For example, many computer air dispersion models for emergency response use the TLVs as action levels.

Some agencies have applied modifiers to the occupational exposure limits to adjust them for public health use. These modifiers may include adjustments for exposure time (168 hours for the public compared to 40 hours for occupational situations) and safety factors for sensitive populations (dividing the exposure limit by 10). While groups like ACGIH discourage this application of their data, the users argue that modification of human data is preferred to extrapolation of animal data.

In some cases, ambient air quality standards or guidelines have been developed for application to public exposure. The federal government and many states have developed them. They are based on modification of occupational exposure limits, risk assessment data, or both. EPA has developed national ambient air quality standards in response to the Clean Air Act. The current list is very limited and only some chemicals (e.g., lead and particulates) are applicable to waste sites.

In the risk assessment approach for chemical exposure, it is recognized that the public exposure to a chemical may involve more than one route of exposure. With this approach, it is not appropriate to use just an inhalation exposure limit. Results from air sampling are combined with other sample results (e.g., drinking water and soil) to determine total exposure and risk.

ACTION LEVELS

Action levels can be developed for specific chemicals, hazards, or situations. The concept of an action level is that if the action level is not exceeded, then there is little probability that a hazardous exposure will occur.

In some of its specific standards, OSHA uses an action level that is one-half of the PEL. For example, the action level for benzene is 0.5 ppm calculated as an 8-hour TWA. If this level is exceeded, continual air monitoring and medical surveillance can be required.

EPA in its *Standard Operating Safety Guides* gives actions to take if certain instrument readings (levels) are obtained during monitoring. These are listed in **Table 1**.

In some situations, site-specific action levels for direct-reading instruments may be developed. This is done by using knowledge about what chemicals are present on the site and the instrument's response to the chemicals. Whereas this may not be as accurate as using special monitoring equipment and laboratory analysis, it allows rapid response to a potentially hazardous situation.

CONCLUSION

There are many sources for exposure limits and action levels. Some of these are legal requirements; some are guidelines. The goal is to use these numbers to protect personnel working with hazardous materials.

TABLE 1. ATMOSPHERIC HAZARD ACTION GUIDES

Monitoring Equipment	Atmospheric Hazard ^a	Level	Action
Combustible gas indicator	Explosive	< 10% LEL	Continue monitoring with caution.
		10–25% LEL	Continue monitoring, but with extreme caution, especially as higher levels are encountered.
		≥ 25% LEL	Explosion hazard! Withdraw from area immediately.
Oxygen concentration		< 19.5%	Monitor wearing SCBA. <i>Note:</i> Combustible gas readings not valid in atmospheres with less than 19.5% oxygen.
		19.5–25%	Continue monitoring with caution. SCBA not needed based <u>only</u> on oxygen content.
		> 25%	Discontinue monitoring. Fire potential! Consult specialist.
Radiation survey instrument	Gamma radiation	Above background:	
		< 1 mR/hr	Continue monitoring. Consult a Health Physicist.
		≥ 1 mR/hr	Withdraw. Continue monitoring only upon the advice of a Health Physicist.
Colorimetric tubes	Organic and inorganic vapors/gases	Depends on chemical	Consult reference manuals for air concentration vs. PEL/TLV and toxicity data.
Photoionization detector	Organic vapors/gases	Depends on chemical	Consult reference manuals for air concentration vs. PEL/TLV and toxicity data.
Flame ionization detector	Organic vapors/gases	Depends on chemical	Consult reference manuals for air concentration vs. PEL/TLV and toxicity data.

^a Hazard classes are general and not all compounds in these classes can be measured by realtime instruments.

Note: The correct interpretation of any instrument readout is difficult. If the instrument operator is uncertain of the significance of a reading, especially if conditions could be unsafe, a technical specialist should immediately be consulted. Consideration should be given to withdrawing personnel from the area until approval by the safety officer is given to continue operations.

OXYGEN MONITORS, COMBUSTIBLE GAS INDICATORS, AND SPECIFIC CHEMICAL MONITORS

PERFORMANCE OBJECTIVES

At the end of this lesson, participants will be able to:

- Identify the purpose for oxygen monitoring
- List the four factors that can affect oxygen monitor response
- Identify the purpose for combustible gas monitoring
- List the four factors that can affect combustible gas indicator response
- Identify the purpose of toxic atmosphere monitoring
- List three types of toxic atmosphere monitors
- List four types of specific chemical monitors
- List four factors that can affect the response of specific chemical monitors.

NOTES

OXYGEN MONITORS, COMBUSTIBLE GAS INDICATORS, AND SPECIFIC CHEMICAL MONITORS

HAZARDS

- Oxygen-deficient atmospheres
- Combustible/explosive atmospheres
- Toxic atmospheres
- Radiation

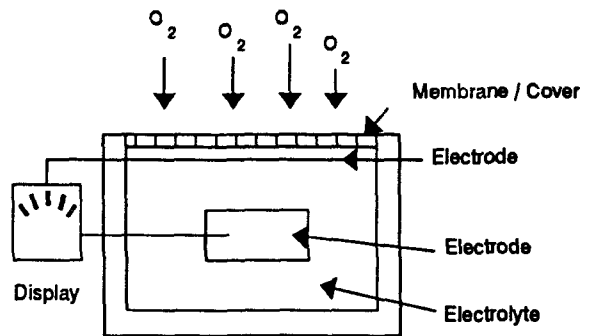
OXYGEN MONITORING

Aid in determining:

- Type of respirator needed
- Flammability risk
- Sufficient oxygen for combustible gas indicators (CGIs)
- Presence of contaminants

NOTES

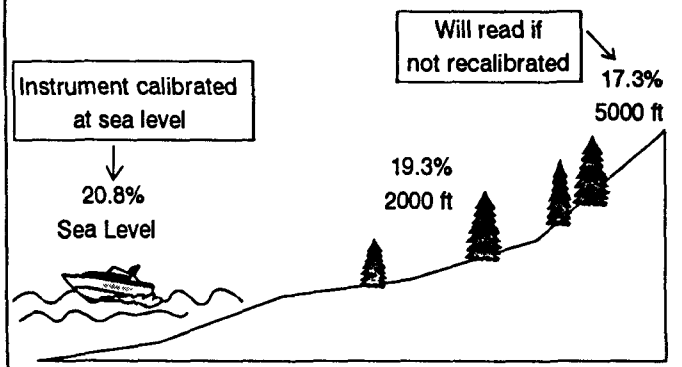
OXYGEN SENSOR



OXYGEN MONITORS Considerations

- Life span
- Operating temperature
- Interfering gases
- Atmospheric pressure

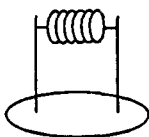
ALTITUDE/OXYGEN METER READING



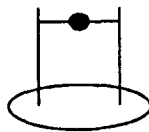
FLAMMABLE ATMOSPHERE MONITORING

- Used to determine risk of fire or explosion
- CGI readings are indicative of relatively high concentrations of contaminants

COMBUSTIBLE GAS INDICATORS Catalytic Sensors

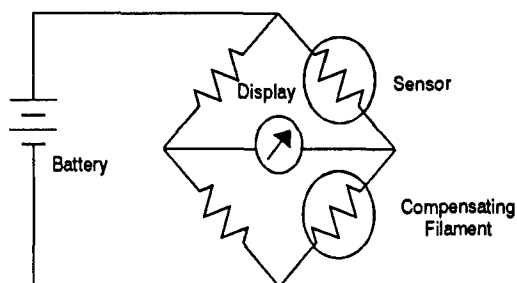


Filament



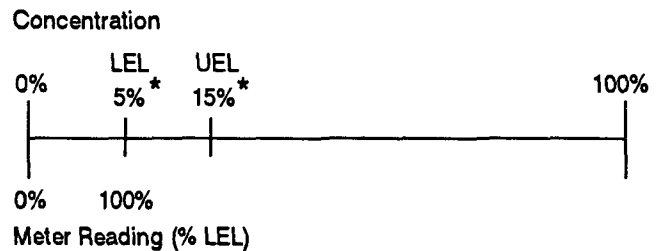
Bead

COMBUSTIBLE GAS INDICATORS Wheatstone Bridge Circuit



NOTES

COMBUSTIBLE GAS INDICATORS Instrument Reading vs Concentration

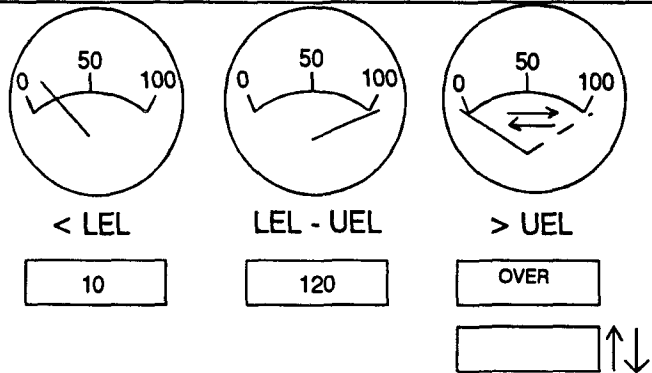


Note: * = methane

LEL = lower explosive limit

UEL = upper explosive limit

COMBUSTIBLE GAS INDICATORS Readouts



COMPARISON OF LEL READINGS WITH ACTUAL CONCENTRATIONS

Hexane LEL = 1.1%

For an instrument calibrated to hexane measuring hexane:

100% = 1.1% (11,000 ppm)

50% = 0.55% (5,500 ppm)

25% = 0.275% (2,750 ppm)

10% = 0.11% (1,100 ppm)

1% = 0.011% (110 ppm)

NOTES

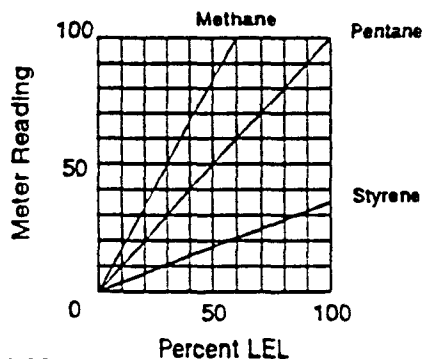
COMBUSTIBLE GAS INDICATORS Readout Ranges

- "Normal" units
 - 0 - 100% LEL
 - 0 - 10% LEL
- "Supersensitive" units
 - Parts per million (ppm)
 - Example: TLV Sniffer, Gastech Model 1314

COMBUSTIBLE GAS INDICATORS Considerations

- Oxygen requirements
- Contaminants that foul sensor
- Temperature
- Relative response

COMBUSTIBLE GAS INDICATORS Relative Response Curves



Source: MSA 260

NOTES

TOXIC ATMOSPHERE MONITORING

The purpose of monitoring is to:

- Identify chemicals and their concentrations
- Evaluate worker/public exposures
- Evaluate protective equipment selection
- Help develop exposure controls

TOXIC ATMOSPHERE MONITORS

- Specific chemical monitors
- Total vapor survey monitors
- Gas chromatographs
- Aerosol monitors

SPECIFIC CHEMICAL MONITORS

- Designed to respond to a specific chemical
- Common types include
 - Electrochemical
 - Metal-oxide semiconductor (MOS)
 - Colorimetric indicators
 - Mercury detectors

NOTES

METAL-OXIDE SEMICONDUCTOR (MOS)

- Metal-oxide coating on a ceramic substrate wrapped around a wire
- Contaminant alters conductivity by removing oxygen
- Change in current is proportional to the amount of contaminant present
- Also called "solid-state" sensor

MOS Considerations

- Interferences
- Saturation
- Temperature
- Minimum oxygen requirements

COLORIMETRIC INDICATORS

Contaminant reacts with a chemical on a tape, badge, or tube and causes a color change

NOTES

COLORIMETRIC INDICATORS Considerations

- Interferences
- Humidity
- Temperature

MERCURY DETECTORS

- Ultraviolet light absorption
 - Mercury vapor absorbs a specific wavelength of light
- Gold film
 - Mercury reacts with film and changes the electrical resistance of the film

MERCURY DETECTORS Considerations

- Ultraviolet light
 - Interferences
 - Humidity
- Gold film
 - Factory calibration
 - AC power needed to "clean"

OXYGEN MONITORS, COMBUSTIBLE GAS INDICATORS, AND SPECIFIC CHEMICAL MONITORS

INTRODUCTION

Many hazards may be present when responding to hazardous materials spills or uncontrolled waste sites. These include oxygen-deficient atmospheres, combustible/explosive atmospheres, toxic atmospheres, and radiation. There are several types of instrumentation for detecting hazardous atmospheres. This section will discuss oxygen monitors, combustible gas indicators (CGIs), and monitors for specific chemicals.

OXYGEN MONITORS

Oxygen monitors are used to evaluate an atmosphere for:

- Oxygen content for respiratory purposes. Normal air contains 20.8% oxygen. Generally, if the oxygen content decreases below 19.5%, it is considered oxygen-deficient and special respiratory protection is needed.
- Increased risk of combustion. Generally, concentrations above 25% are considered oxygen enriched and increase the risk of combustion.
- Use of other instruments. Some instruments require sufficient oxygen for operation. For example, CGIs do not give reliable results at oxygen concentrations below 10%. Also, the inherent safety approvals for instruments are for normal atmospheres and not for oxygen-enriched ones.
- The presence of contaminants. A decrease in oxygen content can be due to the consumption (by combustion or a reaction such as rusting) of oxygen or the displacement of air by a chemical. If it is due to consumption, then the concern is the lack of oxygen. If it is due to displacement, then there is something present that could be flammable or toxic. Because oxygen makes up only 20.8% of air, a 1% drop in oxygen means that about 5% air (air being 1 part oxygen and 4 parts nitrogen) has been displaced. This means that 5% or 50,000 ppm (1% = 10,000 ppm) of "something" could be there.

Most indicators have meters that display the oxygen concentration from 0 to 25%. There are also oxygen monitors available that measure concentrations from 0 to 5% and from 0 to 100%. The most useful range for hazardous material response is the 0–25% oxygen content readout because decisions involving air-supplying respirators and the use of CGIs fall into this range.

The oxygen sensor can be on the outside (external) or inside (internal) of the instrument. Internal sensors need a pump—battery operated or hand operated—to draw a sample to it. Units that combine O₂ meters and CGIs into one instrument are available from many manufacturers. Also, flashing and audible alarms can be found on many instruments. These alarms go off at a preset oxygen

concentration to alert the users even if they are not watching the meter. A list of manufacturers of oxygen monitors is found in this manual under *Manufacturers and Suppliers of Air Monitoring Equipment*.

Principle of Operation

Oxygen monitors use an electrochemical sensor to determine the oxygen concentration in air. A typical sensor consists of two electrodes, a housing containing a basic electrolytic solution, and a semipermeable Teflon® membrane (Figure 1).

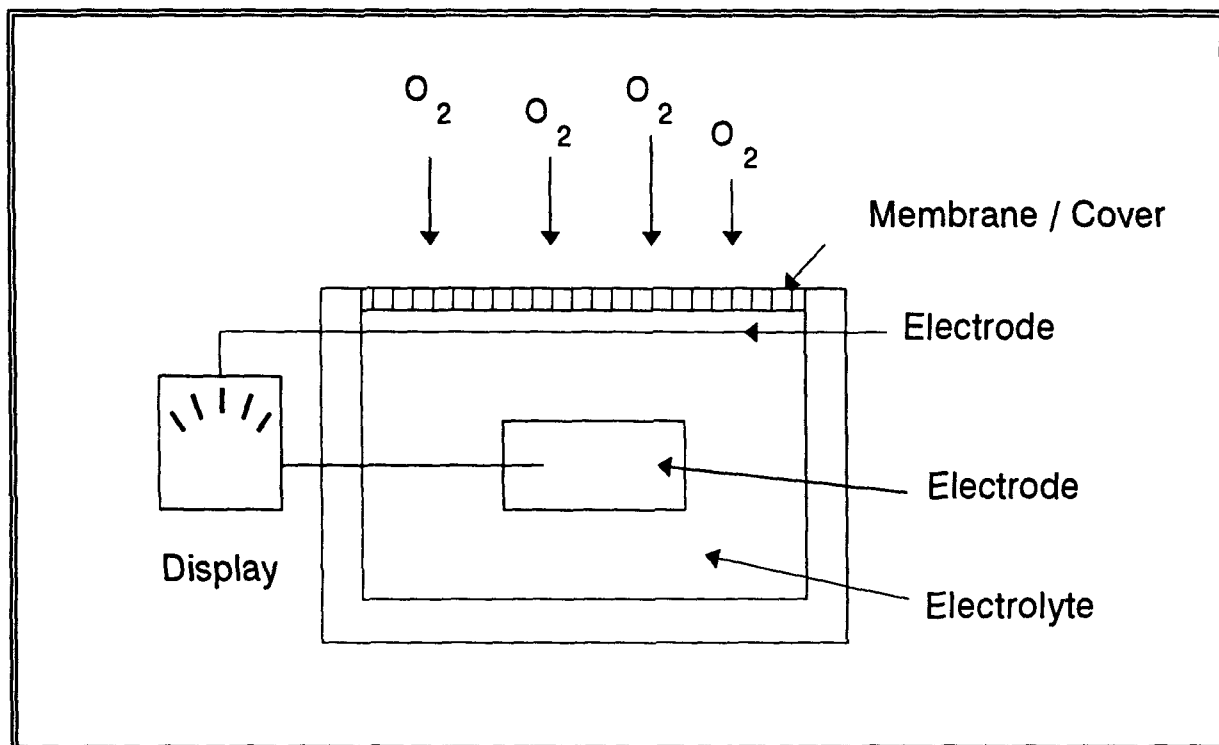


FIGURE 1. SCHEMATIC OF OXYGEN SENSOR

Source: *Atmospheric Monitoring for Employee Safety*, BioMarine Industries Inc.

Oxygen molecules (O_2) diffuse through the membrane into the solution. Reactions between the oxygen, the solution, and the electrodes produce a minute electrical current proportional to the oxygen content. The current passes through an electronic circuit which amplifies the signal. The resulting signal is shown as a needle deflection on a meter or as a digital reading.

In some units, air is drawn into the oxygen detector with an aspirator bulb or pump; in other units, the ambient air is allowed to diffuse to the sensor.

Limitations and Considerations

The operation of oxygen monitors depends on the absolute atmospheric pressure. The concentration of atmospheric oxygen is a function of the atmospheric pressure at a given altitude. Whereas the actual percentage of oxygen does not change with altitude, at sea level the weight of the atmosphere above is greater, and more O₂ molecules (and the other components of air) are compressed into a given volume than at higher elevations. As elevation increases, this compression decreases, resulting in fewer air molecules being "squeezed" into a given volume. Consequently, an O₂ indicator calibrated at sea level and operated at an altitude of several thousand feet will falsely indicate an oxygen-deficient atmosphere because less oxygen is being "pushed" into the sensor. Therefore, it is necessary to calibrate at the altitude the instrument is used.

The reaction that produces the current in the sensor is nonreversible. Thus, once the sensor is exposed to oxygen, it begins to wear out. The normal life span of a sensor is 6 months to 1 year. Sensors are shipped in sealed packages that have been purged with nitrogen. The packet should not be opened until the sensor is to be used. Storing the sensor in an oxygen absent atmosphere after opening the package can prolong the sensor life, but may not be practical.

High concentrations of carbon dioxide (CO₂) may shorten the useful life of the oxygen sensor. As a general rule, the unit can be used in atmospheres greater than 0.5% CO₂ only with frequent replacing or rejuvenating of the sensor. Lifetime in a normal atmosphere (0.04% CO₂) can be from 6 months to 1 year depending on the manufacturer's design. The service life of one sensor is 100 days in 1% CO₂ and 50 days in 5% CO₂.

Strong oxidizing chemicals, like ozone and chlorine, can cause increased readings and indicate high or normal O₂ content when the actual content is normal or even low.

Temperature can affect the response of oxygen indicators. The normal operating range for them is between 32°F and 120°F. Between 0°F and 32°F the response of the unit is slower. Below 0°F the solution may freeze and damage the sensor. High temperature can also shorten the sensor life. The instrument should be calibrated at the temperature at which it will be used.

COMBUSTIBLE GAS INDICATORS

CGIs measure the concentration of a flammable vapor or gas in air, indicating the results as a percentage of the lower explosive limit (LEL) of the calibration gas. The LEL (or LFL - lower flammable limit) of a combustible gas or vapor is the minimum concentration of the material in air which will propagate flame on contact with an ignition source. The upper explosive limit (UEL) is the maximum concentration. Below the LEL there is insufficient fuel to support combustion. Above the UEL, the mixture is too "rich" to support combustion, so ignition is not possible. Concentrations between the LEL and UEL are considered flammable.

CGIs are available in many styles and configurations. The combustible gas sensor can be on the outside (external) or inside (internal) of the instrument. Internal sensors need a pump—battery operated or hand operated—to draw a sample to it. Many units are "combination meters." This means they have an O₂ meter and a CGI (and sometimes one or two specific gas indicators)

combined in the same instrument. Flashing and audible alarms are options on many units. The alarms go off at a preset concentration to warn the instrument operator of potentially hazardous concentrations. Other options such as longer sampling lines, moisture traps, and dust filters are also available. Manufacturers of CGIs are listed in *Manufacturers and Suppliers of Air Monitoring Equipment*.

Principle of Operation

CGIs use a combustion chamber containing a filament that combusts the flammable gas. To facilitate combustion, the filament is heated or is coated with a catalyst (like platinum or palladium), or both. The filament is part of a balanced resistor circuit called a Wheatstone bridge (Figure 2). The hot filament combusts the gas on the immediate surface of the element, thus raising the temperature of the filament. As the temperature of the filament increases, so does its resistance. This change in resistance causes an imbalance in the Wheatstone bridge. This is measured as the ratio of combustible vapor present compared to the total required to reach the LEL. For example, if the meter reads 50% (or 0.5, depending upon the readout), this means that 50% of the concentration of combustible gas needed to reach a flammable or combustible situation is present. If the LEL for the gas is 5%, then the meter would be indicating that a 2.5% concentration is present. Thus, the typical meter indicates concentration up to the LEL of the gas (Figure 3a).

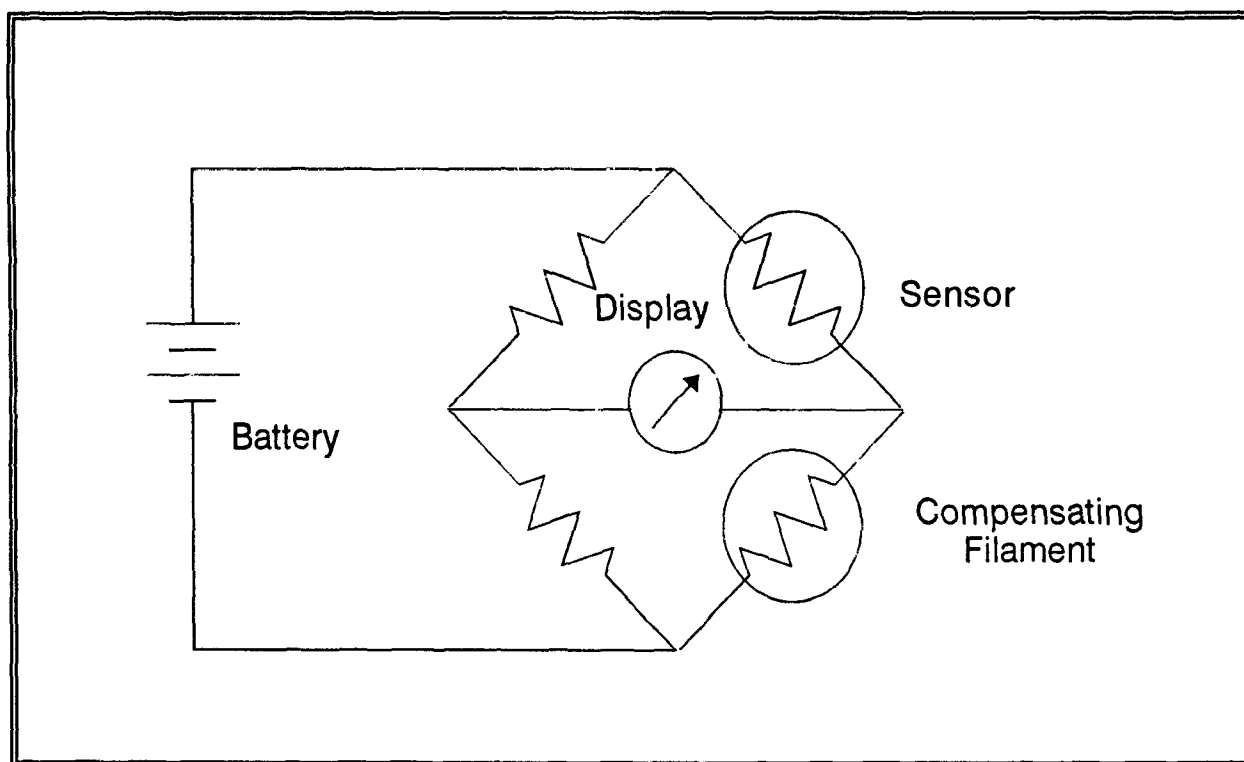


FIGURE 2. WHEATSTONE BRIDGE CIRCUIT

Source: *Atmospheric Monitoring for Employee Safety*, BioMarine Industries Inc.

If a concentration greater than the LEL and lower than the UEL is present, then the meter needle will stay beyond the 100% (1.0) level on the meter (Figure 3b). This indicates that the ambient atmosphere is readily combustible. When the atmosphere has a gas concentration above the UEL, the meter needle may rise above the 100% (1.0) mark and then return to zero (Figure 3c). This occurs because the gas mixture in the combustion cell is too rich to burn. This permits the filament to conduct a current just as if the atmosphere contained no combustibles at all. Some instruments have a lock mechanism that prevents the needle from returning to zero when it has reached 100%. This mechanism must be reset in an atmosphere below the LEL.

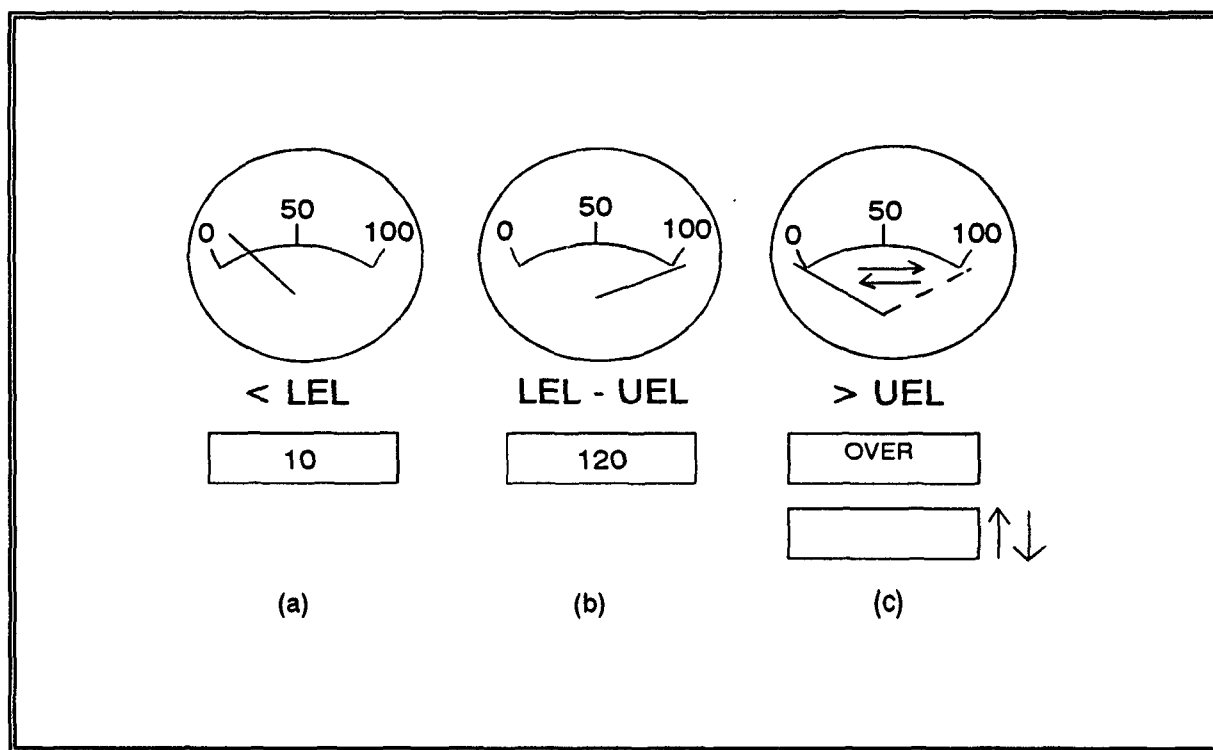


FIGURE 3. COMPARISON OF METER READINGS TO COMBUSTIBLE GAS CONCENTRATIONS

Limitations and Considerations

The instruments are intended for use only in normal oxygen atmospheres. Oxygen-deficient atmospheres will produce lowered readings. Also, the safety guards that prevent the combustion source from igniting a flammable atmosphere are not designed to operate in an oxygen-enriched atmosphere.

Organic lead vapors (e.g., leaded gasoline), sulfur compounds, and silicone compounds will foul the filament. Acid gases (e.g., hydrogen chloride and hydrogen fluoride) can corrode the filament. Most units have an optional filter that protects the sensor from leaded vapors.

The response of the instrument is temperature dependent. If the temperature at which the instrument is zeroed differs from the sample temperature, the accuracy of the reading is affected. Hotter temperatures raise the temperature of the filament and produce a higher than actual reading. Cooler temperatures will reduce the reading. The instrument should be calibrated and zeroed at the same temperature that a reading will be taken. Some instruments have a compensating filament (**Figure 2**). This filament is similar to the sensor and is exposed to the same atmosphere, but it does not combust the atmosphere. It compensates for any temperature changes not caused by the combustible gas.

There is no differentiation between petroleum vapors and combustible gases. If the flammability of the combined vapors and gases in an atmosphere is the concern, this is not a problem. However, if the instrument is being used to detect the presence of a released flammable liquid—like gasoline—in a sewer system where methane may be present, the operator cannot tell whether the reading is the contaminant or the methane. A prefilter can be used to remove the vapors, but it will not remove the methane. Thus, if readings are made with and without the filter, the user can compare the readings and can conclude that differences in the values indicate that a petroleum vapor (i.e., the contaminant) is present.

Relative response is also a concern. If the CGI is used to monitor a gas/vapor that the unit is not calibrated to, it can give inaccurate results. **Figure 4** illustrates the effect of relative response.

TOXIC ATMOSPHERE MONITORS

Along with oxygen concentration and flammable gases or vapors, there is also a concern about chemicals present at toxic concentrations. This usually involves measurements at concentrations lower than what would be indicated by oxygen indicators or CGIs. There is a need to determine whether toxic chemicals are present and identify them so the environmental concentration can be compared to exposure guidelines. Toxic atmosphere monitoring is done to:

- Identify airborne chemicals and their concentrations
- Evaluate the exposure of workers and the public
- Evaluate the need for and type of personal protective equipment
- Develop controls for exposure in the form of engineered safeguards, work practices, safety plans, and work zones.

Several different groups of instruments can be used for these functions. In this manual the following types will be discussed:

- *Specific chemical monitors* are instruments designed to respond to a specific chemical. Common types include instruments that use electrochemical cells or metal-oxide semiconductors (MOS), colorimetric indicators, and mercury detectors.

- *Total vapor survey meters* have detectors (e.g., photoionization detector [PID] or flame ionization detector [FID]) that respond to a variety of chemicals. Additional information can be found in *Total Vapor Survey Instruments*.
- *Gas chromatographs* are used to help identify what chemicals are present in the atmosphere. Additional information is available in *Introduction to Gas Chromatography*.

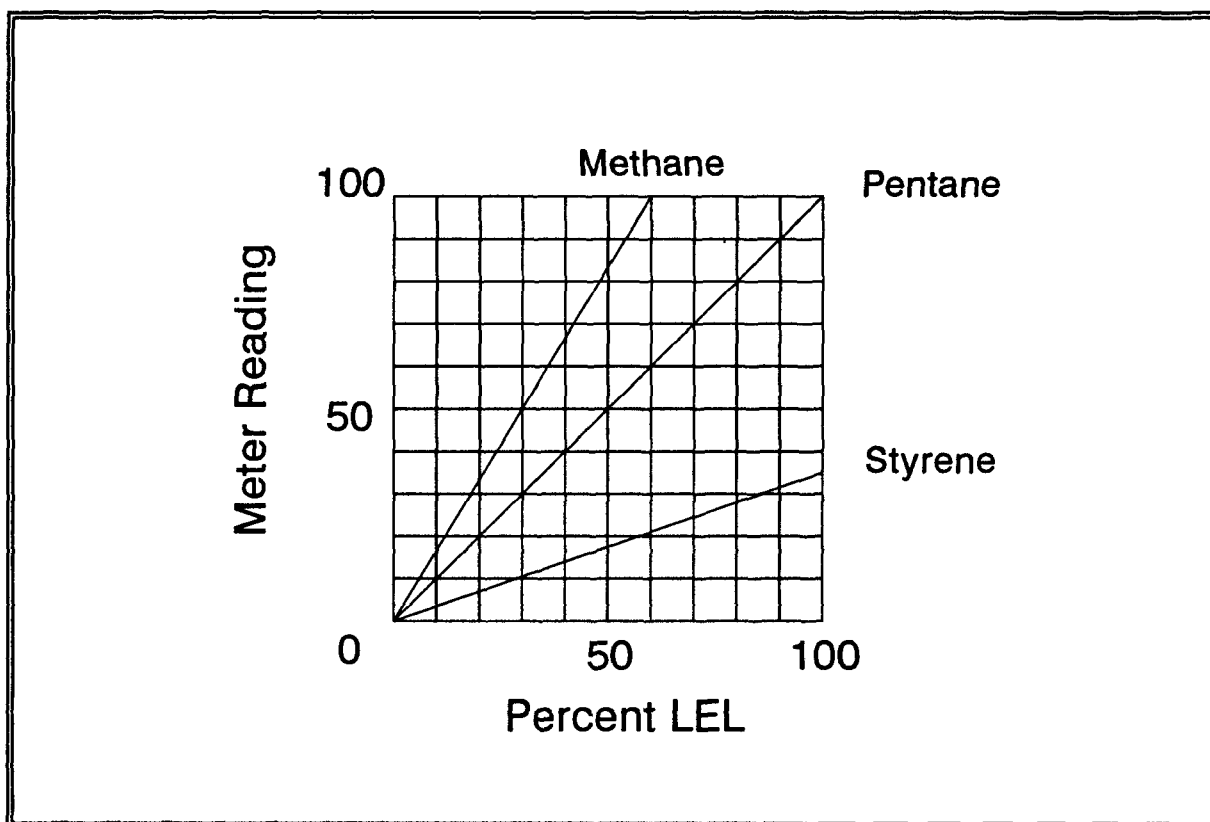


FIGURE 4. EXAMPLES OF RELATIVE RESPONSE CURVES FOR MSA MODEL 260

Source: *Portable Gas Indicator, Model 250 and 260, Response Curves*, Mine Safety Appliances Company, Pittsburgh, PA.

SPECIFIC CHEMICAL MONITORS

Electrochemical Cells

Electrochemical cells (Figure 1) contain a chemical solution and two or more electrodes. The chemical reacts with the solution or the electrodes. The reaction can be a generation of electrical current or a change in conductivity of the solution. The change in signal is expressed as a needle

movement or a digital response on a meter. The selectivity of the sensor depends on the selection of the chemical solution and the electrodes.

In addition to the previously mentioned oxygen monitors (**Figure 1**), there are electrochemical sensors for ammonia, carbon monoxide, carbon dioxide, chlorine, hydrogen chloride, hydrogen cyanide, and hydrogen sulfide. Examples of these instruments are Compur's **Monitox®** Personal Monitor Alarms, MDA's **MSTox 8600** series, and National Draeger's **PAC** series of personal monitors.

Limitations and Considerations

Like the oxygen sensor, these electrochemical sensors also can wear out and are affected by temperature and humidity.

Electrochemical cells are also affected by interferences. For example, many of the carbon monoxide sensors will also respond to hydrogen sulfide. In fact, one manufacturer uses the same sensor for both carbon monoxide and hydrogen sulfide detectors. The user must inform the instrument which chemical is being monitored so the readout is in the proper units.

Metal-Oxide Semiconductors

MOS detectors, also called solid-state sensors, consist of a metal-oxide film coating on heated ceramic substrate fused or wrapped around a platinum wire coil. When a gas comes in contact with the metal oxide, it replaces oxygen in the oxide and alters the conductivity of the semiconductor. The change in conductivity can be expressed in a meter readout. The substrate is heated to give a constant baseline as oxygen in the air can combine with the oxide. Selectivity can be determined by selecting specific metal oxides and/or using specific temperatures from the heater to prevent chemicals from reacting.

There are MOS detectors for ammonia, carbon monoxide, hydrogen chloride, hydrogen cyanide, hydrogen sulfide, methyl chloride, nitrogen oxides, and sulfur dioxide. Examples of instruments that use an MOS to detect specific toxic compounds are the Enmet **Tritechtor®** and Biosystem's **Model 100** series.

Even though the choice of metal oxide and sensor temperature can make the detector somewhat selective, interferences are a major problem.

Because the sensor reaction is based on presence (or absence) of oxygen in the metal-oxide film, factors that affect oxygen concentration affect meter response. The sensor needs a minimum 14% ambient oxygen for operation. High concentrations can saturate the sensor, causing a slow recovery.

A minimum of 10% humidity is need for some sensors (check the manufacturer's specifications).

Colorimetric Indicators

Colorimetric indicators use a chemical to react with the contaminant to produce a color change. The chemical can be impregnated on a tape or a badge or put inside a glass tube. The color change can be read by the human eye or by a spectrophotometer to determine the concentration of the contaminant.

The chemicals are not always specific and can be affected by interfering chemicals. Humidity can act as an interference by producing a reaction. Cold temperatures can slow the chemical reaction. Hot temperatures may also cause the chemicals to indicate a reaction.

Examples of colorimetric indicators are the Envirometrics, Inc. **ACT™ cards** (badges), MDA Scientific's **7100 Series** (tape), and Draeger detector tubes.

Mercury Detectors

Mercury detectors use either ultraviolet light absorption or a gold film detector. Mercury vapor absorbs a certain wavelength of ultraviolet light. The instrument draws a sample into a chamber and exposes it to the ultraviolet light source. The concentration of mercury vapor is measured by the amount of light absorbed.

Some organic chemicals can absorb the ultraviolet light and act as an interference. Water vapor also absorbs ultraviolet light, but can be adjusted for if the instrument is zeroed in the same humidity as the sample area.

The gold film detector has a gold film as part of a circuit. Mercury reacts with the gold and changes the resistance of the film. The change in resistance is used to determine concentration.

Because most operators do not have a mercury vapor standard, the gold film detector must be factory calibrated. After long exposures or high concentrations, the film needs to be "cleaned." This requires heating the film and using an AC power source.

An example of an ultraviolet absorption instrument is the Bacharach **Model MV-2**. An example of a gold film instrument is the Jerome Instruments **Model 411**.

CONCLUSION

Many hazards can be present at a hazardous materials operation. Instruments are available for determining the presence of hazardous situations like combustible atmospheres, oxygen-deficient atmospheres, and toxic atmospheres. The instruments discussed in this section can only identify certain hazardous situations and should be selected and used accordingly. Additional information on identifying and evaluating toxic atmospheres will be discussed in the following sections.

TOTAL VAPOR SURVEY INSTRUMENTS

PERFORMANCE OBJECTIVES

At the end of this lesson, participants will be able to:

- Explain the principle of detection for the PID, FID, supersensitive CGI, and metal-oxide semiconductor (MOS)
- Determine whether a chemical can be detected by photoionization, given the ionization potential of the chemical and the lamp energy of the photoionization detector
- Identify three considerations when using a PID
- Identify three considerations when using a FID
- Identify three consideration when using a supersensitive CGI
- Explain the difference between a CGI and a supersensitive CGI.

TOTAL VAPOR SURVEY INSTRUMENTS

TOTAL VAPOR SURVEY INSTRUMENTS

Instruments using detectors that respond to a wide variety of chemicals and give readings in the parts per million range

WHAT ARE TOTAL VAPOR SURVEY INSTRUMENTS USED FOR?

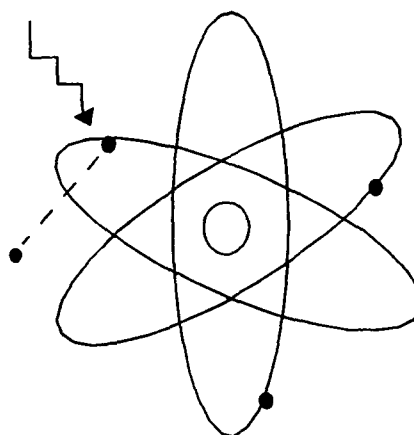
- Site characterization
- Exposure monitoring
- Soil and water sample screening
- Soil gas monitoring

NOTES

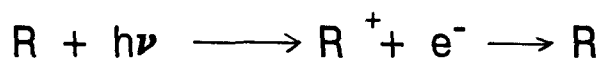
TYPES OF TOTAL VAPOR SURVEY INSTRUMENTS

- Photoionization detector (PID)
- Flame ionization detector (FID)
- Supersensitive CGI
- Metal-oxide semiconductor (MOS)

PHOTOIONIZATION



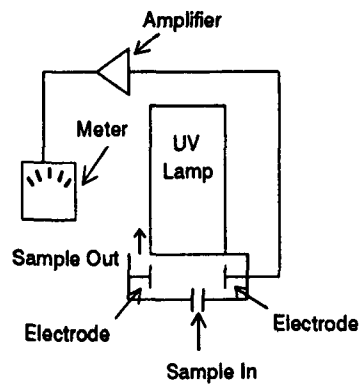
PHOTOIONIZATION



R = chemical-absorbing UV
h(nu) = photon with energy
≥ ionization potential
(IP) of chemical

NOTES

PHOTOIONIZATION DETECTOR



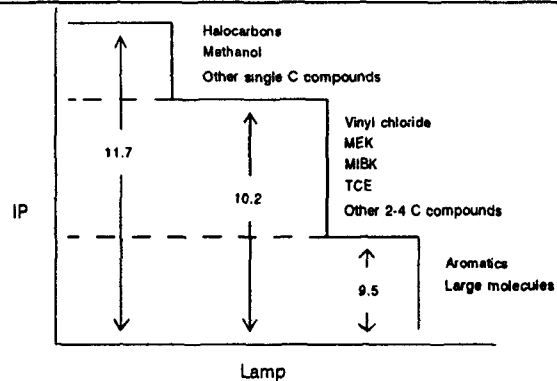
IONIZATION POTENTIAL

Chemical	IP (eV)
Carbon monoxide	14.0
Hydrogen cyanide	13.9
Methane	13.0
Hydrogen chloride	12.7
Water	12.6
Oxygen	12.1
Chlorine	11.5
Propane	11.1
Hydrogen sulfide	10.5
Hexane	10.2
Ammonia	10.1
Acetone	9.7
Trichloroethylene	9.45
Benzene	9.2
Triethylamine	7.5

NOTES

NOTES

EXAMPLES OF LAMP ENERGIES AND DETECTABLE CHEMICALS



SELECTIVE DETERMINATION OF VINYL CHLORIDE

Compound	IP
Carbon dioxide	13.8
Propane	11.1
Vinyl chloride	10.0
Acetone	9.7

PHOTOIONIZATION DETECTOR 11.7 vs. 10.2 Lamp

- 11.7 wears out faster than 10.2
- 11.7 is more susceptible to humidity
- 10.2 provides better response to chemicals it can detect

NOTES

PHOTOIONIZATION DETECTOR Considerations

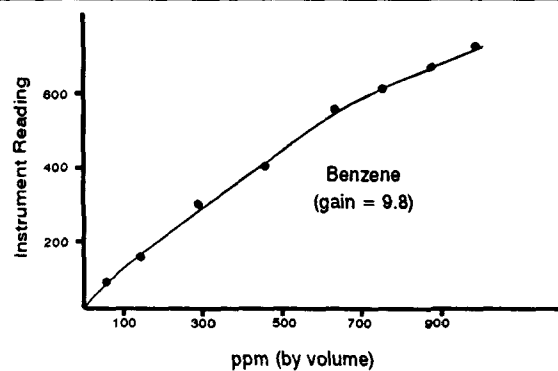
- Lamp energy/chemical IP
- Dust/humidity
- Interferences
- Electromagnetic interferences
- Lamp aging
- Relative response
- High concentrations

PHOTOIONIZATION DETECTOR Relative Response

Chemical	Relative Response*	IP
m-Xylene	1.12	8.56
Benzene	1.00	9.25
Phenol	0.78	8.69
Acetone	0.63	9.69
Isobutylene	0.55	9.25
Hexane	0.22	10.18
Ammonia	0.03	10.15

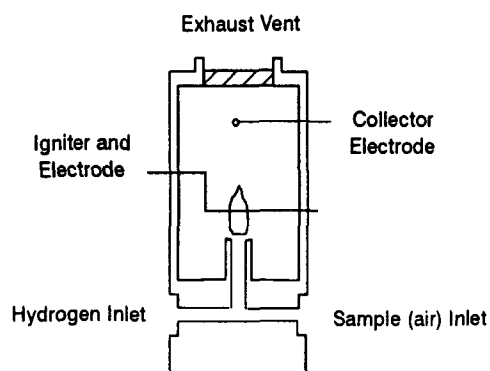
* HNU PI-101 with 10.2 eV lamp calibrated to benzene

PHOTOIONIZATION DETECTOR High Concentration Effects

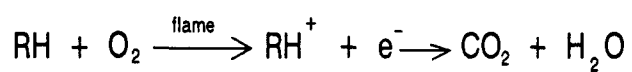


NOTES

FLAME IONIZATION DETECTOR



FLAME IONIZATION



Note: This ionization process is destructive.

COMPOUNDS GIVING LITTLE OR NO RESPONSE IN THE FID

He	N ₂	HCHO (formaldehyde)
Ar	NO	CO
O ₂	NO ₂	CO ₂
H ₂ O	N ₂ O	CS ₂
H ₂ S	NH ₃	Ethanolamine
SO ₂	HCN	

NOTES

FLAME IONIZATION Considerations

- Detects only organics
- Detects methane
- Hydrogen gas needed
- Flame out
- Electromagnetic interferences
- Relative response

FLAME IONIZATION Relative Response

Chemical	% Relative Response*
Benzene	185
Toluene	126
Methane	100
Acetone	82
Trichloroethylene	54
Freon - 12	13
Carbon tetrachloride	8

* OVA-128 calibrated to methane

SUPERSENSITIVE CGI

- Detects combustible gases and vapors
- Detector is the same as a regular CGI, but an amplifier is used to obtain ppm readings

NOTES

SUPERSENSITIVE CGI Considerations

- Detects only combustibles
- Detects methane
- Temperature
- Chemicals that foul sensor
- Minimum oxygen
- Electromagnetic interference
- Relative response

METAL-OXIDE SEMICONDUCTOR (MOS)

- Metal-oxide coating on a ceramic substrate wrapped around a wire
- Contaminant alters conductivity by removing oxygen
- Change in current is proportional to the amount of contaminant present
- Also called "solid-state" sensor

MOS Considerations

- Saturation
- Temperature
- Minimum oxygen requirements
- Relative response

NOTES

CONCLUSION Considerations
<ul style="list-style-type: none">• What the instrument can detect• Survey, not identification• Logistical factors• Environmental factors• Special features

TOTAL VAPOR SURVEY INSTRUMENTS

INTRODUCTION

Total vapor survey instruments are designed to respond to a wide range of gases and vapors. Although they lack selectivity, this broad response allows the operator to detect the presence of chemicals with one instrument. This allows the instrument to be used as a warning device during survey operations.

If the identity of a chemical is known, the instruments can be calibrated to give a one-to-one response for that chemical. If there is a mixture present, the instrument gives a total vapor reading. The detectors themselves cannot identify the components of an atmosphere. The detectors can be used in instruments, like the gas chromatograph (see *Introduction to Gas Chromatography* that are used for identification.

This section will focus on total vapor survey instruments that are used for parts per million (ppm) concentrations. It will discuss four types of toxic vapor survey instruments: photoionization detectors (PIDs), flame ionization detectors (FIDs), supersensitive combustible gas indicators (CGIs), and metal oxide semiconductors.

APPLICATIONS

Because of their ability to detect a wide range of chemicals, total vapor survey instruments are used in site survey and characterization. Although they cannot identify what chemicals are present, they can indicate what areas may have higher concentrations (hot spots) than others and delineate work areas based on levels of concentrations.

If the identities of the contaminants are known, the instruments can also be used in exposure assessment. The readings can give an approximate concentration and the information can be used in selecting exposure controls.

The instruments are also used to screen water and soil samples to determine whether further, and more complicated and expensive, analysis is needed. Usually specific reading (or any response) is used to determine which samples need further analysis.

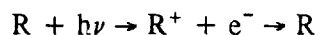
Total vapor survey instruments are also used in soil gas sampling as a screening tool to indicate "hits" and hot spots that need further sampling.

PHOTOIONIZATION DETECTORS

These instruments detect concentrations of gases and vapors in air by using an ultraviolet light source to ionize the airborne contaminant. Once the gas or vapor is ionized in the instrument, it can be detected and measured.

Principle of Operation

The photoionization process can be illustrated as:



where R is an organic or inorganic molecule and $h\nu$ represents a photon of ultraviolet (UV) light with energy equal to or greater than the ionization potential (IP) of that particular chemical species. R^+ is the ionized molecule.

When a photon of ultraviolet radiation strikes a chemical compound, it ionizes the molecule if the energy of the radiation is equal to or greater than the IP of the compound. Because ions are charged particles, they may be collected on a charged plate and produce a current. The measured current will be directly proportional to the number of ionized molecules. The R in the above equation indicates that photoionization is nondestructive and the chemical exits the detector unchanged.

PIDs use a fan or a pump to draw air into the instrument's detector. There the contaminants are exposed to UV light and the resulting negatively charged particles (ions) are collected and measured (Figure 1).

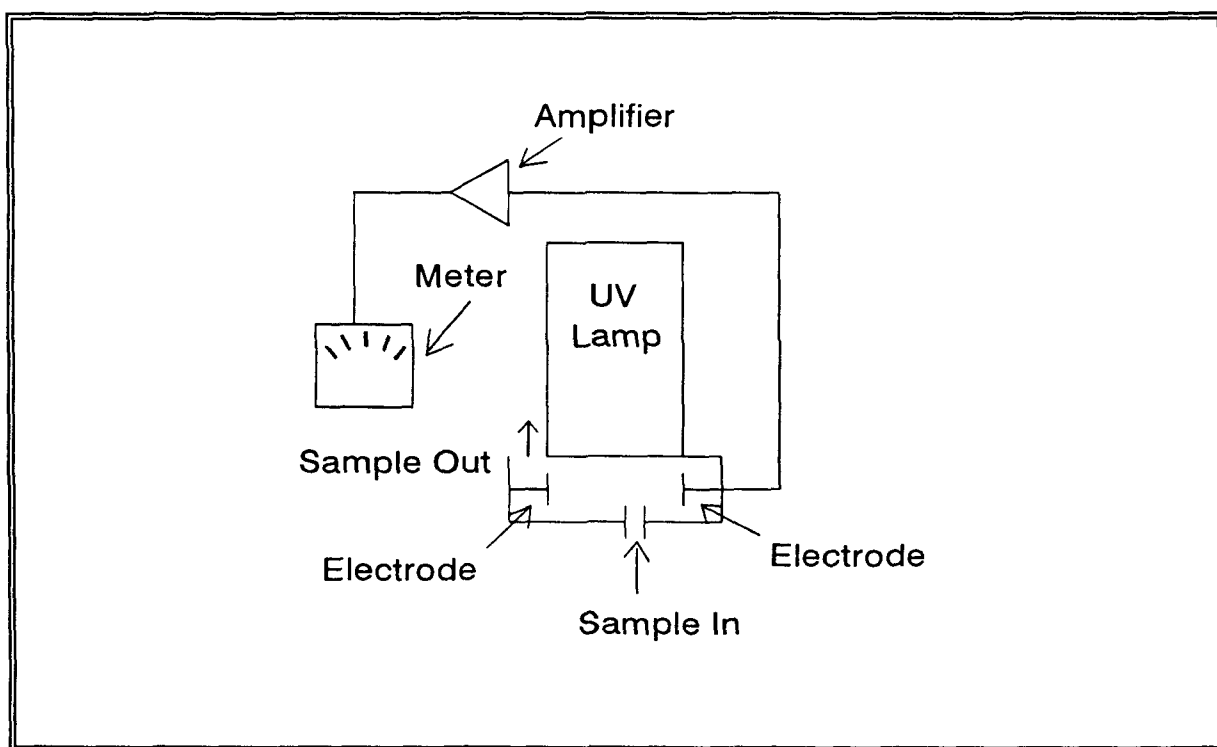


FIGURE 1. DIAGRAM OF PHOTOIONIZATION DETECTOR LAMP AND COLLECTING ELECTRODES

The energy required to remove the outermost electron from the molecule is called the ionization potential (IP) and is specific for any compound or atomic species (Table 1). Ionization potentials are measured in electron volts (eV).

The ultraviolet light used to ionize the chemicals is emitted by a gaseous discharge lamp. The lamps contain low-pressure gas through which a high-potential current is passed. A variety of lamps with different ionization energies are made by varying the composition of the lamp gas. The energy of lamps available are 8.4, 9.5, 10.0, 10.2, 10.6, and 11.7 eV. Not all lamps are available from a single manufacturer.

The lamp energy designation is for the predominant UV wavelength emitted by the lamp. The spectra from the lamp may have other wavelengths. Wavelengths of less energy do not have a major impact because chemicals ionized by those wavelengths will also be ionized by the predominant wavelength. The higher energy (but less photons) wavelengths will ionize the higher IP chemicals but the response will be low. Thus, a 10.2 lamp may give a response (although a small one) for a chemical with an IP of 10.9.

Photoionization Detector Considerations

Because the ability to detect a chemical depends on the ability to ionize it, the IP of a chemical to be detected must be compared to the energy generated by the UV lamp of the instrument. As discussed earlier, it may be possible to detect a chemical even if the chemical's IP is slightly greater than the lamp energy. However, the response will be poor.

TABLE 1. IONIZATION POTENTIALS OF SELECTED CHEMICALS

Chemical	Ionization Potential (eV)
Carbon monoxide	14.0
Hydrogen cyanide	13.9
Methane	13.0
Hydrogen chloride	12.7
Water	12.6
Oxygen	12.1
Chlorine	11.5
Propane	11.1
Hydrogen sulfide	10.5
Hexane	10.2
Ammonia	10.1
Acetone	9.7
Trichloroethylene	9.45
Benzene	9.2
Triethyl amine	8.0

One use for the different lamps is for selective determination of chemicals. For example, if a spill of propane and vinyl chloride were to be monitored with a PID, the first check would be to see whether the chemicals can be detected. The IP of propane is 11.1 eV and the IP of vinyl chloride is 10.0 eV. To detect both, a lamp with an energy greater than 11.1 eV is needed (like a 11.7). If vinyl chloride was the chemical of concern, then a lamp with an energy greater than 10.0 but less than 11.1 (such as 10.2 or 10.6) could be used. The propane would neither be ionized nor detected. Thus, propane would not interfere with the vinyl chloride readings.

The lamp window also affects response. The two types of windows are magnesium fluoride and lithium fluoride. The former is used for the lower energy lamps and the latter is for the 11.7 eV lamp. The lithium fluoride is used to permit the higher energy photons to be emitted. Lithium fluoride has two disadvantages. The first is that humidity and the high-energy photons degrade the window. This reduces the life span of the lamp. The 11.7 eV lamps are expected to have a life expectancy one-tenth of that of 10.2 or 10.6 lamps. The second disadvantage is that lithium fluoride also limits the amount of photons being emitted. Thus, if both a 10.2 and an 11.7 lamp have enough energy to ionize a chemical (e.g., a chemical with an IP of 9.7), the 10.2 may give a higher response because it is emitting more light.

The sample drawn into the instrument passes over the lamp to be ionized. Dust in the atmosphere can collect on the lamp and block the transmission of UV light. This will cause a reduction in instrument reading. The lamp should be cleaned regularly. Newer models of PIDs have dust filters.

Humidity can cause two problems. When a cold instrument is taken into a warm moist atmosphere, the moisture can condense on the lamp. Like dust, this will reduce the available light. Moisture in the air can also reduce the readings. It is thought that the water molecules collide with the ionized chemical and deactivate them. This reduction in response has been reported to be as much as 50% for a relative humidity of 90%. As mentioned earlier, the 11.7 lamp window is especially sensitive to moisture.

Because an electric field is generated in the sample chamber of the instrument, radio-frequency interference from pulsed DC or AC power lines, transformers, generators, and radio wave transmission may produce an error in response.

As the lamp ages, the intensity of the light decreases. It will still have the same ionization energy, but the response will decline. This will be detected during calibration and adjustments can be made. However, the lamp will eventually burn out.

Methane can act as an interference by absorbing the UV energy without ionization. This reduces the ionization of other chemicals present. The net effect is a reading lower than the true concentration.

Although oxygen is not needed for photoionization, a change in oxygen will affect the response. Thus, there are oxygen limits for their use. The instruments are calibrated and used in normal oxygen atmospheres. The HNU PI-101 requires a minimum of 10% oxygen for reliable results.

Photoionization detectors are calibrated to a single chemical. The instrument's response to chemicals other than the calibration gas/vapor can vary. **Table 2** shows the relative responses of several chemicals for a specific PID.

In some cases, at high concentrations the instrument response can decrease. While the response may be linear (i.e., 1 to 1 response) from 1 to 400 ppm for an instrument, a concentration of 900 ppm may only give a meter response of 700 (**Figure 2**). Some instruments use a microprocessor to compensate for this effect by storing calibration information for the high concentrations.

Manufacturers who make photoionization detectors can be found in this manual in the *Manufacturers and Suppliers of Air Monitoring Equipment* section.

**TABLE 2. RELATIVE RESPONSES FOR SELECTED
CHEMICALS USING THE HNU MODEL PI 101
WITH 10.2 eV PROBE CALIBRATED TO BENZENE**

Chemical	Relative Response
m-Xylene	1.12
Benzene	1.00
Acetone	0.63
Isobutylene	0.55
Vinyl chloride	0.50
Hexane	0.22
Phosphine	0.20
Ammonia	0.03

Source: *Instruction Manual for Model PI 101, Portable Photoionization Analyzer*, HNU Systems, Inc., Newton, MA, 1986.

Examples of Photoionization Detector Instruments

HNU Systems, Inc.

HNU Systems, Inc., manufactures four models of photoionization detector survey instruments: PI-101, IS-101, HW-101, and the DL-101.

All four consist of two modules connected via a single power cord (**Figure 3**):

- A readout unit having an analog meter or digital display, a rechargeable battery, and power supplies for operation of the amplifier and the UV lamp
- A sensor unit consisting of the UV light source, pump, ionization chamber, and a preamplifier.

The **PI-101** has a fan instead of a pump and cannot draw a sample through a resistance (like a piece of long tubing). The PI-101 is rated for Class I, Division 2, Group A, B, C, and D locations.

The **IS-101** is similar to the PI-101 except it is intrinsically safe for Division 1 locations.

The **HW-101** has a pump instead of a fan, so it can be used to draw a sample through tubing or through a probe used for soil gas sampling. The HW-101 also has a dust filter and is more moisture resistant than the other models. It also has a light-emitting diode (LED) display on the handle that indicates concentration changes.

The **DL-101** has a pump and dust filter like the HW-101. However, it has many different fixtures than other units. It has a pistol grip for holding the probe. There is a LED display on the handle. The instrument has a datalogger to store calibration information and to record time and location of readings. Information from the datalogger can be transferred to a computer. It has a digital readout instead of an analog meter.

These units have a separate sensor unit because the lamps available - 9.5, 10.2 (standard), and 11.7 eV - require separate electronic circuits. To change the energy of ionization, the whole sensor or

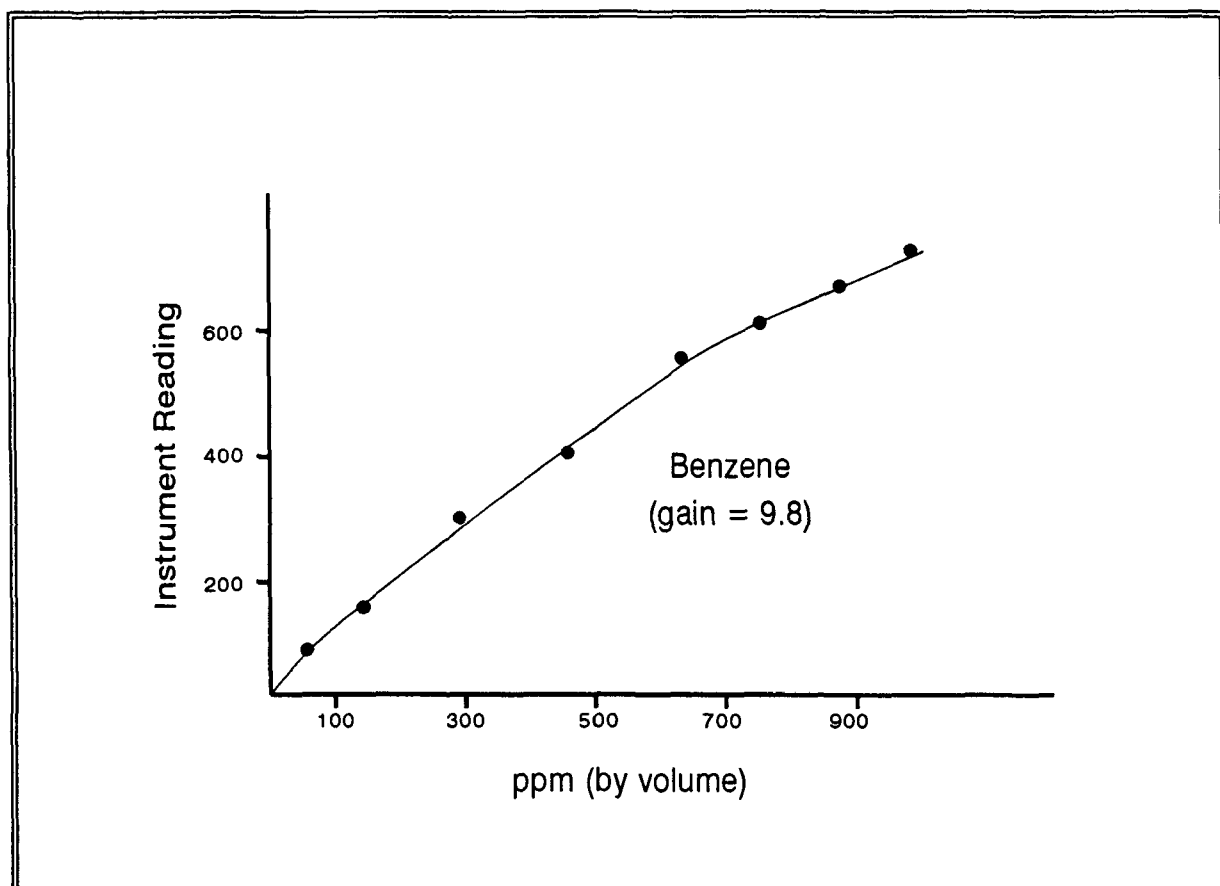


FIGURE 2. TYPICAL CALIBRATION CURVE FOR PHOTOIONIZATION ANALYZER

Source: *Instruction Manual for Model PI-101 Photoionization Detector*, copyright 1975, HNU Systems, Inc.; reprinted with permission of publisher.

probe has to be switched, not just the lamp. The exception is the DL-101. With the DL-101, lamps can be interchanged and the datalogger/microprocessor makes the proper adjustments. In all models the lamps are replaceable.

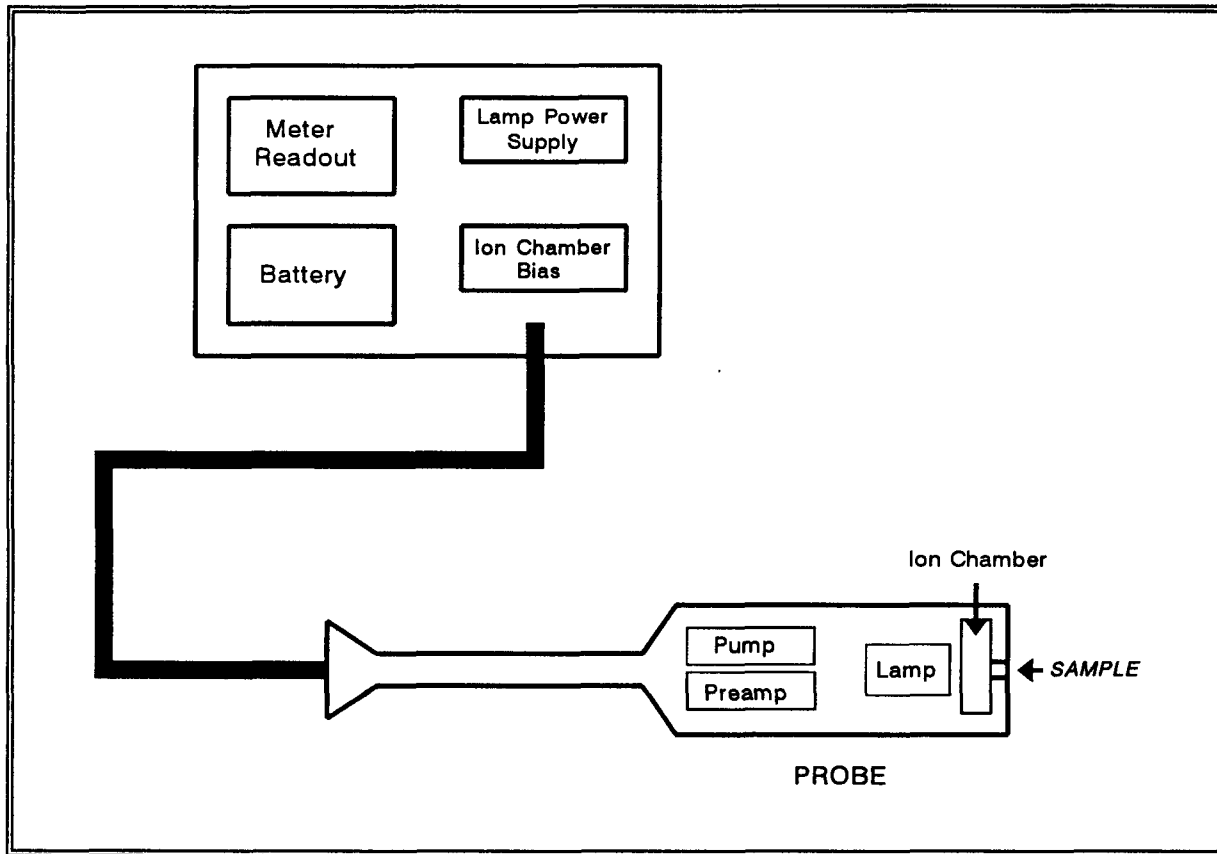


FIGURE 3. PORTABLE PHOTOIONIZATION DETECTOR

Source: *Instruction Manual for Model PI-101 Photoionization Detector*, copyright 1975, HNU Systems, Inc.; reprinted with permission of publisher.

Photovac, Inc.

Photovac has three versions of its **MicroTIP®**. All three have a microprocessor that is used to calibrate the instrument and a datalogger to store data. Information from the datalogger can be transferred to a computer. The standard lamp is 10.6 eV, but it can be easily replaced with a 8.4, 9.5, 10.2 or 11.7 eV lamp. The readout is digital with a range of 0 to 2000. They all have a dust filter. The **MP-1000** does not have an inherent safety approval. The **HL-2000** is approved for Class I, Division 2, Groups A, B, C, and D locations. The **IS-3000** is intrinsically safe.

Thermo Environmental Instruments

The **Organic Vapor Meter (OVM) Model 580B** is 5" by 5" by 10" with a handle in the center on top. It can use any of four different lamps - 9.6, 10.0, 10.6 and 11.8 eV. The instrument has a digital readout with a range of 0 to 2000. It has a maximum hold feature so that you can get two readings - the current concentration or the maximum concentration during the survey. The meter has a lock-out if the readout exceeds 2000 so that high concentrations are not missed. It must be reset in an area of low concentrations. The instrument has a microprocessor for assistance in calibration and lamp changing.

The **OVM-580S** is similar to the 580B, but is intrinsically safe.

Both have connections and software for interfacing the unit with a personal computer. They also have a datalogger for recording readings at coded locations so that the readings can be looked at later or downloaded into a computer.

Photoionization detectors are also used in gas chromatographs made by Photovac, HNU and Thermo Environmental Instruments. Gas chromatography will be discussed in a later section.

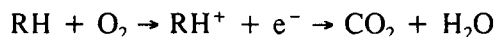
FLAME IONIZATION DETECTOR

These units use a flame to ionize airborne contaminants. Once they are ionized, they can be detected and measured.

Principle of Operation

FIDs use a hydrogen flame as the means to ionize organic vapors. FIDs respond to virtually all organic compounds; that is, compounds that contain carbon-hydrogen or carbon-carbon bonds. FIDs will not respond to inorganic compounds.

Inside the detector chamber, the sample is exposed to a hydrogen flame which ionizes the organic vapors (**Figure 4**):



When most organic vapors burn, positively charged carbon-containing ions are produced. These can be collected by a negatively charged collecting electrode in the detector chamber. An electric field exists between the conductors surrounding the flame and a collecting electrode. As the positive ions are collected, a current proportional to the hydrocarbon concentration is generated on the input electrode. This current is measured with a preamplifier which has an output signal proportional to the ionization current. A signal conducting amplifier is used to amplify the signal from the detector and to condition it for subsequent meter or external recorder display.

Flame ionization detectors have a more generalized response in detecting organic vapors. This generalized sensitivity is due to the breaking of chemical bonds which require a set amount of energy and is a known reproducible event. When this is compared to photoionization (PID), a major

difference should be noted between the detectors. PID detection is dependent upon the ionization potential (in eV) and the ease in which an electron can be ionized (displaced) from a molecule. This mechanism is variable, highly dependent on the individual characteristics of a particular substance. This results in a more variable response factor for the vast majority of organics that are ionizable. Therefore, in general, one does not see large sensitivity shifts between different substances when using an FID as compared to a PID. FIDs are the most sensitive for saturated hydrocarbons (alkanes), unsaturated hydrocarbons (alkenes and alkynes), and aromatic hydrocarbons. Substances that contain substituted functional groups, such as hydroxide (OH) and chloride (Cl), tend to reduce the detector's sensitivity.

Companies that manufacture FIDs are listed in the *Manufacturers and Suppliers of Air Monitoring Equipment* section. The Foxboro Century Organic Vapor Analyzer (OVA) will be discussed as an example later.

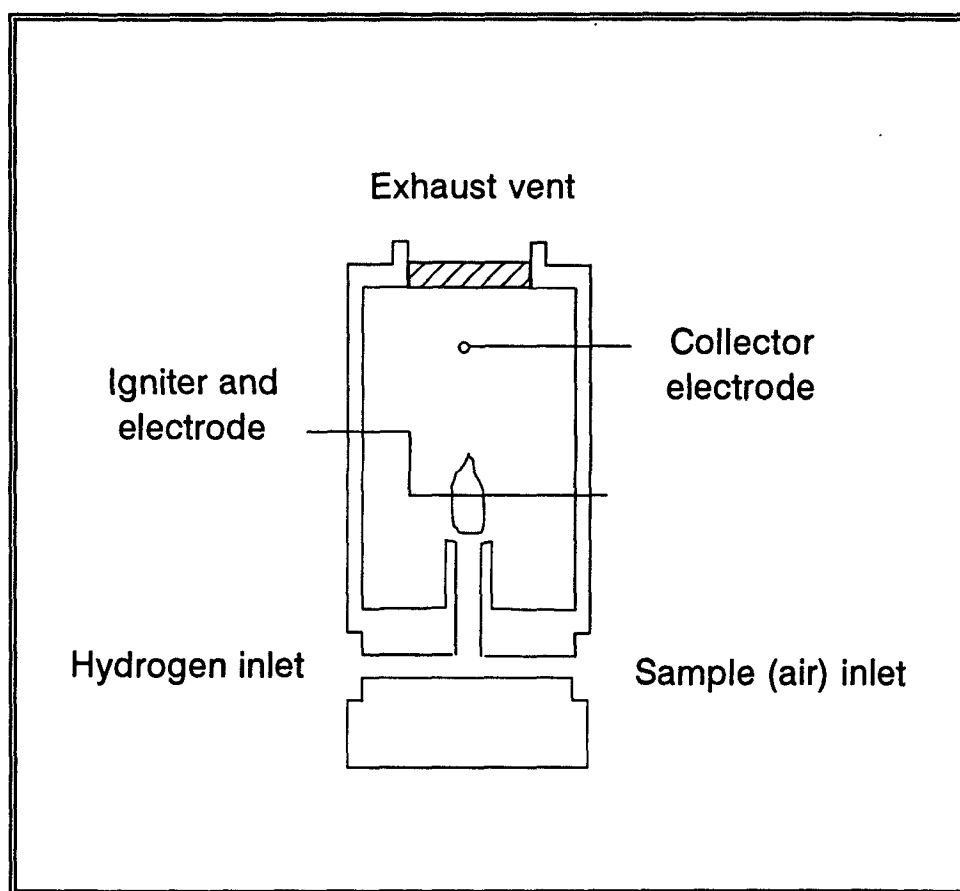


FIGURE 4. EXAMPLE OF A FLAME IONIZATION DETECTOR SCHEMATIC

Flame Ionization Detector Considerations

Flame ionization detectors respond only to organic compounds. Thus, they do not detect inorganic compounds like chlorine, hydrogen cyanide, or ammonia. There are some carbon containing chemicals for which the FID gives little or no response also. Table 3 illustrates this situation.

**TABLE 3. CHEMICALS GIVING LITTLE OR NO RESPONSE
WITH FLAME IONIZATION DETECTORS**

He	N ₂	HCHO (formaldehyde)
Ar	NO	CO
O ₂	NO ₂	CO ₂
H ₂ O	N ₂ O	CS ₂
H ₂ S	NH ₃	TDI
SO ₂	HCN	ethanol amine

Source: *Relative Response Data Sheet for Organic Vapor Analyzer*,
January 16, 1989. The Foxboro Company.

Flame ionization, unlike photoionization, is a destructive form of monitoring. Typically, the combustion products are carbon monoxide and water. However, substituted hydrocarbons (e.g. chlorinated compounds) may produce toxic or corrosive byproducts.

The FID responds very well to methane. Methane is used as a calibration gas for many FIDs. However, if monitoring is being done near a landfill or in a sewer system, the methane can mask the response to low concentrations of other organics.

Hydrogen gas is used as fuel for the flame. This requires the extra logistics of maintaining a hydrogen gas supply and recharging the instrument. It also involves working with a flammable compressed gas.

Inadequate oxygen can cause the flame to go out. High concentrations of organics can also cause a flame out. Without the flame, there is no detection.

Cold weather can also cause the flame to extinguish or inhibit startup (ignition) of the instrument.

Because an amplifier is used to enhance the signal from the detector, radio-frequency interference from pulsed DC or AC power lines, transformers, generators, and radio wave transmission may produce an error in response.

As with all instruments, flame ionization detectors respond differently to different compounds. **Table 4** is a list of the relative responses of the Foxboro CENTURY OVA to some common organic compounds. Since that instrument is factory calibrated to methane, all responses are relative to methane and are given by percentage, with methane at 100%.

**TABLE 4. RELATIVE RESPONSES FOR SELECTED
CHEMICALS USING THE OVA CALIBRATED TO METHANE**

Compound	Relative Response (%)
Methane	100
Ethane	77
Propane	70
Acetylene	225
Benzene	185
Toluene	126
Acetone	82
Methanol	12
Isopropyl alcohol	65
Carbon tetrachloride	8
Freon-12	13
Trichloroethylene	54

Source: Product Literature, The Foxboro Company; used
with permission of The Foxboro Company.

Examples of Flame Ionization Detector Instruments

Foxboro CENTURY Organic Vapor Analyzer (OVA)

One of the more common FID instruments is the Foxboro CENTURY OVA. There are two models: the OVA-128 and the OVA-108. Both consist of two major parts (**Figure 5**):

- A 12-pound package containing the sampling pump, battery pack, support electronics, flame ionization detector, hydrogen gas cylinder, and an optional gas chromatography (GC) column.
- A hand-held meter/sampling probe assembly.

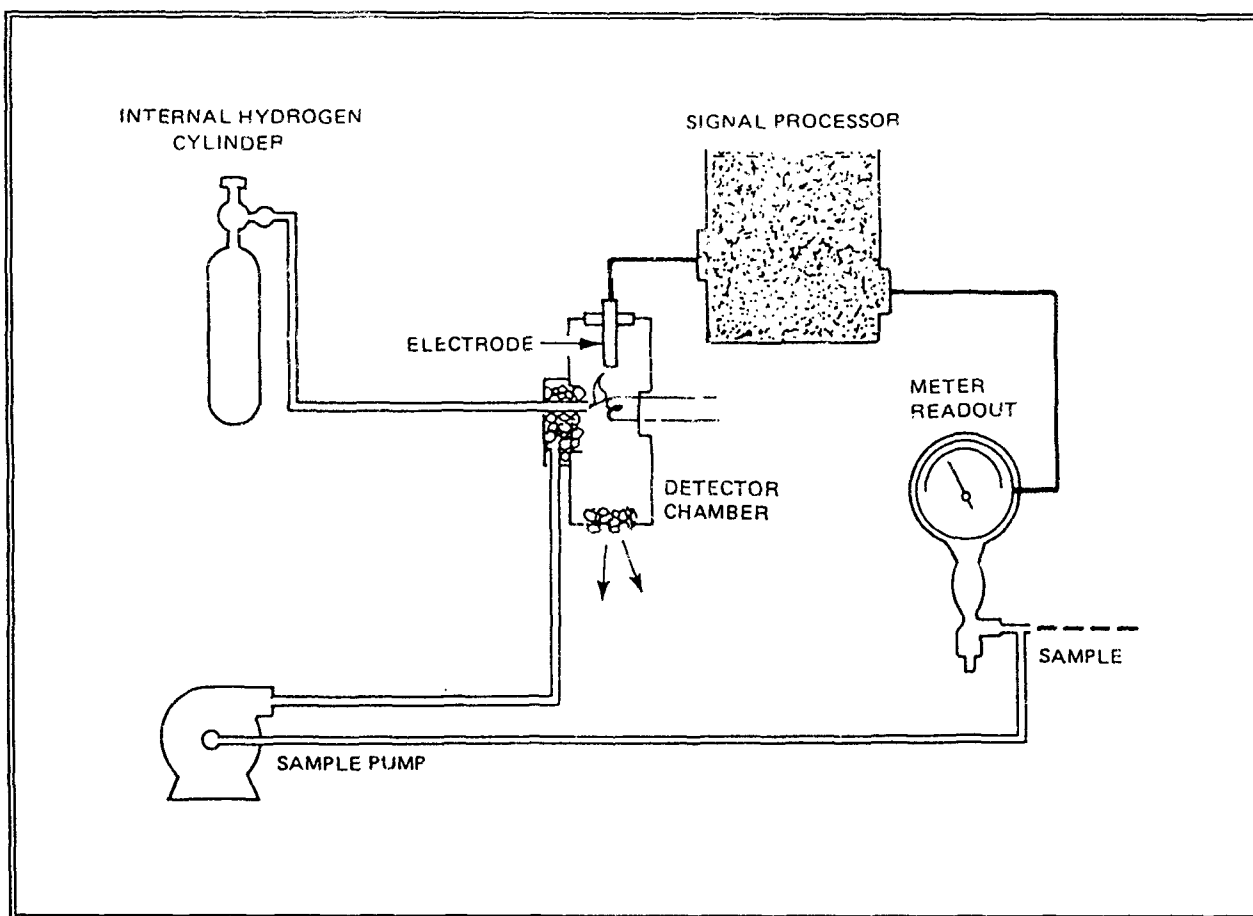


FIGURE 5. ORGANIC VAPOR ANALYZER SCHEMATIC

Source: Product Literature, The Foxboro Company; used with permission of The Foxboro Company.

The OVA-128 has a range of 0-1000 ppm. The OVA-108 reads from 0-10,000. Both are intrinsically safe for Class 1, Division 1, Groups A, B, C and D. Both models are factory calibrated to methane, but can be calibrated to other chemicals.

Other FID units are the Sensidyne **Portable FID**, Heath Consultants **Porta-FID II**, and Summit Industries **SIP-1000**. The Portable FID and the SIP-1000 have gas chromatograph options.

Combination PID and FID

Foxboro also manufactures the TVA-1000. The instrument can use a PID, an FID, or both. The instrument has datalogging capabilities and digital readouts on a probe and side pack.

SUPERSENSITIVE COMBUSTIBLE GAS INDICATORS

The CGI is a type of total vapor survey monitor. However, the normal range for a CGI is in the percent LEL concentration. This range is too high for toxic concentration monitoring. Super-sensitive combustible gas indicators use the combustible gas sensor with circuitry to amplify the signal. Instead of measuring per cent of the LEL, the readout is in part per million. Because the detection is based on combustion, the instruments can detect both organic and inorganic combustible gases/vapors.

Some units—like the Bacharach TLV Sniffer—only measure in the ppm range. Other units (e.g., the GasTech Model 1314) can be switched from percent LEL to ppm readout.

These units have the same limitations and considerations as the regular combustible gas indicators. In some cases, like sensitivity to temperature changes, the effects are a bigger problem because of the amplifier circuit. Because of the amplifier, they are more sensitive to electromagnetic radiation than standard combustible gas indicators.

METAL-OXIDE SEMICONDUCTORS (MOS)

MOS, also called solid-state sensors, consist of a metal oxide film coating on a heated ceramic substrate fused or wrapped around a platinum wire coil. When a gas comes in contact with the metal oxide, it replaces oxygen in the oxide and alters the conductivity of the semiconductor. The change in conductivity can be expressed in a meter readout. The bead is heated to give a constant baseline as oxygen in the air can combine with the oxide. Oxygen can combine with the sensor to cause an instrument response.

Selectivity can be determined by selecting specific metal oxides and/or using specific temperatures from the heater to prevent chemicals reacting. To use as a toxic atmosphere survey monitor, the sensor should respond to a wide variety of chemicals. Thus, the sensor should be designed to be nonselective.

Examples of instruments using a MOS for a total vapor sensor are the **AIM 2000/3000** and the **Dynamation Model CGM™**.

CONCLUSION

This section has described several types of detectors used for monitoring the presence of a wide range of gases and vapors. While these are not the only types of detectors or monitors available, they are the more commonly used devices for field surveys.

AIR SAMPLE COLLECTION

PERFORMANCE OBJECTIVES

At the end of this lesson, participants will be able to:

- List four advantages to using air sample collection
- List three sources of sampling and analysis methods
- List three considerations when using liquid sorbent samplers
- List three considerations when using solid sorbent samplers
- List three considerations when using whole air samplers
- Describe two methods of collecting whole air samplers.

AIR SAMPLE COLLECTION

DIRECT-READING INSTRUMENTS (DRI) vs. AIR SAMPLE COLLECTION

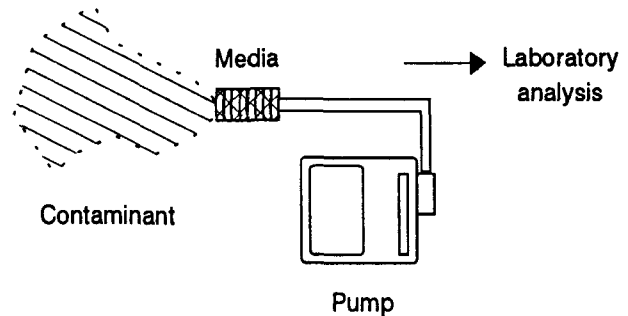
<u>Features</u>	<u>DRI</u>	<u>Air Sample Collection</u>
Response time	Seconds to minutes	Hours to days
Quantitative	Yes	Yes
Identification	No	Yes
Detection range	Parts per million (ppm) to percent	Parts per trillion (ppt) to parts per million (ppm)
Cost	Inexpensive	Expensive

AIR SAMPLE COLLECTION Uses

- Identify and quantify airborne chemicals onsite
- Evaluate personal exposures
- Evaluate releases from site
- Data for public health/ecological risk assessment

NOTES

AIR SAMPLE COLLECTION Components



COLLECTION AND ANALYTICAL METHODS

- EPA
 - *Compendium of Methods for Determination of Toxic Organic Compounds in Ambient Air*
 - *Compendium of Methods for Determination of Air Pollutants in Indoor Air*
 - *Compendium of Methods for Determination of Toxic Inorganic Compounds in Ambient Air*

COLLECTION AND ANALYTICAL METHODS

- *NIOSH Manual of Analytical Methods*
- *OSHA Analytical Methods Manual*
- American Society for Testing and Materials
- Specialty methods

NOTES

COLLECTION AND ANALYTICAL METHODS

- Air Methods Database
 - Combines previous methods into a database
 - Free from EPA
 - See fact sheet

COLLECTION MEDIA Types of Contaminants

- Aerosols/particulates (nonvolatile)
- Gases and vapors (volatile)
- Combination (semivolatile)

FILTER MEDIA Examples

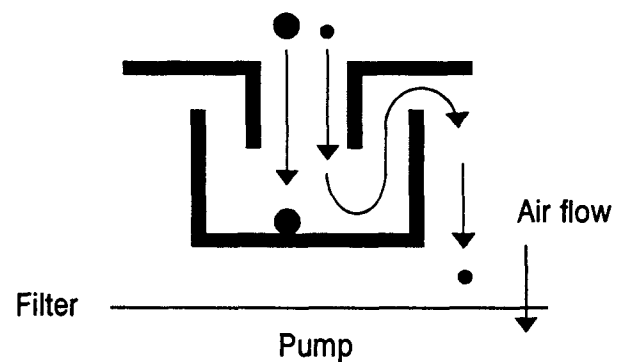
<u>Filter Media</u>	<u>Application</u>
0.8-micron (μ) mixed cellulose ester (MCE)	Metals; asbestos
Glass fiber	Pesticides
Polyvinyl chloride (PVC)	Total particulates; hexavalent chromium
Polytetrafluoroethylene	Alkaline dusts

NOTES

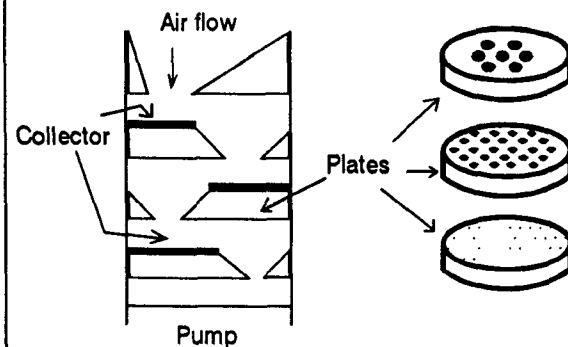
AEROSOLS/PARTICULATES Size Selection Terminology

- Total suspended particulate (TSP)
- Particulate matter - 10μ (PM-10)
- Total
- Respirable

AEROSOL SIZE SELECTION Inertial Impactor



AEROSOL SIZE SELECTION Cascade Impactor



NOTES

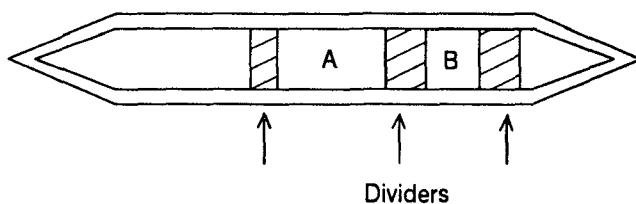
GASES AND VAPORS Examples

- Organic vapors
 - Benzene
 - Trichloroethylene
 - Ethyl alcohol
- Inorganic gases
 - Ammonia
 - Hydrogen cyanide
 - Hydrogen chloride

SOLID SORBENT MEDIA Examples

<u>Solid Sorbent</u>	<u>Compound</u>
Activated carbon	Nonpolar organics (NIOSH)
Tenax [®]	Volatile, nonpolar organics (EPA)
Carbon molecular sieve	Highly volatile, nonpolar organics (EPA)
Silica gel	Polar organics (NIOSH)

SOLID SORBENT TUBE Example



A = Solid sorbent
B = Solid sorbent (backup or different sorbent)

NOTES

SOLID SORBENT CONSIDERATIONS

- Breakthrough
- Sorption efficiency
- No universal media
- Stability/handling
- Desorption
 - Thermal
 - Solvent

LIQUID SORBENT MEDIA Examples

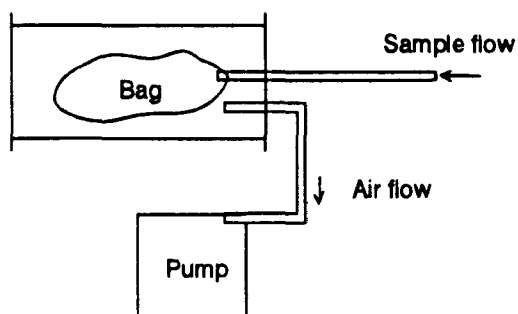
<u>Media</u>	<u>Compound</u>
0.1N NaOH	Cresol/phenol (EPA) Phenol (NIOSH)
Aniline	Phosgene (EPA)
DNPH reagent + isooctane	Aldehydes/ketones (EPA)
0.1M HCl	Hydrazine (NIOSH)

LIQUID SORBENT CONSIDERATIONS

- Spillage
- Fragile holders
- Hazardous liquids?
- Stability
- Evaporation

NOTES

WHOLE AIR COLLECTION "Sampling Lung"



Source: "Sampling and Analysis of Emissions from Stationary Sources," Schuetzle et al., *Journal of the Air Pollution Control Association*, Volume 25, No. 9, Sept. 1975.

BAG SAMPLING vs. CANISTER SAMPLING

<u>Bag</u>	<u>Canister</u>
Grab	Integrated
Need field pump	Need lab pump
Less stable sample	More stable sample
Cannot clean	Clean to reuse
Disposable	Reusable
Cannot pressurize	Can pressurize

COMBINATION MEDIA Examples

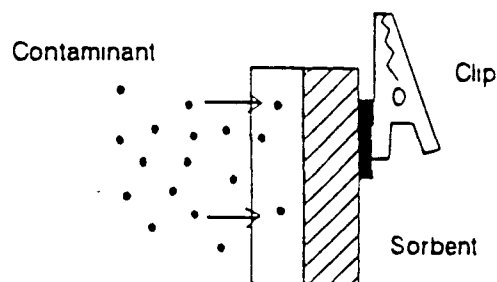
<u>Media</u>	<u>Compound</u>
Quartz filter + polyurethane foam (PUF)	PCBs/pesticides (EPA) PAHs (EPA)
Quartz filter + XAD-2	PAHs (EPA)
Glass filter + Florisil®	PCBs (NIOSH)
MCE filter + 0.1N KOH	Cyanides (NIOSH)

NOTES

SAMPLING PUMPS

- Most collection methods require a pump to pull air through medium
- Exceptions
 - Evacuated canister
 - Passive dosimeter

PASSIVE DOSIMETER Example



PASSIVE DOSIMETERS Considerations

- No pump
- Sorbent limits
 - Breakthrough
 - Humidity
 - Temperature
- Early and late exposure problems
- Gases and vapors only

NOTES

SAMPLE PUMPS High Flow Rates

- Greater than 10 cubic feet per minute
- Ambient air sampling

SAMPLE PUMPS Medium/High Flow Rates

- 1 to 6 liters per minute
- Personal sampling
- Aerosol sampling

SAMPLE PUMPS Low Flow Rates

- 10 to 750 cubic centimeters (milliliters) per minute
- Personal sampling
- Gas and vapor sampling

NOTES

SUMMARY

- Collect sample for laboratory analysis
- Determine whether air sampling is appropriate
- Identify appropriate air sampling method

AIR SAMPLE COLLECTION

INTRODUCTION

The types of equipment discussed in this section are media (filters and sorbents), containers (gas bags and canisters) and pumps for collecting air samples. Unlike direct-reading instruments that give immediate results, these samples must be analyzed by instruments that are not usually taken onsite. The analysis may be done in the support area of a site or at a laboratory many miles away. This causes a delay in receiving information. However, there are advantages to their use.

- The chemicals in the atmosphere can be concentrated so that the detection limit can be lower than for a direct-reading instrument, even when the same type of detector is used.
- Specialized detectors can be used. Some detectors (e.g., PID and FID) are used in both direct-reading instruments and analytical instruments. However, some detectors are only found in analytical instruments (e.g., electron capture detector). For specific analysis of aerosols (e.g., lead), there are no direct-reading instruments. A sample must be collected and then analyzed by a nonportable instrument.
- The analytical instruments used generally allow identification and quantification of the chemicals. Instead of a total vapor reading, it may be possible to get an identification and concentration of the components.
- The collection devices allow long duration (hours to days) and unattended sampling.

SAMPLE COLLECTION COMPONENTS

General

The basic components of a sample collection system are:

- A collection media for separating the contaminants from the atmosphere or a collection container for holding part of the atmosphere.
- A pump to pull air through the media to push the sample into a container. When a pump is used, the method is called "active" sampling. Some methods do not require a pump and are called "passive" samplers.
- A method to analyze the collected sample. This part will not cover the analysis of a sample. A limited discussion of analyses and detector types is found in *Total Vapor Survey Instruments* and *Introduction to Gas Chromatography*.

Selection of Components

Several factors affect the selection of the components for a sample collection system. These include 1) the chemical and physical properties of the chemical to be collected, 2) the purpose of the sample, 3) the analytical method used by the laboratory, 4) the laboratory's capability to do a specific procedure and their experience with the method, and 5) equipment characteristics. The following elaborate on these factors:

- Chemical and physical properties of the chemical—The chemical/physical properties of the chemical to be collected affect the type of media used. Volatile chemicals pass readily through a filter. Therefore, some kind of sorbent is needed. In some cases, a reaction, like an acid gas with an alkaline solution, may be used instead of sorption.
- Purpose of the sample—Two types of samples are the "personal" sample and the "area" sample:
 - Personal sample—A personal sample requires a pump that can be worn by the person being sampled. This means the pump must be compact and battery operated. A personal sample is used to evaluate the exposure level of the person being sampled. The sample results are usually compared to an exposure limit (see *Exposure Limits and Action Levels*). A personal sample collects the contaminants in the "breathing zone," a 12-inch-radius hemisphere in front of the wearer's nose.
 - Area sample—An area sample, to determine chemicals and concentrations in a specific area, can use the same type of pump. However, area samples generally are for checking lower concentrations than personal samples. This is because they are used for identification or evaluation of public exposure. The lower concentrations require a larger volume of air to concentrate the sample. This can be done by using a higher flow rate, by sampling longer, or both. Longer sampling times are used because public exposure can be 24 hours each day compared to a site worker's exposure of 8 to 10 hours each day. A long sampling time and a high flow rate require a pump that is AC powered. Battery pumps are only rated for 8 to 10 hours of use.
- Analytical method used by the laboratory—The analytical method used by the laboratory also affects the collection devices used. There are commonly used methods developed by the U.S. Environmental Protection Agency (EPA), National Institute of Occupational Safety and Health (NIOSH), and Occupational Safety and Health Administration (OSHA) that specify sampling and analysis procedures. These methods are found in EPA's *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air*, NIOSH's *Manual of Analytical Methods*, and OSHA's *Analytical Methods Manual*.

Although these methods were developed for similar chemicals, there are differences in the procedures. The laboratory being used may also have different requirements. The laboratory should be consulted prior to sampling.

EPA's Environmental Response Team (EPA-ERT) has developed an *Air Methods Database* so that the user can determine what methods are available for sampling a chemical. The database includes EPA, NIOSH, OSHA, and American Society for Testing and Materials (ASTM) methods. Further information is found in a technical bulletin (Appendix A).

- **Capability of the laboratory**—When you choose a laboratory for analysis, make sure you consider its capability to do a specific procedure and its experience with the desired method. For NIOSH and OSHA methods, use an American Industrial Hygiene Association (AIHA) accredited laboratory.
- **Equipment characteristics**—This is an important consideration. For example, some pumps have timers that may be useful or even necessary. Some collection devices are fragile and may not be desirable under certain operating conditions.

AEROSOL (NONVOLATILE CHEMICALS) SAMPLERS

Media

Airborne aerosols include both dispersed liquids (mists and fogs) and solids (dusts, fumes, and smoke). The most common method of sampling aerosols, especially the solids or particulates, is to trap them on filters using active systems. Impingers (see *Liquid Sorbents* in the *Gas and Vapor (Volatiles) Samplers* section) have been used, but filters are more convenient. Two types of filters are used.

- **Fiber filters** are composed of irregular meshes of fibers forming openings or pores of 20 μm in diameter or less. As particulate-laden air is drawn through such filters, it is forced to change direction. Particulates then impinge against the filter fibers and are retained. A number of fiber filters are available (Table 1). The two with the greatest application to hazardous materials operations are cellulose and glass. Filters of these materials typically consist of thick masses of fine fibers and have low mass-to-surface area ratios. Of the two, cellulose is the least expensive, is relatively low in ash, has high tensile strength, and is available in a variety of sizes. Its greatest disadvantage is its tendency to absorb water, thus creating problems in weighing.
- **Membrane filters** are microporous plastic films formed by precipitating a resin. Pore sizes of 0.01–10 μm can be formed during manufacture. Membrane filters act as a sieve with collection of most particulates on the surface. This can be useful for visual examination of the sample. This group of filters includes such materials as cellulose ester, polyvinyl chloride, and polytetrafluoroethylene (Table 1). These filters have an extremely low mass and ash content. Some are completely soluble in

organic solvents. This allows particulates to be concentrated into a smaller volume for analysis.

TABLE 1. FILTER MEDIA FOR AIRBORNE PARTICULATES

Filter Medium	Representative Application/Analysis
Mixed cellulose ester (MCE), 0.8- μ m pore	Metals/atomic adsorption; asbestos/phase contrast microscopy
Glass fiber	Pesticides/various
Polyvinyl chloride (PVC)	Total particulates/gravimetric; hexavalent chromium/visible spectrophotometry
Polycarbonate	Fibers
Polytetrafluoroethylene	Alkaline dusts/acid-base titration

Source: NIOSH *Manual of Analytical Methods*, Third Edition, Volume 1, February 1984 and supplements.

Filter sizes range from 13 mm in diameter to 40 by 40 inches. Small sizes (25 mm and 37 mm diameter) are generally used for personal samples and the larger sizes are normally used for Hi-Vol sampling. Selection of the size and type of filter depends on the user application and analysis. Table 1 gives examples of different filters and their applications.

The common filter holder used for personal samples is the polystyrene plastic cassette (Figure 1). It consists of two or three stacked sections, the number depending on the contaminant and the collection method. The sections of a cassette are molded to fit tightly when stacked and to tightly grip the outer edge of the filter. Each cassette has end plugs to seal the inlet and tubing connector part once the sample collection is completed.

Other materials than polystyrene can be used. Metal is used in large samplers with high flow rates. Carbon-filled polypropylene is used for asbestos sampling because it prevents an accumulation of a static charge, which would result in the attraction of the asbestos fibers to the cassette walls.

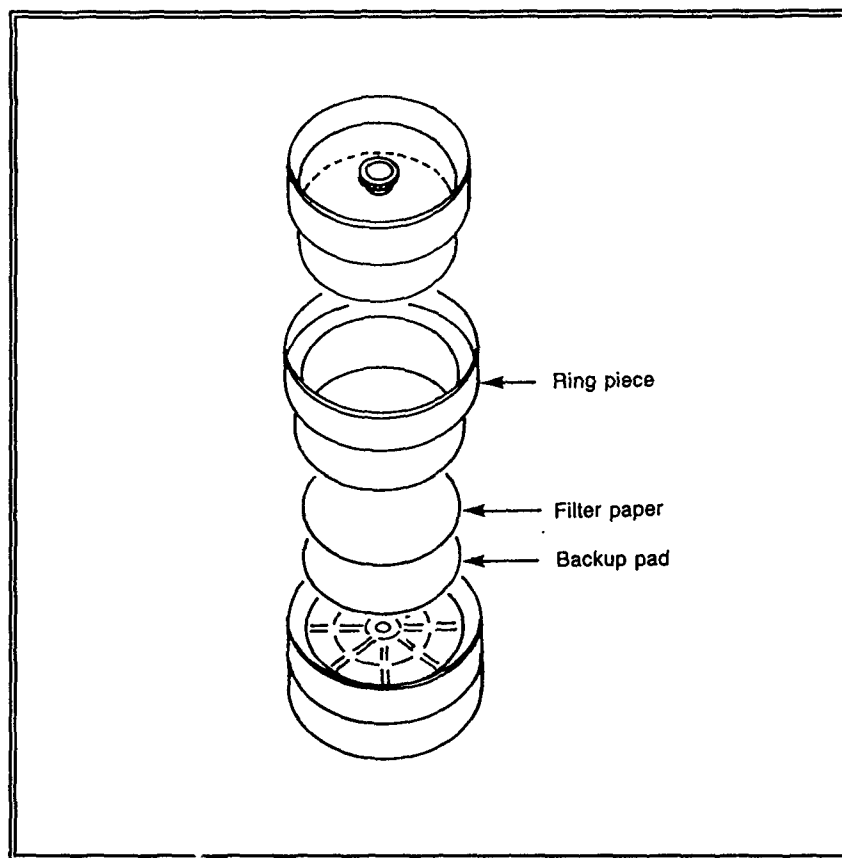


FIGURE 1. ASSEMBLY OF A THREE-PIECE FILTER CASSETTE

Source: *OSHA Technical Manual*, U.S. Department of Labor, OSHA, 1990.

Size Selection

Unlike gases and vapors, not all aerosols reach the deeper portions of the respiratory system. The nose and bronchioles remove the larger sizes. Environmental or public health samples are usually classified as total suspended particulates (TSP) or particulate matter - $10\ \mu$ (PM_{10}). PM_{10} samples collect particulates that are $10\ \mu$ and smaller. This represents the fraction of airborne particles that would be inhaled. PM_{10} samples are used to assess the inhalation route of exposure. TSP is used to assess exposure to contaminants that may be deposited downwind and available through ingestion.

Occupational samples are classified as total or respirable. Total samples are equivalent to TSP. Respirable samplers are designed to collect particles that would reach farther into the respiratory system. Most occupational exposure limits for particles are based on total samples. A few, silicon dust, coal dust, and nuisance dust, are based on respirable samples.

The most common devices used for aerosol size separation are the inertial impactor, the centrifugal separator, and the cascade impactor.

- The inertial impactors rely on a sudden change in velocity and direction to separate the sizes of particles. **Figure 2** illustrates the principle. The example shows that the larger particles (having more inertia) cannot follow the change in air direction and impact in the separator. The smaller particles can make the turns and are collected at the filter.
- The centrifugal separator or cyclone is similar to the inertial impactors. Cyclones commonly are conical or cylindrical in shape, with an opening through which particulate-laden air is drawn along a concentrically curved channel. Larger particles impact against the interior walls of the unit due to their inertia and drop into the base of the separator. The lighter particles continue on through and are drawn up through the separator and collected on a filter. Cyclones can be very compact and thus are often used for personal sampling.

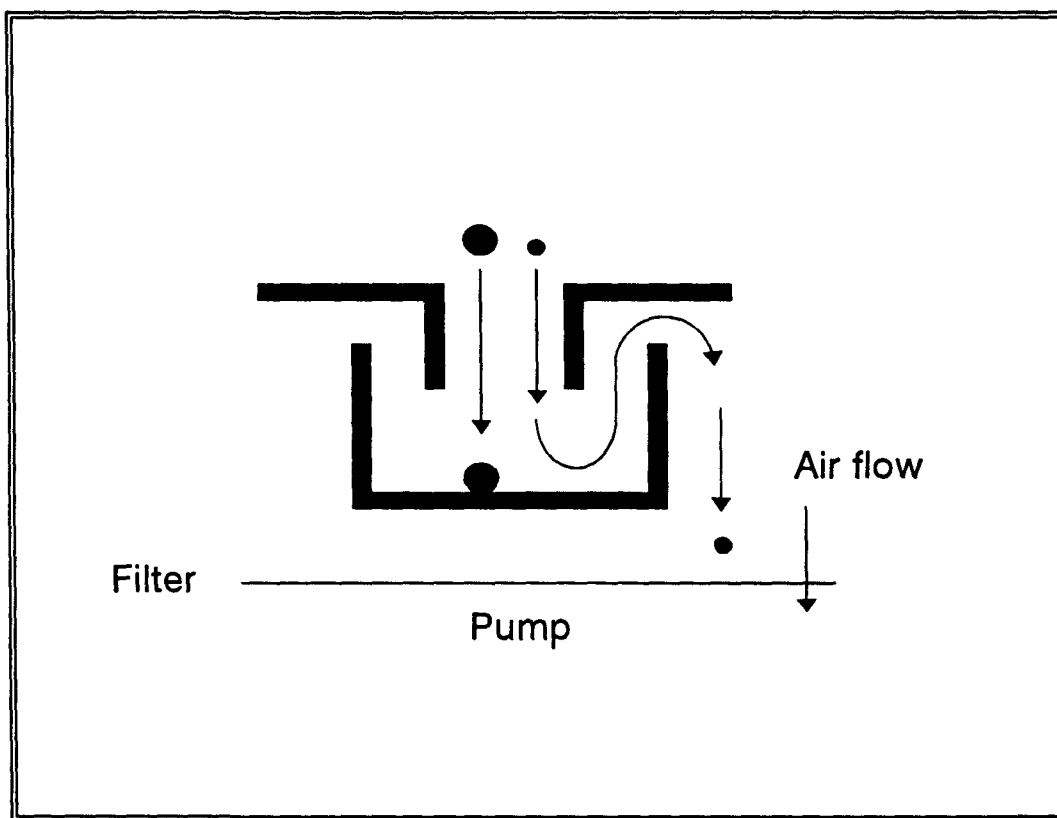


FIGURE 2. ILLUSTRATION OF AN INERTIAL IMPACTOR

- Cascade impactors (**Figure 3**) are composed of a number of stacked perforated collection beds or plates, each with openings narrower than the one before it. The cascade impactor separates particulates in an airstream by directing them toward a dry or coated flat surface. As the particulate-laden air moves through the plates, larger particles are deposited near the top and smaller near the bottom.

One major difference between the cascade impactor and other separators is that it can be used to collect each separate fraction for analysis. The other separators are used to separate the "respirable" fraction for analysis from the "total" mass of particulates.

With all preselectors, the separation efficiency is dependent on flow rate control. A specific flow rate is needed for the device to do proper separation.

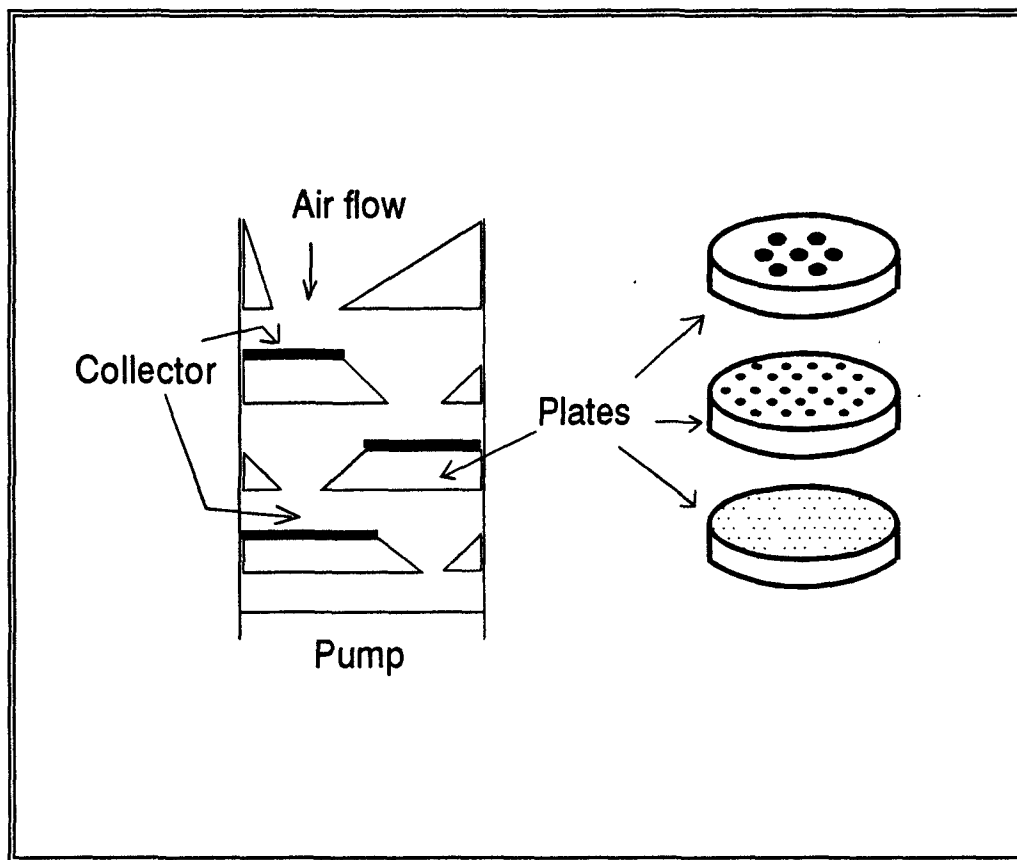


FIGURE 3. CASCADE IMPACTOR

GAS AND VAPOR (VOLATILES) SAMPLERS

Gases and vapors have different physical properties than aerosols and thus would pass through untreated filters without being collected. For gas and vapor collection, a sorbent is needed to separate the contaminant from the atmosphere or a container is needed to collect a whole air sample. The sorbents may be solid or liquid and the containers can be glass, plastic, or metal.

Solid Sorbents

Solid sorbents are a class of media widely used in hazardous materials sampling operations. Table 2 gives some examples and their applications. These materials collect by sorption and are often the media of choice for insoluble or nonreactive gases or vapors. Their advantages include high collection efficiencies, indefinite shelf lives while unopened, ease of use and specific analytical procedures.

TABLE 2. COMMONLY USED SOLID SORBENTS

Solid Sorbent	Representative Gas or Vapor Adsorbed
Activated charcoal	Nonpolar organics (NIOSH)
Tenax®	Volatile, nonpolar organics (EPA)
Carbon molecular sieve	Highly volatile, nonpolar organics (EPA)
Silica gel	Polar organics (NIOSH)

Sources: NIOSH *Manual of Analytical Methods*, Third Edition, Volume 1, February 1984 and Supplements; EPA's *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air*, EPA/600/4-89/017, June 1988.

There are several considerations when using solid sorbents. One of the major concerns with the use of solid sorbents is the potential for "breakthrough." Breakthrough occurs when the sorptive capacity of the media is exceeded. There is a limit to the amount of chemical that the sorbent can hold. Most methods limit the volume of air pulled through the sorbent to prevent this problem; hence, the use of low flow pumps for sorbent tube sampling. A way to check for breakthrough is to use a double section tube (Figure 4) and analyze each section separately. If a excessive amount of the total sample—one agency uses 25%—is found in the "back-up" section, then the sample is considered incomplete. Breakthrough is affected by humidity, temperature, total amount of chemicals in air, and the type and amount of sorbent. The problem of breakthrough can be reduced by reducing the air sample volume, increasing the amount of sorbent (e.g., use a 750 mg tube instead of a 150 mg tube) or using tubes in series. For example, the NIOSH methods for vinyl chloride and methylene chloride use two tubes in series.

A sorbent may not be able to collect all of a chemical. The efficiency will vary with sorbent and chemical. That is why there is no universal collection media. The sampling method usually selects the sorbent that will get the highest sorption efficiency (the closer to 100% the better).

Storage and handling of the sorbent samples can also be a problem. They cannot be stored indefinitely. Analysis usually must be done within 2 weeks. Some sorbents require special handling. The EPA method that uses Tenax® tubes for sampling requires the operator to wear cotton gloves so as not to contaminate the media with skin oils. The method requires storage away from sunlight.

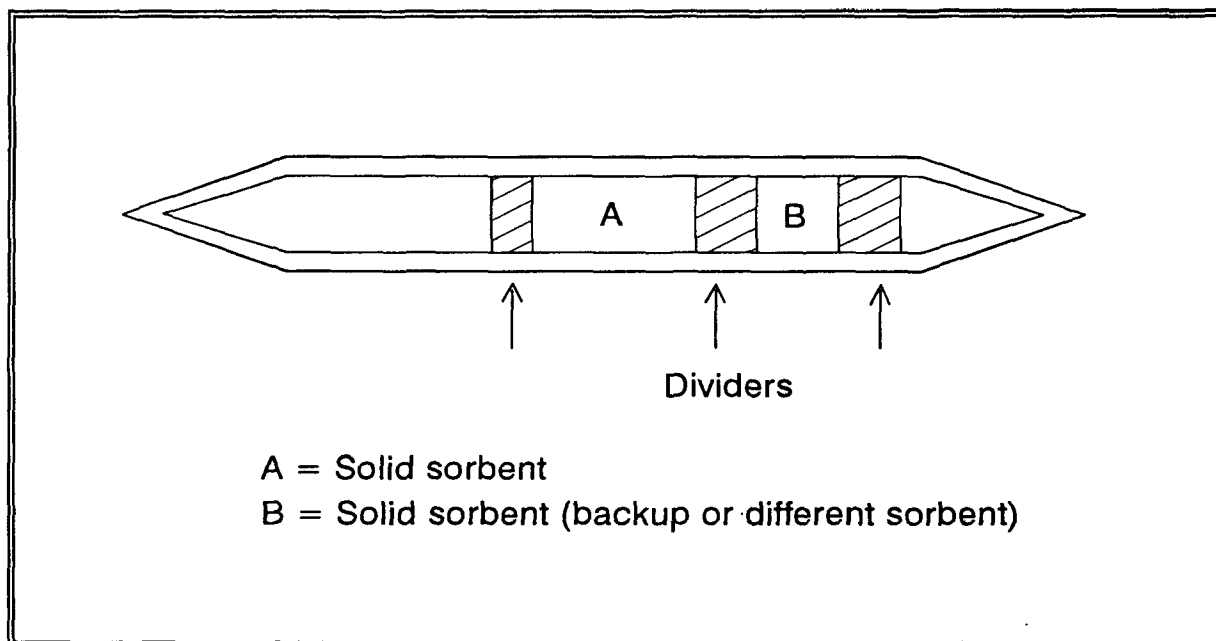


FIGURE 4. TYPICAL 150 MG SOLID SORBENT TUBE

When the samples are analyzed, the chemicals must be desorbed from the media. This can be done with solvents (e.g., carbon disulfide) or with heat (thermal desorption). Solvent desorption can involve hazardous liquids and needs a controlled laboratory environment. Thermal desorption can be done with automated equipment and does not need hazardous chemicals. However, the elevated temperatures may cause a change in some unstable chemicals.

Once the sample is desorbed, it can be analyzed by a variety of detectors.

Liquid Sorbents

Liquid sorbents are used to collect soluble or reactive gases and vapors (**Table 3**). Only a relatively few analytical methods use liquid sorbents. Further, most of the common liquid absorbers tend to be contaminant-specific and have limited shelf lives.

The liquid sorbents need a sampler to hold the liquid during sampling. These samplers ensure that contaminants in the sampled air are completely absorbed by the liquid sampling medium. There are several varieties of samplers. Differences in design are due to the efficiency needed for absorption.

- Impingers, or simple gas washers (**Figure 5a**), are a basic liquid holding sampler. This device consists of an inlet tube connected to a stopper fitted into a graduated vial such that the inlet tube rests slightly above the vial bottom. A measured volume of liquid is placed into the vial, the stopper inlet is put in place, and the unit is then connected to the pump by flexible tubing. When the pump is turned on, the contaminated air is channeled down through the liquid at a right angle to the bottom of the vial. The air stream then impinges against the vial bottom, mixing the air with the liquid and the necessary air-to-liquid contact achieved by agitation. The

TABLE 3. COMMONLY USED LIQUID ABSORBERS

Absorbing Liquid	Gas/Vapor Absorbed
0.1 N NaOH	Cresol/phenol (EPA); phenol (NIOSH)
0.1 M HCl	Hydrazine (NIOSH)
Aniline	Phosgene (EPA)
DNPH reagent and isooctane	Aldehydes/ketones (EPA)

Sources: NIOSH *Manual of Analytical Methods*, Third Edition, Volume 1, February 1984 and supplements; EPA *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air*, EPA/600/4-89/017, June 1988.

popularity of impingers rests on such qualities as simple construction, ease of cleaning, the small quantity of liquid used (typically less than 25 to 30 milliliters), and a size suitable for use as a personal monitor.

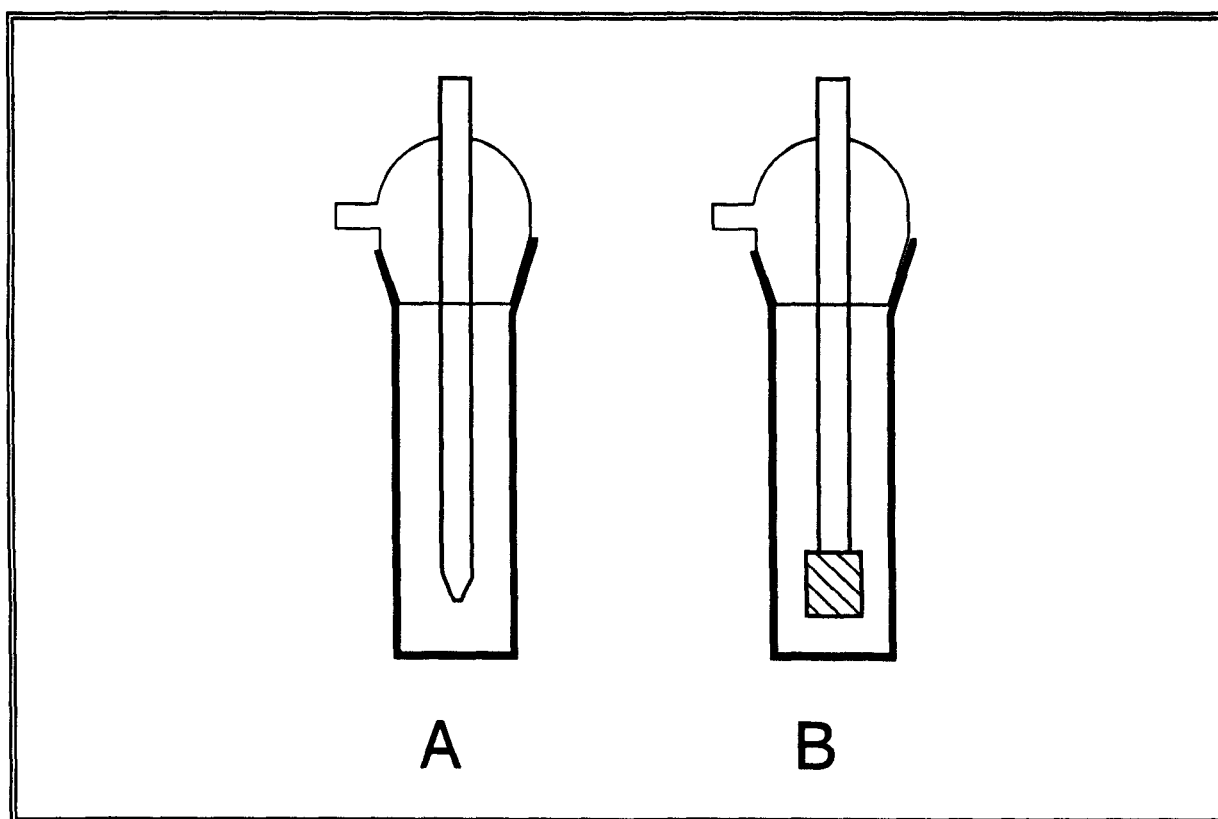


FIGURE 5. A - IMPINGER; B - FRITTED BUBBLER

Source: *The Industrial Environment - Its Evaluation and Control*, NIOSH, 1973.

- Fritted bubblers (**Figure 5b**) are generally used when a high degree of air-liquid mixing is desired. They are similar in construction to the impinger, but have a mass of porous glass, called frits, at the end of the submerged air tube. The frits break the air stream into numerous small bubbles. The frits are categorized as fine, coarse, or extra coarse, depending on the number of openings per unit area. By producing smaller sized bubbles, a greater surface area of the air sample is in contact with the liquid medium.

One of the major disadvantages with liquid sorbent sampling is that the samplers are generally made of glass and, thus, are fragile. Other disadvantages are the need for low, controlled flow rates to prevent overflow of liquid; spillage of liquid if the sampler is worn as a personal sampler; extra handling and storage of liquids; possible evaporation of liquid sorbent during sampling and thus loss of sample; and a need for a safety device (extra impinger, for example) between sampler and pump to prevent liquid contamination of the pump.

Passive Dosimeters

Passive dosimeters now available apply to gas and vapor contaminants only. These devices primarily function as personal exposure monitors, although they have some usefulness in area monitoring. Passive dosimeters are commonly divided into two groups, primarily on how they are designed and operated.

- Diffusion samplers (**Figure 6**) function by the passive movement of contaminant molecules through a concentration gradient created within a stagnant layer of air between the contaminated atmosphere and the collection material.
- Permeation dosimeters rely on natural permeation of a contaminant through a membrane. The efficiency of these devices depends on finding a membrane that is easily permeated by the contaminant of interest and not by other contaminants. Permeation dosimeters are therefore useful in picking out a single contaminant from a mixture of possibly interfering contaminants.

There are liquid and solid sorbents available for passive dosimeters. However, solid sorbents are the most common.

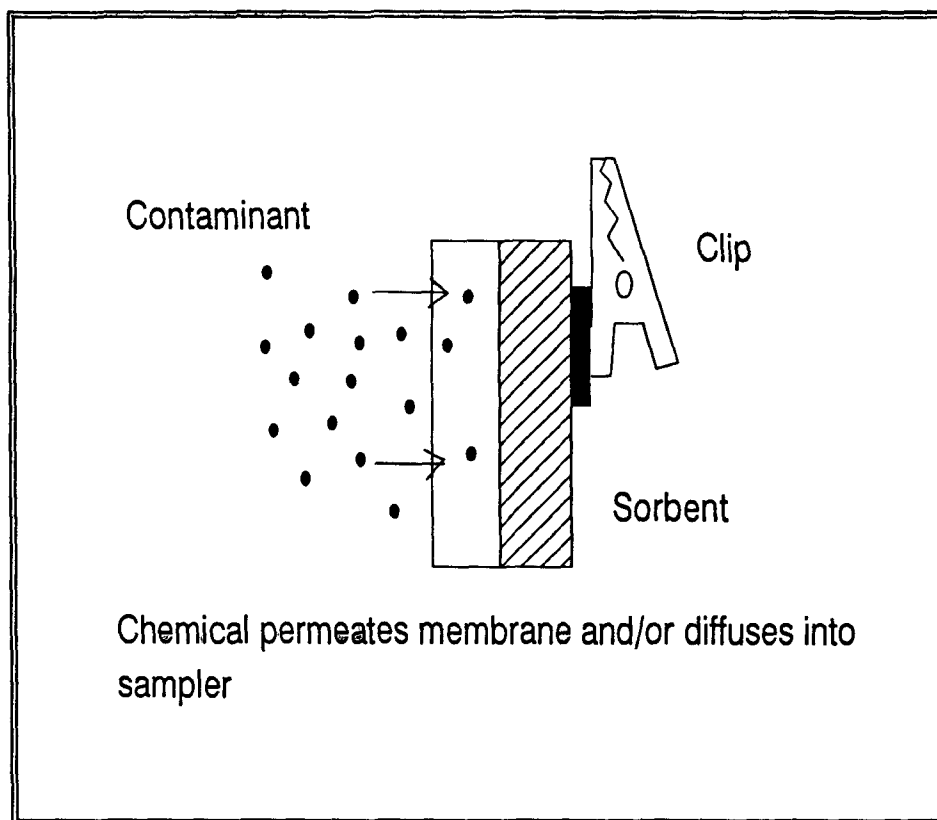


FIGURE 6. DIFFUSION TYPE PASSIVE DOSIMETER

Quantitative passive dosimeters have become available only since the early 1970s, though a semiquantitative passive monitor for carbon monoxide was patented as early as 1927. The key advantage of dosimeters is their simplicity (Figure 6). These small, lightweight devices do not require a mechanical pump to move a contaminant through the collection media. Thus, calibration and maintenance of sampling pumps are not needed. However, the sampling period must still be accurately measured. Like active systems, these devices can be affected by temperature and humidity. Sources of error unique to passive dosimeters arise from the need for minimum face velocities and the determination of contaminant diffusion or permeation coefficients.

Container Sampling

Because of the problems associated with sorbent sampling (breakthrough, sorbent efficiency, etc.), methods have been used to collect a whole air sample in a container. Several types of containers have been used.

Glass bottles have been used because of the relative inertness of glass. The procedure can be done several ways. The glass container can be evacuated to produce a vacuum and then opened in the sampling area. While this technique does not use a sampling pump, some way of evacuating the container is needed. Another method uses a pump to pull air through the container. When the air sample has replaced the air in the container, the container is closed. Another device uses a container

filled with water. When the water is drained, the air sample fills the space left by the departing water. This method is undesirable if water vapor is a problem in the analysis.

The devices have two problems. The containers are fragile and only give a sample at ambient pressure. To get a sample out, a vacuum needs to be pulled on the container or air added to equalize pressure as a sample is taken out. As more and more samples are removed, it becomes harder and harder to get the sample out. This also requires a pressure correction when calculating the contaminant concentration. If air is added to equalize pressure, the sample becomes diluted.

Sample collection bags can be constructed of a number of synthetic materials, including polyethylene, Saran™, Mylar™, Teflon™. They are square or rectangular with heat-sealed seams, hose valve fittings, inlet valves, and septums for syringe extraction of samples. They come in a variety of volumes. The selection of a bag should be based on a number of characteristics, including resistance to adsorption and permeation, tensile strength, performance under temperature extremes, construction features (seams, eyelets, and fittings), and intended service life.

Bag sampling can be done by connecting the bag inlet valve with flexible tubing to the exhaust outlet of a sampling pump. The bag inlet valve is opened, the pump turned on, and the sample collected. Once sampling is completed, the pump is turned off, the bag valve closed and the bag disconnected. The bag contents may be analyzed by connecting the bag to a direct-reading instrument; or a portion of the contents can be taken from the bag by a syringe and injected into a gas chromatograph.

In situations where there is concern about sample contamination due to passing through a pump, an alternate sampling apparatus can be constructed. This apparatus involves using the pump to evacuate a chamber (a desiccator or a sealable box) in which the sample bag is installed (**Figure 7**). As the pump creates a partial vacuum, the sample bag expands and draws the sample in through a sample tube.

The major disadvantage of gas sample bags is sample stability. Chemicals in the sample may sorb to the bag material or permeate through the bag walls. This would cause a decrease in sample concentration. The sample can also be affected by contaminants outside the bag by permeation through the bag walls. If a bag is reused, sorbed chemicals may desorb into the new sample and cause contamination. Because of these problems, bags are seldom reused, and samples are analyzed as quickly as possible (usually within 24 hours).

Chemicals in the bag can degrade with exposure to sunlight. The bags should be stored in a container (e.g., a cooler or garbage bag) to prevent exposure to sunlight.

Recently, *metal canisters* have gained popularity. Until recently, there have been problems with reactions occurring with the metal on the insides of the container. New polishing techniques have greatly reduced the problem. Metal canisters are used similarly to glass containers. They are evacuated to produce a vacuum. Unlike glass containers, metal canisters can be filled several ways. The valve can be opened to get a instantaneous, or grab, sample. The canister can also be connected to a controlled flow orifice so that the sample fills the canister at a fixed rate. This gives a long term sample.

A pump can also be used to pressurize the canister so that a sample volume greater than the canister size is obtained. This latter capability is not available for glass containers or gas bags.

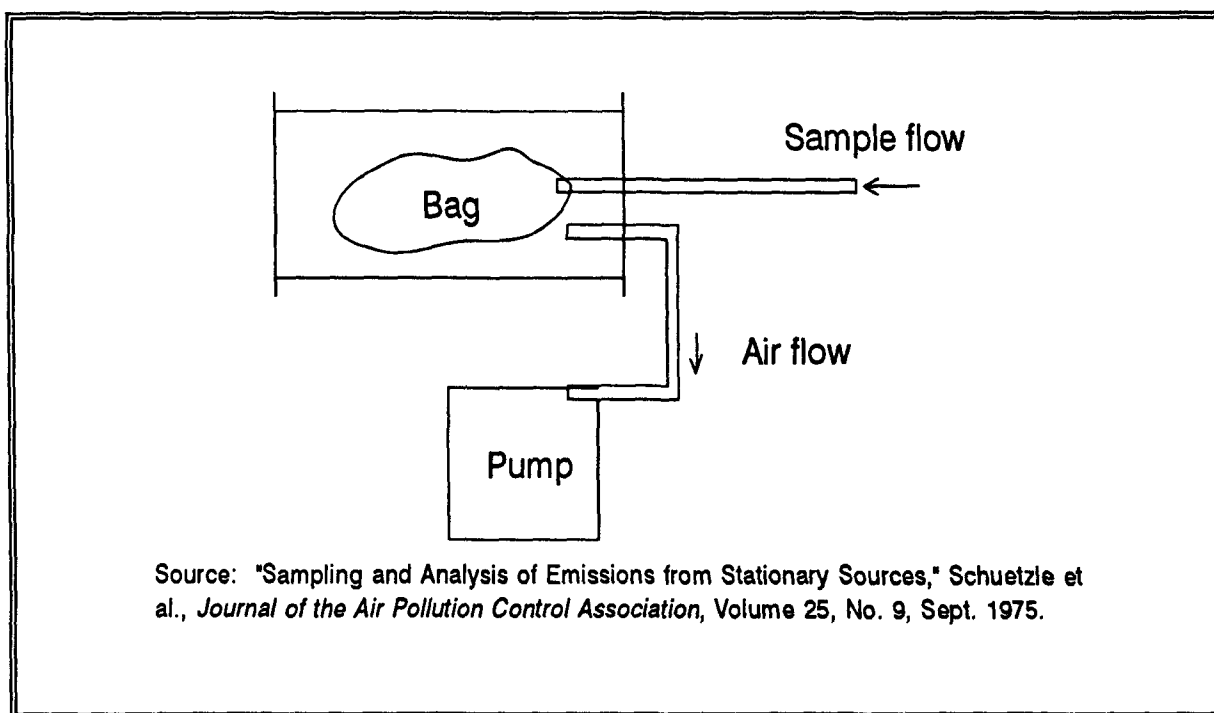


FIGURE 7. NEGATIVE PRESSURE BAG SAMPLING APPARATUS

Metal canisters are more durable than glass containers. They have better sample stability than gas bags. There are special cleaning procedures that allow the canister to be reused.

Metal canisters have a problem with recovery of polar compounds (e.g., alcohols).

Syringes can also be used to take a sample. Although 1-liter syringes are available, most are rather small and there may be a problem with having an adequate amount of sample.

Container sampling allows whole atmosphere sampling. This type of sampler eliminates the problems associated with sorbent media. It also allows the use of more than one analytical method per sample. Glass containers are fairly inert but are fragile. They also are limited in size. Gas bags are more durable and have a variety of sizes, but have sample stability problems. Metal canisters are durable, have good sample stability and can get a larger sample than their actual size (but only if special equipment is used). There are systems for taking personal samples with a gas bag. Gas bags and metal canisters can also obtain long term samples with controlled flow pumps.

SEMIVOLATILE SAMPLERS

Some chemicals, because of their physical properties, may be present in both solid and vapor form. There are also chemicals that are not very volatile, but will vaporize gradually if air is passed over them. This could happen if the chemical was captured on a filter. Because of these situations, some methods use more than one type of media. Usually a filter (for the aerosol phase) is followed by a sorbent (for the vapor phase). **Table 4** gives examples of chemicals that are in this category and the methods used to collect them.

Because two separate media are used, both will probably be analyzed by different methods. It will also take more time and be more expensive for the analysis.

TABLE 4. COMMON MULTIMEDIA SAMPLERS

Media Used	Chemical Being Sampled
0.8- μ m MCE filter + 0.1 N KOH	Cyanides (NIOSH)
13-mm glass fiber filter and Florisil	Polychlorinated biphenyls (PCBs) (NIOSH)
Quartz filter and polyurethane foam (PUF)	PCBs/pesticides (EPA) Polycyclic aromatic hydrocarbons - PAHs (EPA)
Quartz filter + XAD-2	PAHs (EPA)

Sources: NIOSH *Manual of Analytical Methods*, Third Edition, Volume 1, February 1984 and supplements; EPA *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air*, EPA/600/4-89/017, June 1988.

SAMPLING PUMPS

Pump Characteristics

Air sample collection systems, with the exception of evacuated canisters and passive dosimeters, rely on electrically powered pumps to mechanically induce air movement. The power source may be batteries or an AC source. Battery-powered pumps can operate for 6–10 hours. AC-powered pumps can operate longer, but are not usable as personal samplers.

Generally, sampling pumps incorporate several of the following features:

- A diaphragm or a piston-type pumping mechanism
- A flow regulator to control the sampling flow rate
- A rotameter or stroke counter to indicate flow rate or sample volume
- A pulsation dampener to maintain a set flow rate
- A programmable timer to start the pump at a set time and/or to stop the pump after a set sampling period
- An inherent safety approval for gas/vapor and dust atmospheres

Other than differences in features mentioned above, the main difference in pumps is their flow rate. Low flow pumps have a flow rate range from 10 cubic centimeters per minute (cc/min) to about 750 cc/min. Medium flow pumps have a flow rate of about 1–6 liters per minute (lpm). High volume (Hi-Vol) pumps are AC powered and can achieve up to 40 cubic feet per minute (cfm). That is equivalent to 1130 lpm.

The choice of flow rate depends on the type of sampling done. Sorbent media, like carbon tubes, cannot be used with a high flow rate. The capacity of the sorbent would be exceeded and there would be a loss of sample (breakthrough). Also, the Hi-Vol pumps are not used as personal samplers. Some pumps have the ability to do both low and medium flow sampling, but not Hi-Vol.

Calibration

All pumps must be calibrated. The flow rate must be known so that a sample concentration can be calculated. Calibration is also necessary to ensure the constant flow rate needed for some methods. The flow rate stability of a pump should be accurate to within $\pm 5\%$ of its set flow rate.

An active sampling system must be calibrated prior to and after sampling. The overall frequency of calibration depends upon the general handling and use a system received and the quality control considerations of the user. Pump mechanisms must be recalibrated after they have been repaired, when newly purchased, and following any suspected abuse. The sampling system as a whole must be calibrated to the desired flow rate rather than the pump alone. The sampling system should be calibrated prior to and after each use. The system can be adequately examined under field-like conditions only with all components connected.

There are several devices for calibrating sampling pumps:

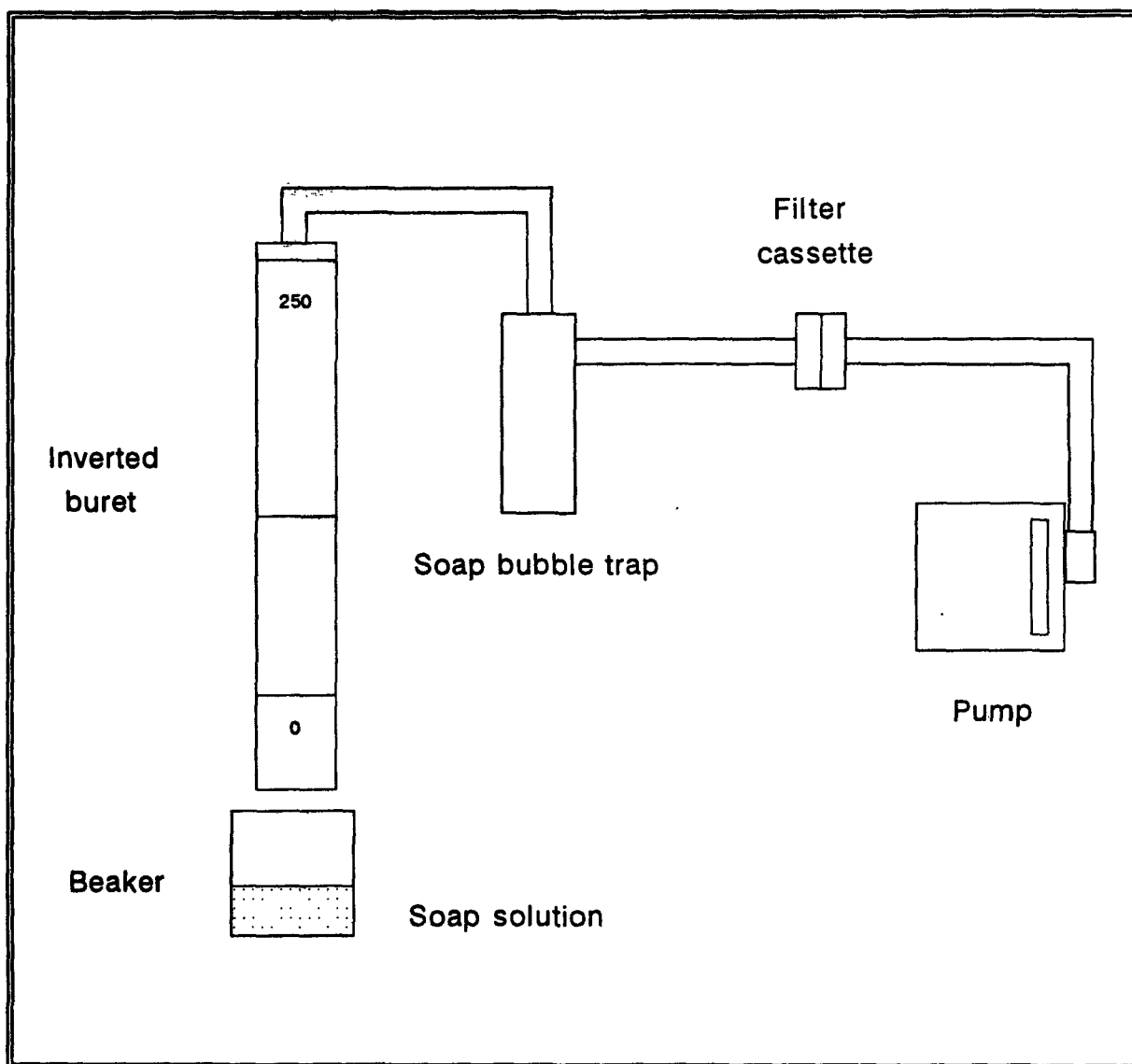
- The soap bubble meter represents a basic method of calibration and is a primary standard. This device typically consists of an inverted graduated burette connected by flexible tubing to the sampling train. **Figure 8** shows one example.

Do the calibration as follows:

- Start the system's pump to create airflow into the burette
- Dip the open end of the burette into a soap solution to create a soap film bubble across the opening
- Remove the solution and allow the bubble to rise up through the burette
- Measure the travel time of the bubble between two graduated points on the burette; vary the flow rate by adjusting the pump flow regulator.

The general formula used for the calculation of the flow rate is:

$$\text{Flow rate} = \frac{\text{volumetric distance traveled by bubble (ml)}}{\text{travel time of bubble (sec)}}$$



**FIGURE 8. CALIBRATION SETUP FOR FILTER SAMPLER
USING A SOAP BUBBLE METER**

Source: *OSHA Technical Manual*, U.S. Department of Labor, OSHA, 1990.

If the desired flow rate is lpm, then the units need to be converted by multiplying the previous equation by the following:

$$\frac{60 \text{ seconds/minute}}{1000 \text{ ml/l}}$$

- There are electronic bubble meters that use sensors to detect the soap bubble and start and stop an electronic timer. The calibrator then automatically calculates and displays the pump flow rate.

- The precision rotameter consists of a vertically mounted tapered tube with a float inside the tube. When attached to an operating pump, the float rises until the rate of flow is sufficient to hold the float stationary. The flow rate is read from markings on the tube at the point the float is stationary. Figure 9 illustrates a precision rotameter.

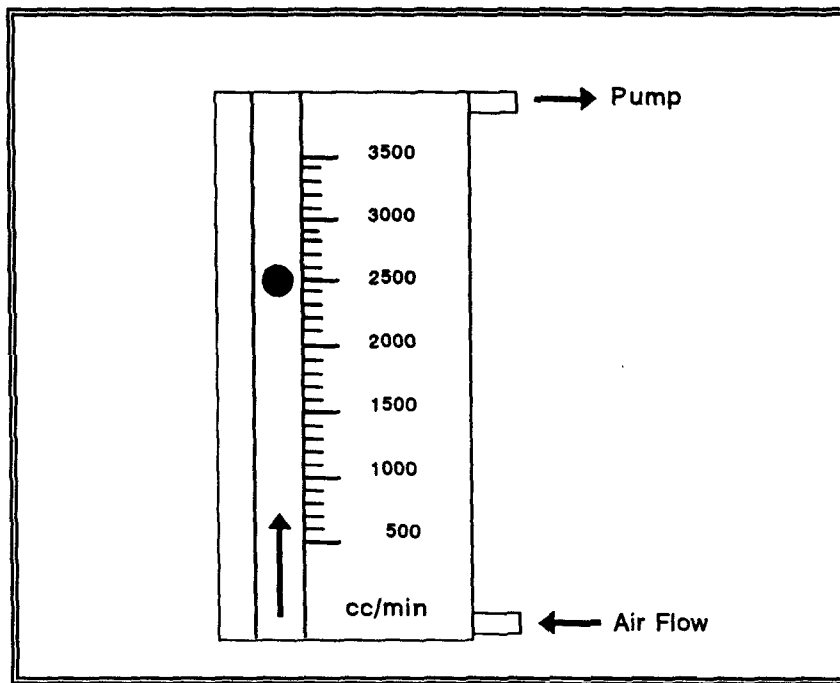


FIGURE 9. EXAMPLE OF A PRECISION ROTAMETER

Whereas the precision rotameter usually is more compact and portable than the soap bubbler meter, it is considered a secondary standard. This means that the rotameter must be checked occasionally with a primary standard such as a bubble meter.

- A manometer is sometimes used to calibrate Hi-Vol samplers because of the high flow rates. A manometer is a tube filled with a liquid. The level of the liquid changes due to pressure changes at the end attached to the sampling pump. A calibration chart is used to convert the change in liquid level to flow rate.

CONCLUSION

When taking air samples for laboratory analysis, several factors need to be considered. Sampling and analytical methods have been developed for many chemicals by several agencies that have looked at these considerations. The *References* section provides a list of references on air monitoring and sampling.



United States
Environmental Protection
Agency

Office of
Solid Waste and
Emergency Response

January 1993

Air Sampling Methods Database

Office of Emergency and Remedial Response
Emergency Response Division

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Volume 1, Number 1

What is the Air Sampling Methods Database?

The Air Sampling Methods Database is a PC-based software package which allows its users to access summarized standard methods for chemical analysis. The program, which was designed to be used in conjunction with the Representative Air Sampling Guidance for the Removal Program document, formulate sampling plans to give the best possible site characterization. This allows users to make quick determinations about which methods are most appropriate to use and which best suit their informational needs in order to plan a sampling event that most aptly depicts the objectives of a particular site investigation.

The user can search the software by method name and number, chemical name, or Chemical Abstracts Number (CAS #). The method summary can be viewed and the method marked for printing. Furthermore, the software can be tailored to its users since they have the capacity to input their own user-developed methods into the database without affecting the established standardized methods. Users can submit supporting documentation for their methods to the United States Environmental Protection Agency's Environmental Response Team (U.S. EPA/ERT) for possible permanent inclusion to the database.

Who Are the Anticipated Users?

On-Scene Coordinators (OSC), Technical Assistance Team (TAT) members, Emergency Response Contractors (ERCs), site Health and Safety air personnel, and U.S. EPA air plan reviewers are the primary users of the Air Sampling Methods Database. By using the program, these individuals gain access to the sampling objectives which best characterize a site. Then, users can assimilate this information into an acceptable repre-

sentative sampling program. The Air Sampling Methods Database also can aid any U.S. EPA personnel or agency that performs air monitoring at hazardous waste sites.

Why Was the Air Sampling Methods Database Designed?

The Air Sampling Methods Database was created to expand the knowledge base during remedial emergency response actions. It gives insight to two major criteria for preparation of a representative air sampling plan: selecting the appropriate air sampling approach and choosing the proper equipment to collect and analyze a sample. Timely decisions regarding health and safety and acute health risks can be made by utilizing these summarized methodologies:

- National Institute of Occupational Safety and Health (NIOSH) 2nd and 3rd Edition Methods.
- Occupational Safety and Health Administration (OSHA) Methods.
- Selected American Society of Testing and Materials (ASTM) Methods. Volume 11.03 Atmospheric Analysis; Occupational Health and Safety.
- EPA Toxic Organic Compounds Methods.
- Contract Laboratory Program - Statement of Work Methods.
- Indoor Air Compendium Methods.
- Code of Federal Regulations (CFR) Methods.

This facilitates a greater variety of options for the users, who then can select the appropriate air sampling objectives and plans that best suit the needs of a particular assignment.

Features of the Air Sampling Methods Database

- Is user friendly.
- Requires no other software for support (self-contained).
- Adds, deletes, and edits methods added by a user.
- Traces information by on-line references.
- Provides single point of update.
- Gives semi-annually updates.
- Allows access to update information available via Environmental Response Center (ERC), Office of Solid Waste and Emergency Response (OSWER), U.S. EPA/ERT, and Dataport bulletin boards by modem.
- Generates hard copy.

Future Features:

- Hot-Key on-line help.
- Hot-Key on-line glossary of terms.

- 50-100 word text summaries discussing sampling trains, flow rates, interferences, detection limits, analysis information, etc.
- Synonym searching of chemical names.

Requirements

To run the Air Sampling Database, you must have the following:

- An IBM PC or IBM-compatible computer
- A hard drive
- 640K RAM
- A printer (for hard copy output)

For more information about the Air Sampling Database, contact:

*Mr. Thomas Pritchett, Phone: (908) 321-6738
U.S. Environmental Response Team
2890 Woodbridge Ave
Building 18, MS-101
Edison, New Jersey 08837-3679*

APPENDIX A

Air Sampling Methods Database

INTRODUCTION TO GAS CHROMATOGRAPHY

PERFORMANCE OBJECTIVES

At the end of this lesson, participants will be able to:

- List the components of a gas chromatograph
- Define retention time
- List the factors that affect retention time
- Name the two types of columns and describe their differences.

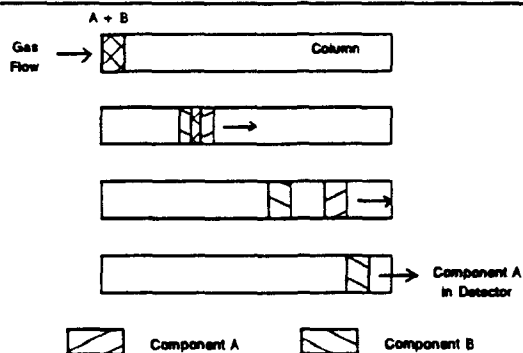
INTRODUCTION TO GAS CHROMATOGRAPHY

GAS CHROMATOGRAPHY Definition

A technique for separating volatile substances in a mixture by percolating a gas stream over a stationary phase

Source: *Basic Gas Chromatography*

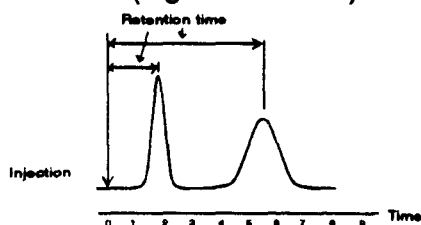
SEPARATION OF A MIXTURE BY GAS CHROMATOGRAPHY



NOTES

RETENTION TIME Definition

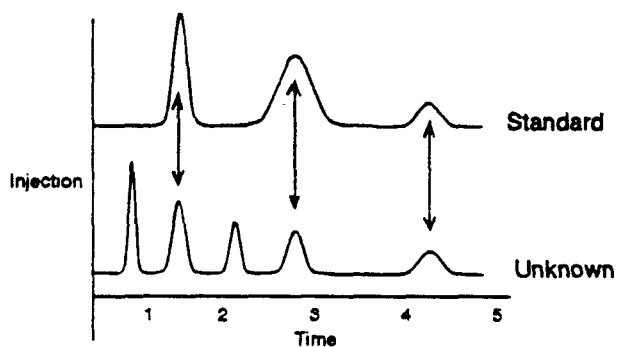
Retention time is the time from sample injection to peak maxima (signal maxima)



RETENTION TIME Application

Used for qualitative identification of chemicals by comparing the retention time of an unknown chemical with retention times of known (standard) chemicals

RETENTION TIME Peak Comparisons



FACTORS AFFECTING RETENTION TIME

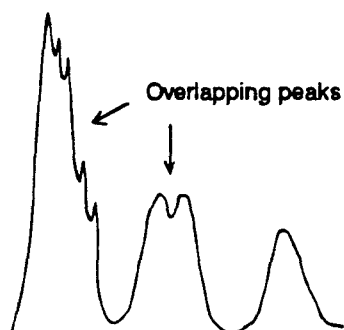
- Column
 - Type
 - Temperature
 - Length
- Carrier gas flow rate

EFFECT OF COLUMN TYPE AND TEMPERATURE

Chemical	Temperature (°C)	Retention Time (min.)	
		G-8 Column	T-8 Column
Benzene	0	1:19	1:43
	40	0:25	0:32
Carbon tetrachloride	0	1:24	0:37
	40	0:25	0:17

Source: The Foxboro Company Chromatographic Column Guide for the Century OVA, 1988

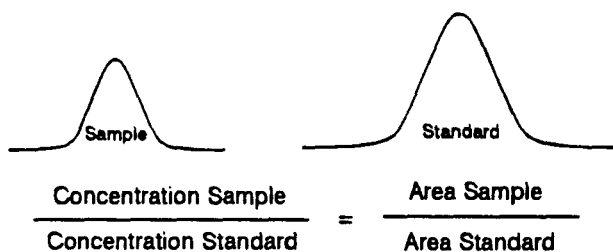
PEAK RESOLUTION Problems



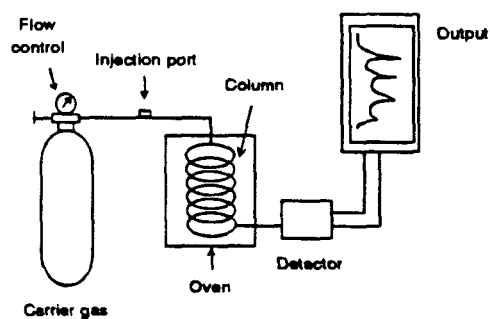
NOTES

PEAK AREA Application

Peak area is used to quantify chemical



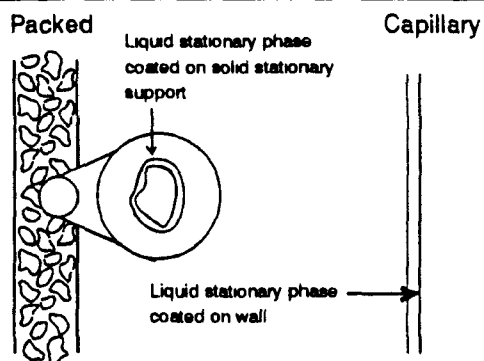
GAS CHROMATOGRAPH Components



CARRIER GAS Characteristics

- Suitable for detector
- High purity
- Does not interfere with sample

GAS CHROMATOGRAPH Columns



COLUMN TEMPERATURE

- Ambient
 - Variable
- Isothermal
 - Constant temperature
- Temperature programming
 - Temperature increases over time

DETECTORS USED IN PORTABLE GCs

- Common detectors
 - Flame ionization detector (FID)
 - Photoionization detector (PID)
- Specialized detectors
 - Thermal conductivity detector (TCD)
 - Argon ionization detector (AID)
 - Electron capture detector (ECD)

NOTES

SPECIALIZED DETECTORS

Why Are They Used?

One detector may be more sensitive than another for certain compounds.

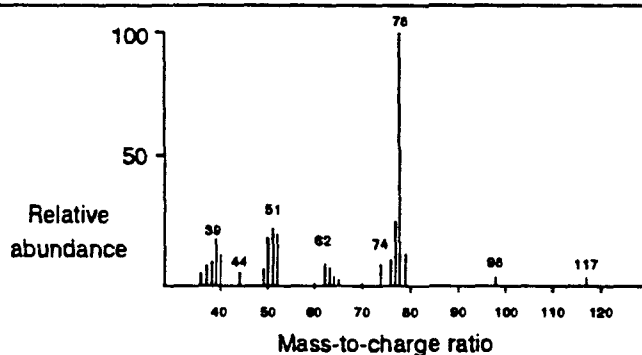
e.g. The ECD is best detector for halogenated compounds.

MASS SPECTROMETER

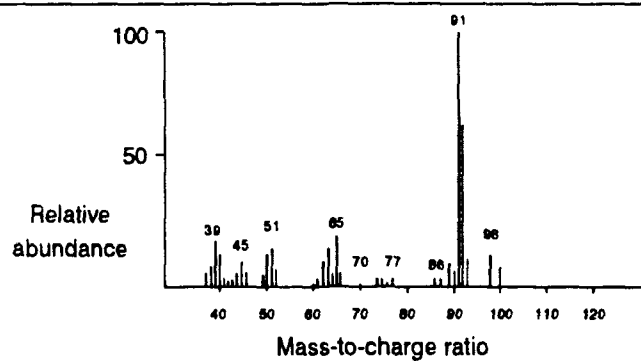
- Chemical exposed to electrons
- Molecule or fragments are ionized
- Ions separated by magnetic field
- Separation based on speed and mass-to-charge ratio
- Only detector capable of providing additional compound identification beyond retention time

MASS SPECTRUM

Benzene



MASS SPECTRUM Toluene



GAS CHROMATOGRAPHY Field Applications

- Air analysis
- Field screening
- Soil gas

SUMMARY

- Gas chromatography is used to identify and quantify chemicals
- Qualified operators are needed
- Right tool for the job?

INTRODUCTION TO GAS CHROMATOGRAPHY

INTRODUCTION

Gas chromatography is a separation technique wherein components of a sample are separated by differential distribution between a gaseous mobile phase (carrier gas) and a solid (gas solid chromatography) or liquid (gas liquid chromatography) stationary phase held in a column. The sample is injected into the carrier gas as a sharp plug and individual components are detected as they come out ("elute") of the column at characteristic "retention times" after injection. **Figure 1** illustrates this concept with a two component mixture.

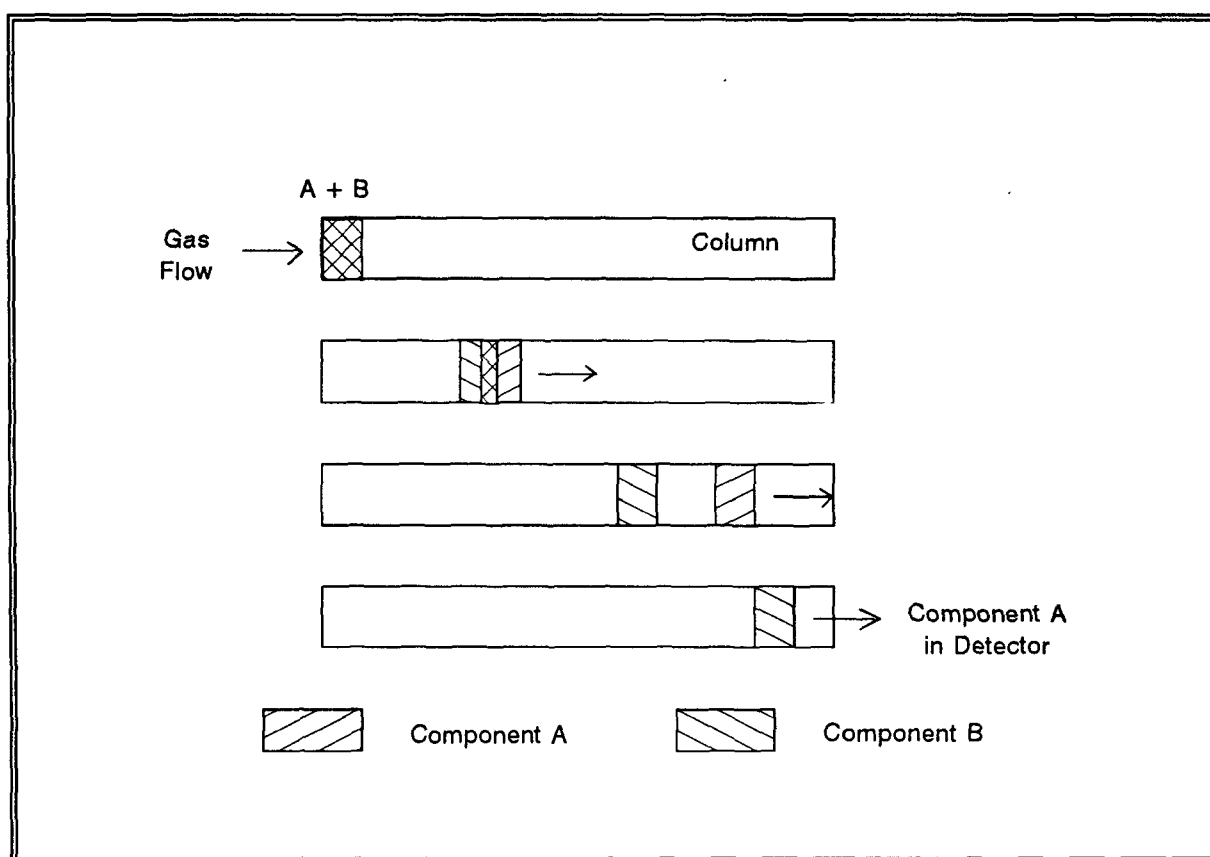


FIGURE 1. SEPARATION OF A TWO COMPONENT MIXTURE BY GAS CHROMATOGRAPHY

As different components elute from the column, they pass through a detector which generates a response (or "peak") based upon the amount of each compound present and upon the sensitivity of the detector. The signal vs. time plot is called the "chromatogram."

QUALITATIVE ANALYSIS

If the temperature of the column and the flow rate of the carrier gas are constant, compounds will elute from the column at a characteristic time (retention time). The retention is characteristic of the compound and the type of column used. Retention time is the time from injection of the sample to peak response of the detector to the eluted compound (**Figure 2**).

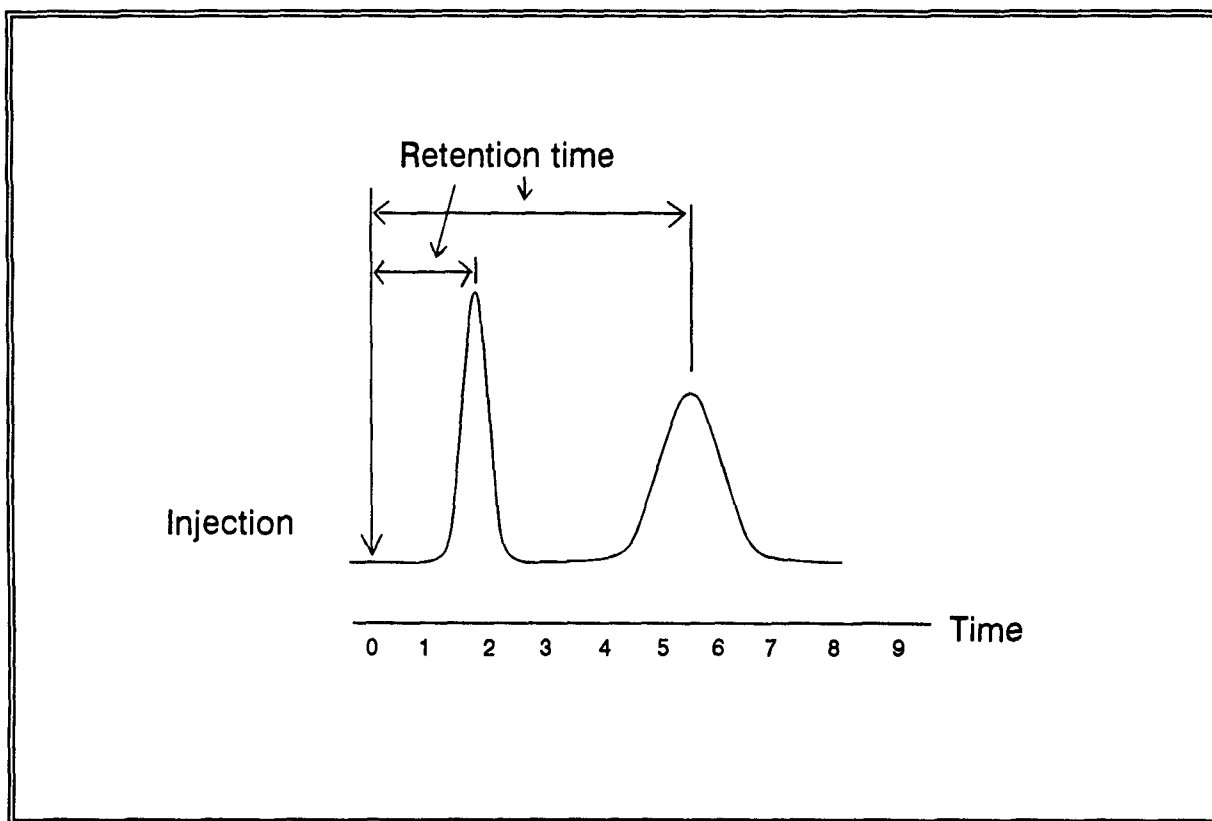


FIGURE 2. CHROMATOGRAM ILLUSTRATING RETENTION TIME

Qualitative analysis can be done by comparing the retention times of the compounds in an unknown sample with the retention times of known compounds in a standard analyzed under identical conditions. **Figure 3** shows a comparison of a sample with a standard.

Retention Time

Retention times are governed by several factors:

1. The type of column used. Different packings and liquid coatings change retention time.
2. The column temperature. As the column temperature increases, the retention time decreases. This is why temperature controls are used to keep the column temperature constant.

3. The column length. Double the column length and double the retention time.
4. The carrier gas flowrate. Double the flowrate and halve the retention time.

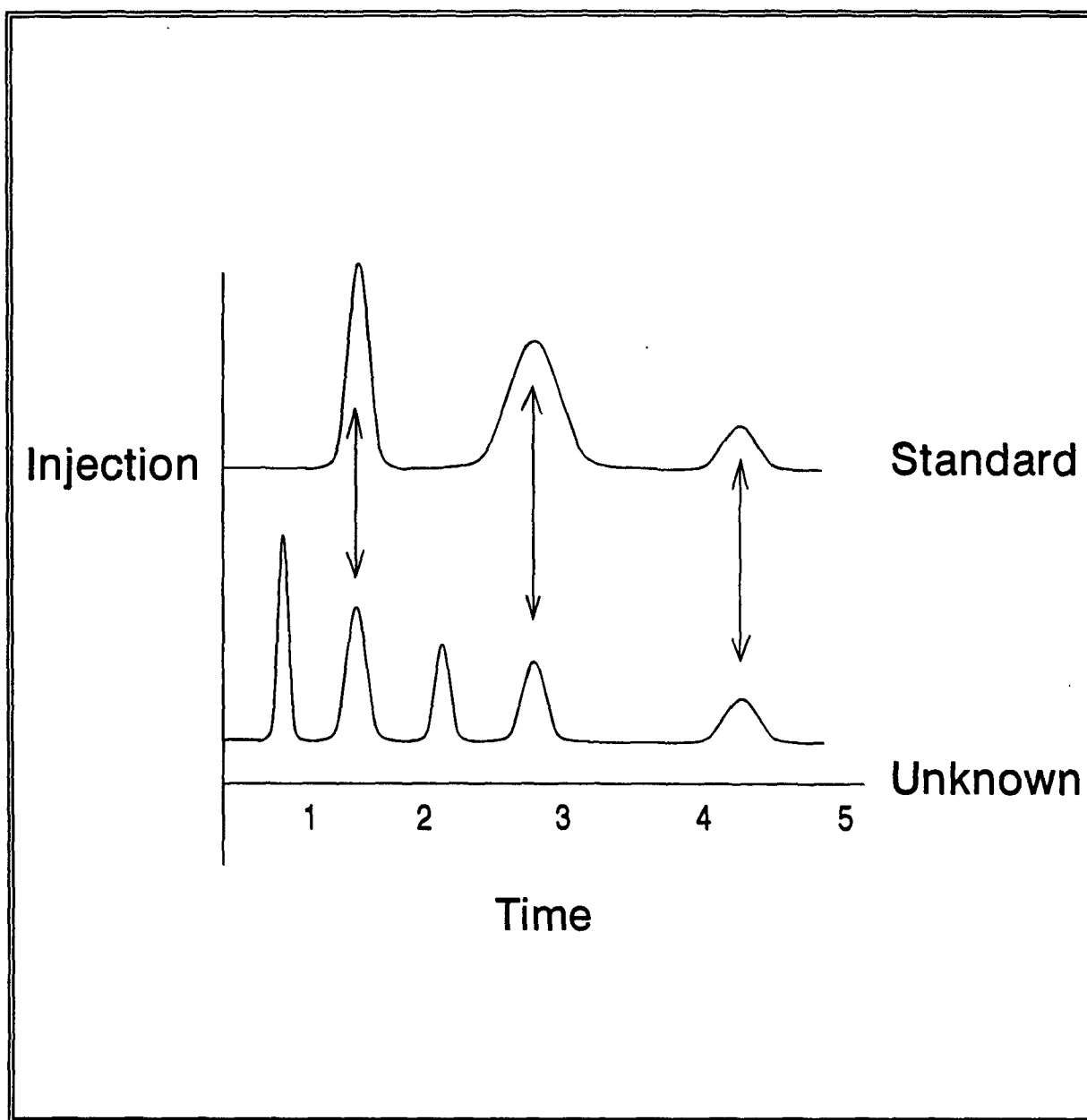


FIGURE 3. EXAMPLE OF A GC CHROMATOGRAM AND THE USE OF RETENTION TIMES TO IDENTIFY COMPOUNDS

Resolution

Resolution, or relative peak width, governs the number of discrete, detectable components of a sample that can be identified and quantified during the GC run. Resolution is governed by:

1. The type of column. Capillary columns have much greater resolution (narrower peak widths) than a packed column.
2. Column length. The longer the column, the narrower the peak width at a given retention time. However, with ambient temperature GCs, increasing the column length will increase the retention times.
3. The carrier gas flowrate. There exists an optimum value for peak resolution. Increasing or decreasing the flowrate from this optimum will widen the peaks.

A problem with poor resolution is co-eluting and overlapping. If two chemicals elute at the same time—co-elute—identification is hindered. If peaks overlap, quantitation of the compounds is difficult. **Figure 4** illustrates overlapping peaks.

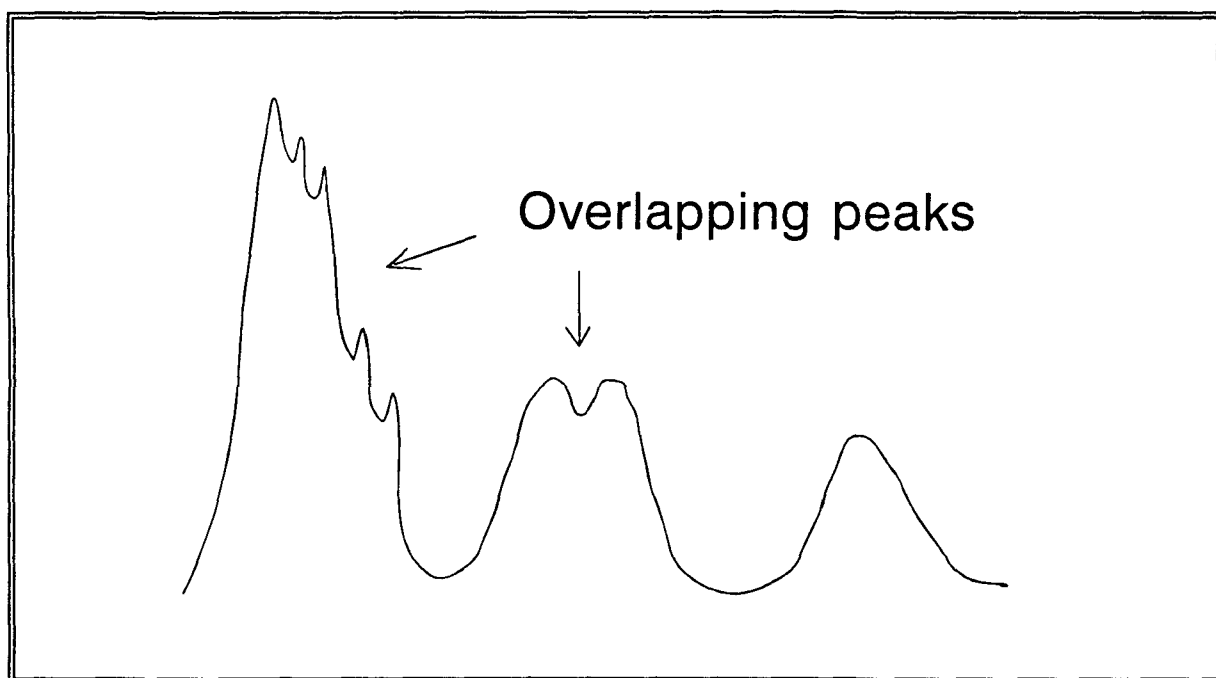


FIGURE 4. EXAMPLES OF OVERLAPPING PEAKS

QUANTITATIVE ANALYSIS

Signal Output

The size of the chromatogram peak for a specific compound is proportional to the amount of chemical in the detector. Quantitative analysis is done by comparing the peak size of the sample compound with the peak size of a known amount of the compound (the standard). The peak size can be quantified in several ways.

Planimetering

Planimetering uses a planimeter to trace the peak. A planimeter is a mechanical device that measures area by tracing the perimeter of the peak. The area is presented digitally on a dial. This method is considered tedious, time-consuming, and less precise than other methods.

Peak Height

Peak height compares the height of the sample compound with the height of the standard. This is a quick and simple method for quantitation. However, peak heights and widths are dependent on sample size and sample feed rate.

Height \times Width at Half-Height

The *height \times width at half-height* uses the height of the peak times the width of the peak at the half-height of the peak. The normal peak base is not used because large deviations may be caused by peak tailing.

Triangulation

Triangulation (**Figure 5**) transforms the peak into a triangle using the sides of the peak to form the triangle and the baseline to form the base of the triangle. The area of the peak is calculated using $\text{Area} = 1/2 \text{ Base} \times \text{Height}$.

Integrators

Peak height, height \times width at half-height, and triangulation are done manually using the chromatogram and a pencil and straight edge. *Integrators* calculate the peak size electronically and record the output. Because of ease of operation, integrators are most frequently used in portable GCs.

When a microprocessor is used, the retention times of the compounds in the sample are compared to the compounds in the standard and the readout identifies the compounds in the sample. Quantitative analysis is done by an integrator. If a compound has been identified, the peak size in the sample is compared to the peak size of the compound in the standard and a sample concentration is given. Thus, the sample is evaluated both qualitatively and quantitatively.

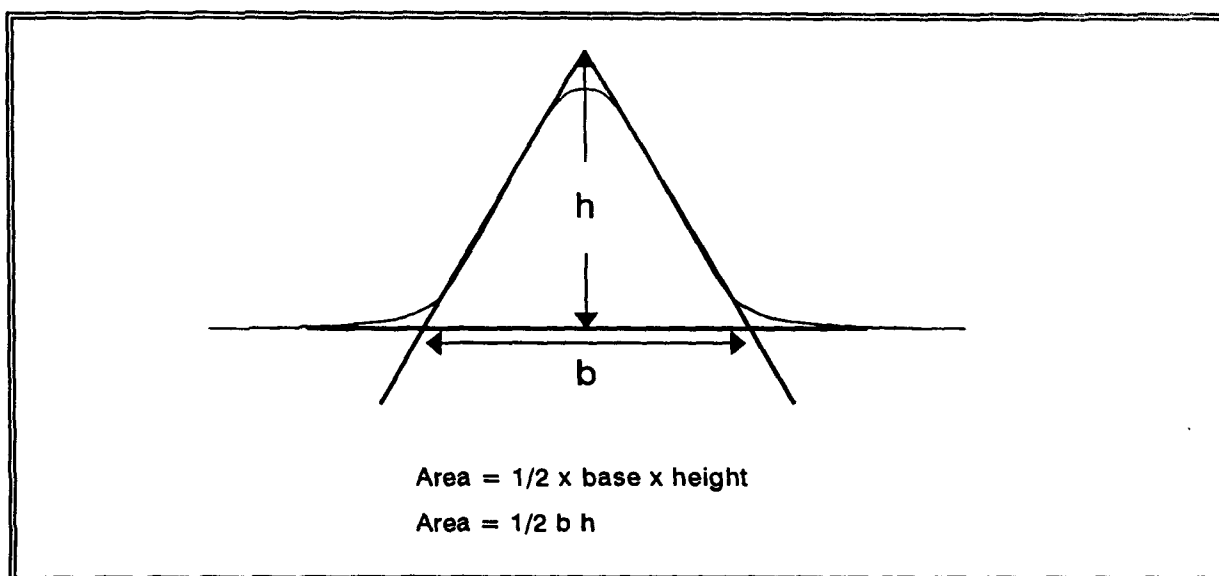


FIGURE 5. MEASUREMENT OF AREA BY TRIANGULATION

Source: *An Introduction to Gas Chromatography*, National Training Center, Water Program Operations, U.S. Environmental Protection Agency, Cincinnati, OH.

COMPONENTS OF A GAS CHROMATOGRAPH

A gas chromatograph (GC) consists of (Figure 6):

- A carrier gas
- A flow control for the carrier gas
- A sample inlet or injector
- A column
- A temperature control for the column
- A detector
- A recorder.

Carrier Gas

A high pressure gas cylinder serves as the source of the carrier gas. The carrier gas should be:

1. Inert to avoid interaction with the sample or solvent
2. Able to provide a minimum of gaseous diffusion
3. Readily available and of high purity
4. Inexpensive
5. Suitable for the detector used.

Commonly used gases are helium, nitrogen, and hydrogen.

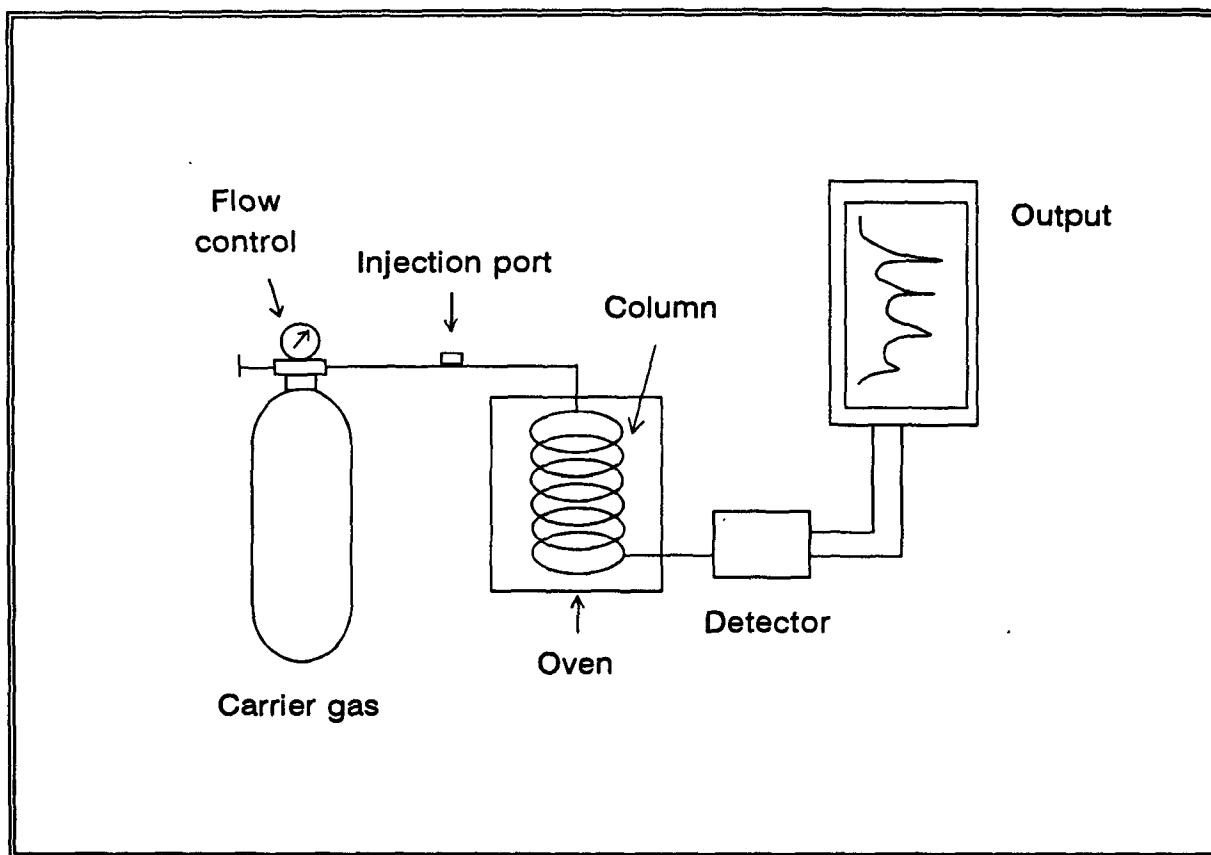


FIGURE 6. COMPONENTS OF A GAS CHROMATOGRAPH

Source: *The Industrial Environment - Its Evaluation & Control*, 1973, National Institute for Occupational Safety and Health.

Portable gas chromatographs (GCs) have internal cylinders that usually have an 8- to 10-hour gas supply. Many of these also have connections for external cylinders to provide longer duration analysis.

Flow Control

Because compounds elute at a characteristic time (retention time) based on a given temperature and a constant flow rate, carrier gas flow control and column temperature are important. A flow controller is necessary to maintain a constant flow rate.

Sample Injection System

Samples are introduced into the column as a single sharp plug. The sample injection system allows introduction of the sample rapidly and in a reproducible manner. Samples can be manually injected by a syringe. Syringe injection allows the operator to control the sample volume. Some GCs have a built-in sample loop that injects a known and consistent volume by manual operation or automatic

programming. Sample volume is important in that the quantitative evaluation of a chromatogram is affected by the sample volume. Also, some columns are limited by the size of sample that can be injected onto them.

Column

The column is a tube made of stainless steel, glass, aluminum, or Teflon®. *Packed columns* contain a solid adsorbent (gas-solid chromatography) or an inert solid support coated with liquid stationary phase (gas-liquid chromatography). *Capillary columns* consist of a liquid stationary phase coated to the inside wall of a thin tube. Gas-liquid chromatography columns and capillary columns are the more common types for the portable GCs.

Tube sizes range from 0.5- to 6-mm outside diameter and from 20 cm to 50 m in length. Capillary columns are usually longer than packed columns. Portable GC columns are typically 4 m in length. Columns can be coiled to fit inside portable units.

Capillary columns give better resolution than packed columns. However, they require smaller injection volumes than packed columns and thus need sample inlets and detectors that can handle small volumes.

Temperature Control

Column temperature affects the retention time of a chemical. A constant temperature is desired to ensure comparison of sample and standards. Temperature control can be:

- *Ambient temperature control*—The column temperature is the same as ambient air. As ambient temperature changes, the retention times change. Consequently, frequent calibration checks are needed. Ambient temperature limits use to volatile compounds. The time to run a sample is longer and thus limits the number of samples that can be run per day.
- *Isothermal temperature control*—The column temperature is maintained at constant temperature by an oven. Retention times are much more stable. Temperatures can be adjusted to reduce analysis time or expand the range of compounds that can be analyzed. Retention times are halved for every 30°C increase in temperature. Isothermal temperature control consumes more electricity than ambient.
- *Temperature programming*—Column temperature is slowly increased under very controlled conditions. This allows simultaneous analysis of compounds with a wide range of boiling points. A lower temperature is used for the volatile components. The temperature is raised to elute the less volatile compounds. More electrical power is needed for this operation.

Temperature control can also be used on the injector and the detector. Heating the injector prevents condensation of the sample (if a vapor) or can ensure vaporization of a liquid sample. The detector may need to be heated to prevent chemical condensation.

Detector

There are a variety of detectors available for GCs. *Flame ionization detectors (FID)* and *photoionization detectors (PID)* are frequently used. Characteristics of these two detectors are discussed in the *Total Vapor Survey Instruments* section. Other detectors include:

- *Thermal conductivity detector (TCD)*—This detector is based on the principle that a hot object will lose heat at a rate that is dependent on the composition of the surrounding gas. When a compound enters the detector, there is a change in the thermal conductivity of the carrier gas. Its advantage is that it is a universal detector for noninert gases and all organics. Its drawback is limited sensitivity—ppm levels. Preconcentration of samples has been used to offset this limitation.
- *Electron capture detector (ECD)*—A radioactive source is used to ionize the carrier gas. Secondary electrons are produced and an electrical current flows between the electrodes in the detector. When a separated compound which has an affinity for the slow electrons enters the detector, electrons are captured with a resultant decrease in electrical current in the detector. This decrease of current is a function of the concentration of the electron capturing compound.

The detector is especially selective for polyhalogenated (e.g., pesticides) and nitro compounds. It has a high sensitivity—mid ppb to high ppt. Sensitivity is a direct function of halogen atoms per molecule.

Its main limitation is that a radioactive source (tritium or nickel-63) is needed, which requires a Nuclear Regulatory Commission (NRC) license.

- *Argon ionization detector (AID)*—Argon ionization detector depends upon two reactions: the excitation of argon to its metastable state by electron bombardment and the ionization of vapor molecules by the transfer of energy from the metastable atoms. When an ionization chamber contains argon and a source of free electrons, the addition of vapor causes an increase in current flow. The current flow change is detected and used as the signal for the presence of the compound in the sample.

Ionization is caused by a radioactive source. As with the ECD, an NRC license is required for use of the radioactive source.

The reaction of the metastable argon atoms with the vapor molecules applies to all molecules with an ionization potential equal to, or less than, the stored energy of the metastable atoms, which is 11.7 eV.

- *Mass Spectrometer (MS)*—In an MS, the chemical is first exposed to a source of electrons. The molecules or fragments are ionized. The ions are passed through a magnetic field. The magnetic field separates the ions based on their speed and mass-to-charge ratio. The ions are collected and a mass spectrum is produced showing the relative abundance of each type of ion. Each chemical has a distinctive mass spectrum. Thus, this detector is the only one listed here that is capable of providing additional compound identification beyond retention time.

Recording Devices

A device is needed to record when a signal is produced in the detector and to record the strength of that signal. A plot of signal vs. time is called a chromatogram. The chromatogram is used for qualitative and quantitative analysis of the sample. Integrators and microprocessors can be used to electronically evaluate the chromatogram.

Power Supply

A power supply is needed to operate the detector, recorder, oven, and additional electronics of the gas chromatograph. To make them portable, field portable GCs usually have a built-in rechargeable battery supply. If only using the battery, time of operation is limited to 8-10 hours. These units are also designed to operate off AC power sources. A few field GCs only operate on AC power.

APPLICATIONS

Portable gas chromatographs allow analysis in the field. Although the results may not be as accurate and precise as a laboratory GC analysis, they can be used for screening purposes. This can reduce the number of samples that need to be handled by a more sophisticated (and more expensive) analysis.

Ambient Air Analysis

Portable GCs can analyze ambient air samples through several methods. Some units can be taken to the area where the sampling is required and an analysis can be performed on the spot. Some units can be programmed to do periodic sampling and store the chromatograms for later retrieval. Newer units can do continual total vapor monitoring and run a sample if the total vapor reading exceeds a designated level. The GC can also be set up in a more stable environment, and grab samples (e.g., a Tedlar bag of ambient air) can be brought to the GC for analysis.

Sample Screening

Soil and water samples can be screened for further analysis by doing headspace sampling. Headspace sampling involves drawing a sample from above the surface of a liquid or soil in a container. The sample is usually drawn with a small syringe which is also used to inject the sample into the GC.

Soil Gas

Gas chromatography can be used to screen soil gas samples. Dissolved volatile organic compounds have a tendency to partition into the atmosphere between the soil particles. By sampling this atmosphere, underground contamination can be tracked.

EXAMPLES OF PORTABLE GAS CHROMATOGRAPHS

The Foxboro Company

The Foxboro Century organic vapor analyzer (OVA) is the instrument described in the *Total Vapor Survey Instruments* section. The OVA-128GC is equipped with a column. The detector used is an FID. The column is at ambient temperature unless an optional temperature pack is used. The portable isothermal pack allows column temperatures of 0°C, 40°C and 100°C. The unit can be purchased with an external recorder/plotter. The company does not supply an integrator, but there are models from other suppliers that can be used.

Photovac International, Inc.

The Photovac series of GCs use photoionization detection. The temperature of the column is controlled by an oven. The currently available models (10S50, 10S70, 10S Plus, Snapshot) have a built-in microprocessor that aids in calibration and handles compound identification and quantitation. These units can be programmed for automatic sampling. The 10S Plus can be programmed to do total vapor monitoring and to do an analysis if an action level is reached. Options include a telephone connection for transferring data from the instrument to a computer and for notifying the user of unusual results during remote monitoring.

Sentex Sensing Technology, Inc.

The Sentex Scentograph is capable of using an AID or an ECD. One of the most notable features of the Scentograph is that a lap-top computer is used for handling the data. This gives a more graphic visual display of the chromatogram and makes operator use easier because of the normal size keyboard. The GC can do automatic functions. It has a temperature controlled column. There is the capability of concentrating the sample before injection. The air sample is pulled through and collected on a sorbent. The sample is then desorbed and injected using a smaller volume than was pulled through the sorbent. A primary consideration with the Scentograph is that, if an AID or an ECD is used, a radioactive source is needed and thus an NRC license is required. A PID and TCD are also available.

The Sentex Scentoscreen is similar to the Scentograph except it uses a PID and can also do total hydrocarbon analysis. It can be switched to an AID/ECD, but can not do total hydrocarbon readout with those detectors.

HNU Systems, Inc.

The HNU Systems' Model 311 is available with a PID or an ECD for its detector. The unit has a microprocessor for data handling. The instrument does not have a battery supply and thus, needs a line power or a portable generator.

Microsensor Technology, Inc.

Microsensor Technology's M200 Microsensor Gas Analyzer uses a TCD. Although this is a more universal detector, it suffers from poor sensitivity. A preconcentrator has been developed and used to reduce this limitation. The more notable characteristic of the M200 is that it sends a sample through two columns at the same time. This gives a better chance of correctly identifying the compounds present.

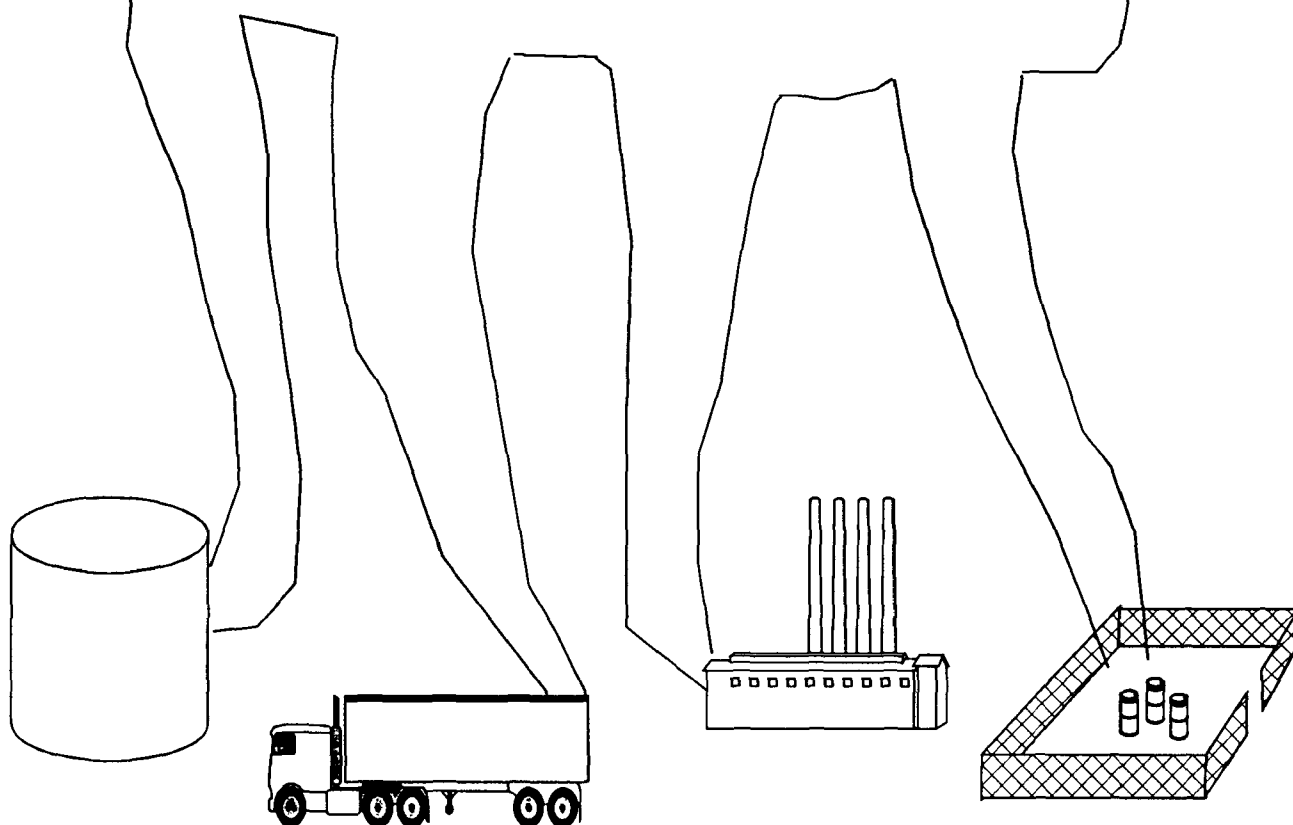
Thermo Environmental Instruments

Thermo Environmental Instruments manufactures the Model 511 Portable Gas Chromatograph. The main features of this GC is the variety of available detectors (FID, PID, ECD, TCD) and their easy changeability. The unit does not have a built-in data handler, so an external integrator or microprocessor is needed.

SUMMARY

Gas chromatography is a separation technique that can be used for identification of the components of a mixture. Portable GCs can be used in the field for a variety of applications. This process of identification can be affected by many factors that must be considered to ensure quality of data. Because the equipment is more complicated to operate than most direct-reading instruments, operators require more training and experience.

AIR DISPERSION MODELING DURING EMERGENCY RESPONSE



Dispersion Modeling During Emergency Response

- Objectives:**
- List five major atmospheric dispersion considerations
 - Describe the concept of stability as it applies to air modeling
 - Given a set of environmental conditions, choose the relevant stability class

Dispersion Modeling During Emergency Response

- Objectives:**
- Describe the concept of Gaussian plume distribution
 - Define near-field meandering and its effects to onsite receptors
 - Given an air dispersion model, list the data inputs needed to run the model for an emergency response
 - Given an emergency response scenario, list the elements of the modeling plan

Notes:

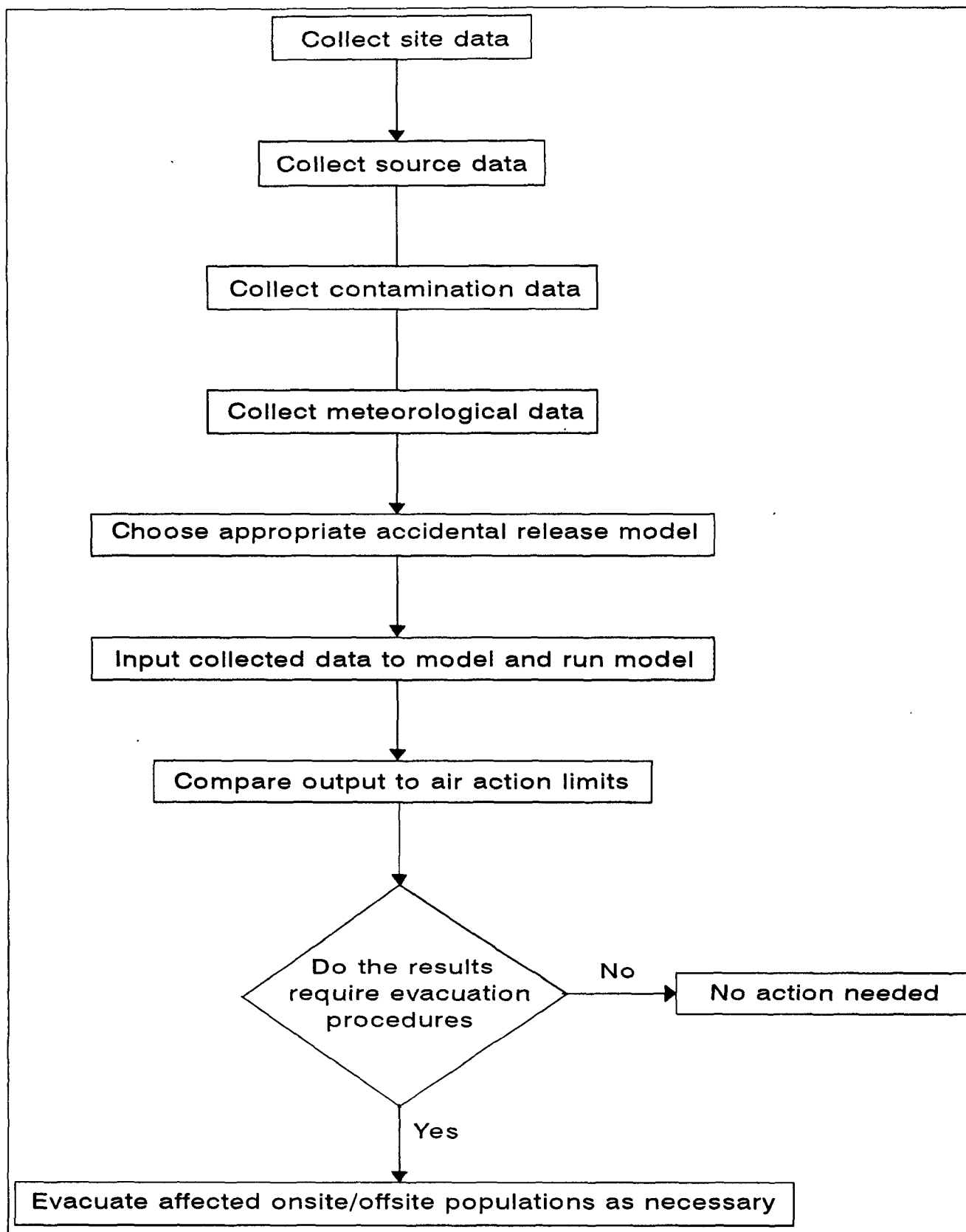


Figure 1. Dispersion modeling during emergency removal.

Dispersion Model Classes	
<p>Physical Models</p> <p>Small-scale, laboratory representations of the overall process (e.g., wind tunnel, water tank)</p>	<p>Mathematical Models</p> <p>A set of analytical or mathematical algorithms that describe the physical and chemical aspects of the problem (e.g., ALOHA, ISC, and PAL)</p>

Dispersion Model Classes

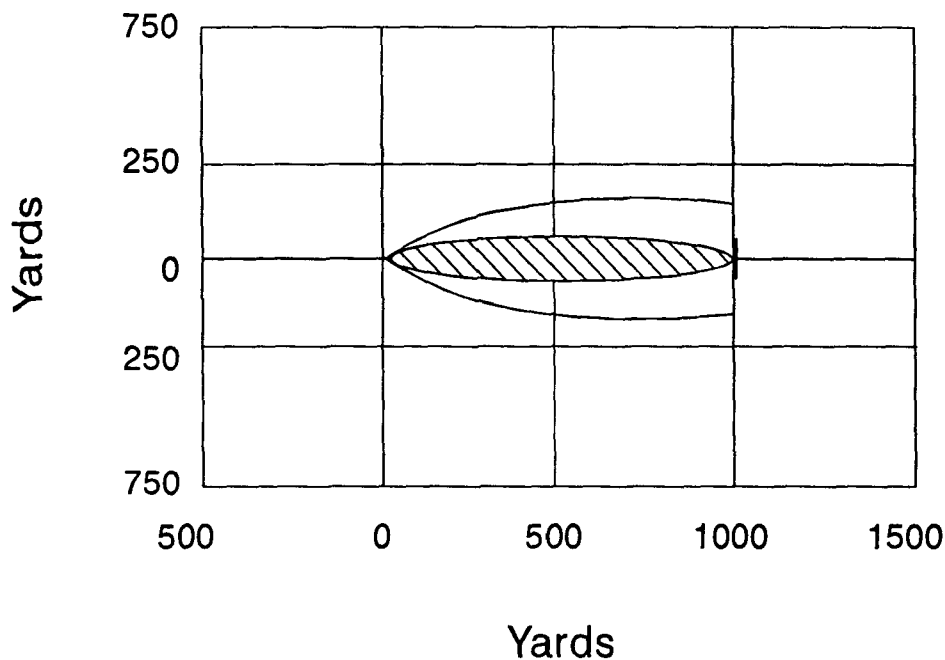
Mathematical models are primarily used because physical models (especially in an emergency response) are much less practical for most Superfund applications.

Mathematical models can be:

- Deterministic models, based on fundamental mathematical descriptions of atmosphere processes, in which effects (i.e., air pollution) are generated by causes (i.e., emissions).
- Statistical models, based on semi-empirical statistical relationships among available data and measurements.

Notes:

Diffusion Model Footprint



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Diffusion Model

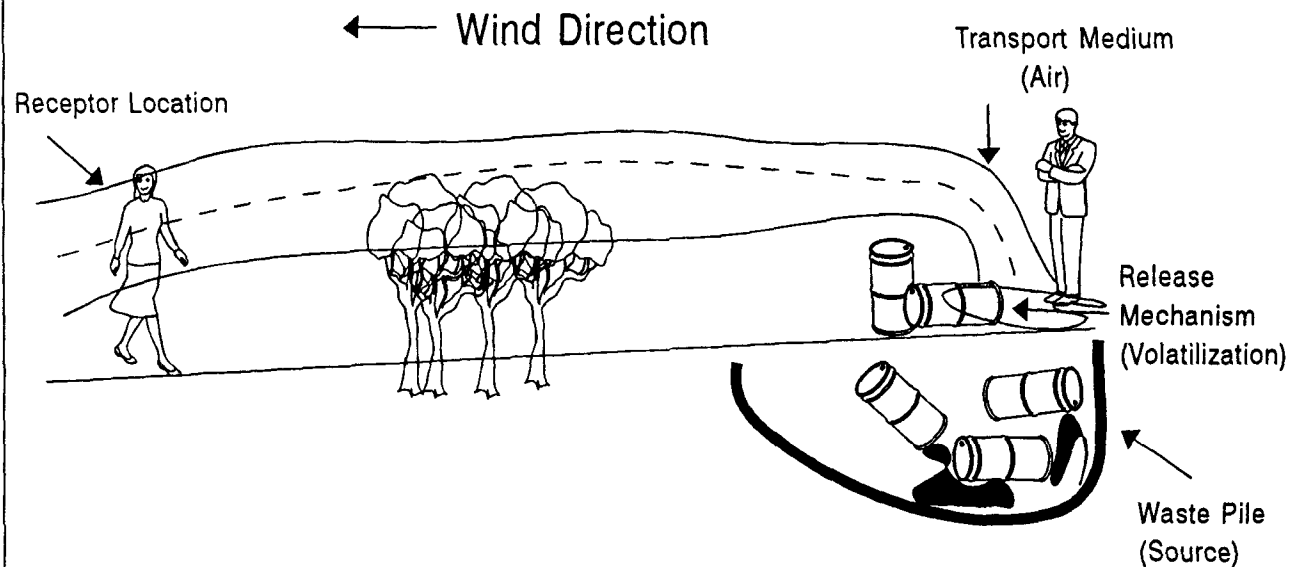
An example of a deterministic model is a diffusion model from which the output (the concentration field or footprint) is computed from mathematical manipulations of specified inputs (emission rates and atmospheric parameters).

A statistical model is given by the forecast, in a certain region, of the concentration levels in the next few hours as a statistical function of:

1. The current available measurements
2. The past correlation between these measurements and the concentration trends.

Notes:

Source-Receptor Relationship



Source-Receptor Relationship

The source-receptor relationship is the goal of studies aimed either at improving ambient air quality (usually the Superfund site goal) or preserving the existing concentration levels from future urban and industrial development. Only a deterministic model can provide an unambiguous assessment of the fraction of the responsibility of each pollutant source to each receptor area. This information then allows the definition and implementation of appropriate emission control strategies.

Notes:

Dispersion Modeling Applications

The two major dispersion modeling applications for Superfund are:

- To design an air monitoring program
- To estimate concentrations at receptors of interest

Dispersion Modeling Applications

Dispersion models can be used when designing an air monitoring program to see how offsite areas of high concentration relate to actual receptor locations. Places where high concentration areas correspond to actual receptors are priority locations for air monitoring stations.

Dispersion models can also be used to provide seasonal dispersion concentration patterns based on available representative historical meteorological data (either onsite or offsite). These dispersion patterns can be used to evaluate the representativeness of any air monitoring data collection period. Data representativeness is determined by comparing the dispersion concentration patterns for the air monitoring period with historical seasonal dispersion concentration patterns.

It is often not practical to place air monitoring stations at actual offsite receptor locations of interest. It will be necessary, however, to characterize concentrations at these locations to conduct a health and environmental assessment. In these cases, dispersion patterns based on modeling results can be used to extrapolate concentrations monitored at the site to offsite receptor locations.

Notes:

Atmospheric Dispersion Considerations

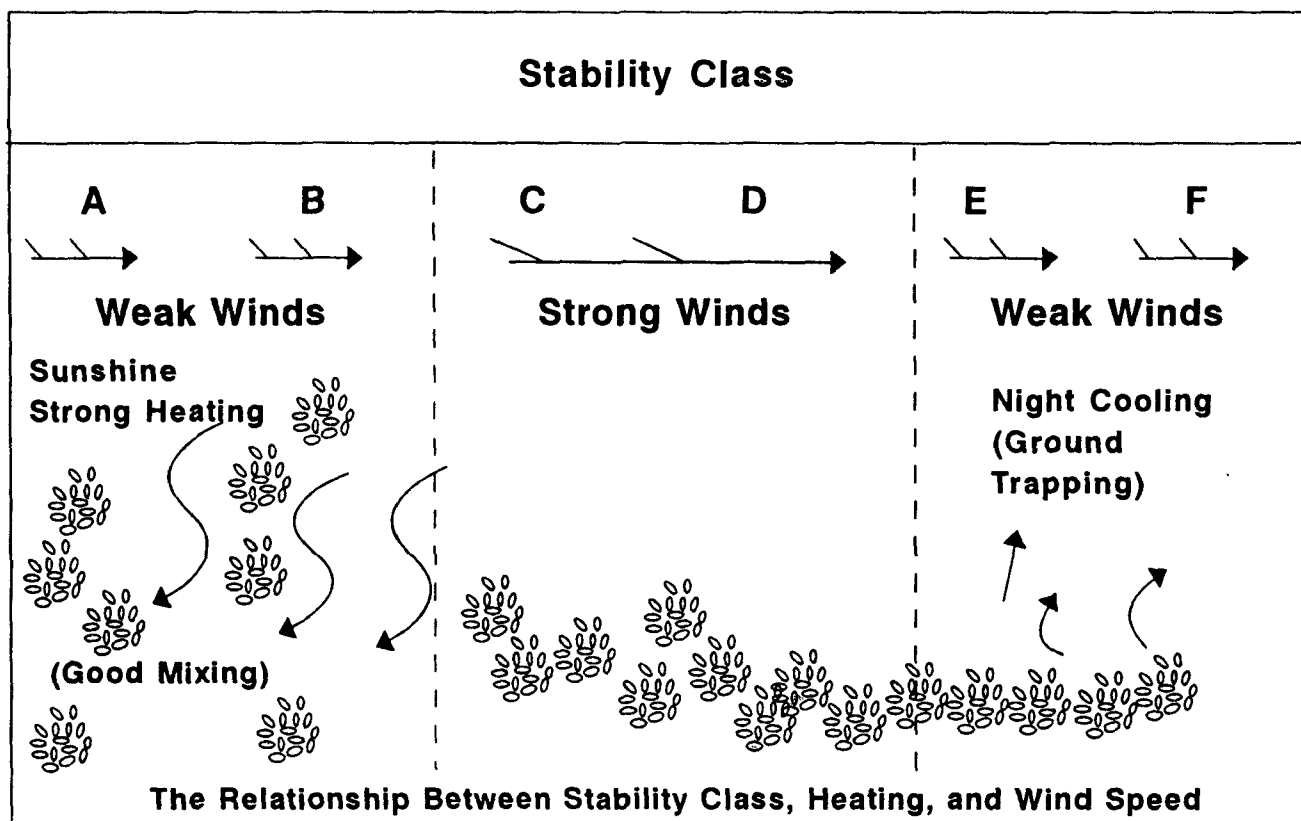
- Stability
- Inversions
- Wind speed and direction
- Air temperature
- Terrain effects

Atmospheric Dispersion Considerations

There are many different types of dispersion models, ranging from simple models that only require a few basic calculations to three-dimensional models that require massive amounts of input data and intense computational platforms to handle the complexity. Choosing the model to use depends on the scale of the problem, the level of detail available for input, the required output, the background of the user, and the turnaround time needed for an answer.

The five atmospheric dispersion considerations (i.e., stability, inversions, wind speed and direction, air temperature, and terrain effects) must all be considered throughout the modeling process.

Notes:

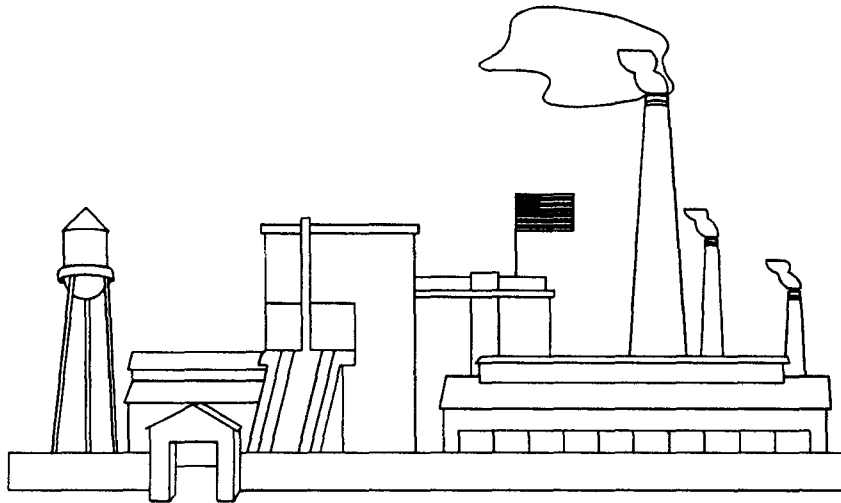


Stability Class

Atmospheric stability is the extent of physical stirring and mixing on the vertical plane. When an atmosphere is stable, there will be little mixing, which results in a persistent concentration. Stable conditions will also generally result in longer, narrower plume shapes.

Notes:

Inversions

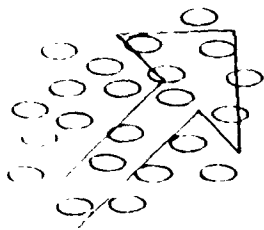


Inversions

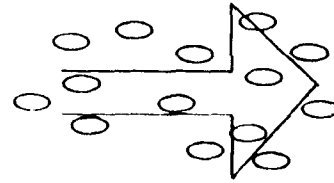
Inversions limit upward movement of air masses due to temperature differentials. The inversion height a modeler is concerned with is generally less than 100 feet. Inversions are generally an evening/night-time phenomenon and their presence results in increased stability.

Notes:

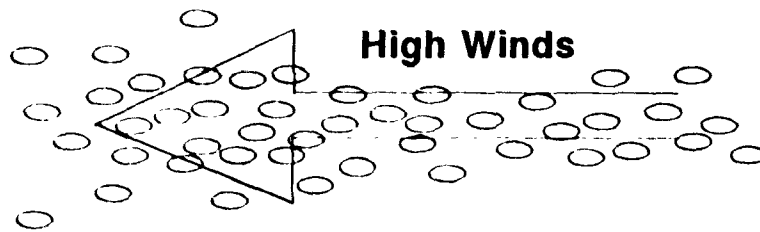
Effects of Wind Speed and Direction



Weak Winds



Moderate Winds



High Winds

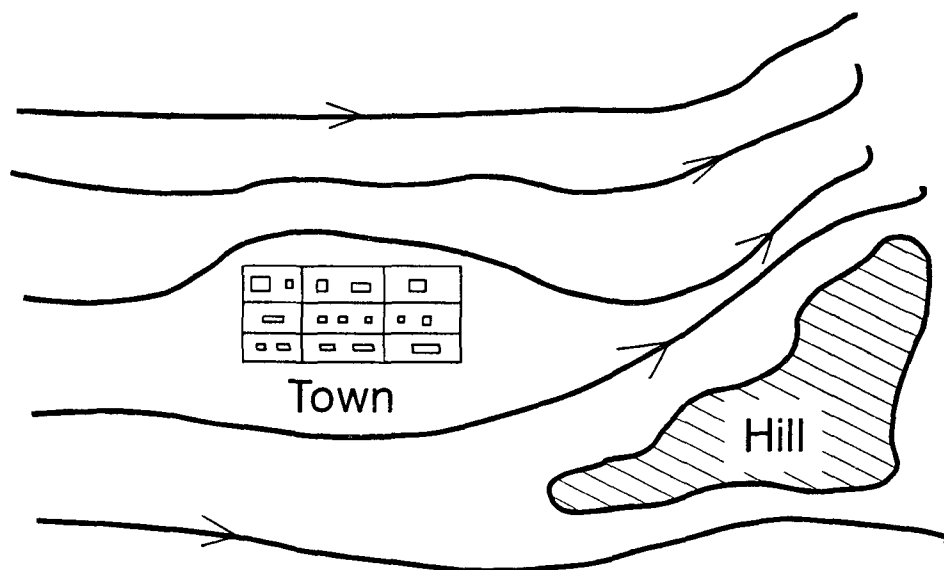
Effect of Wind Speed and Direction on a Plume

Effects of Wind Speed and Direction

Weak winds result in a decrease in stability. As wind speed increases, a corresponding increase in atmospheric stability is produced.

Notes:

Ground Roughness - Terrain Steering Effects

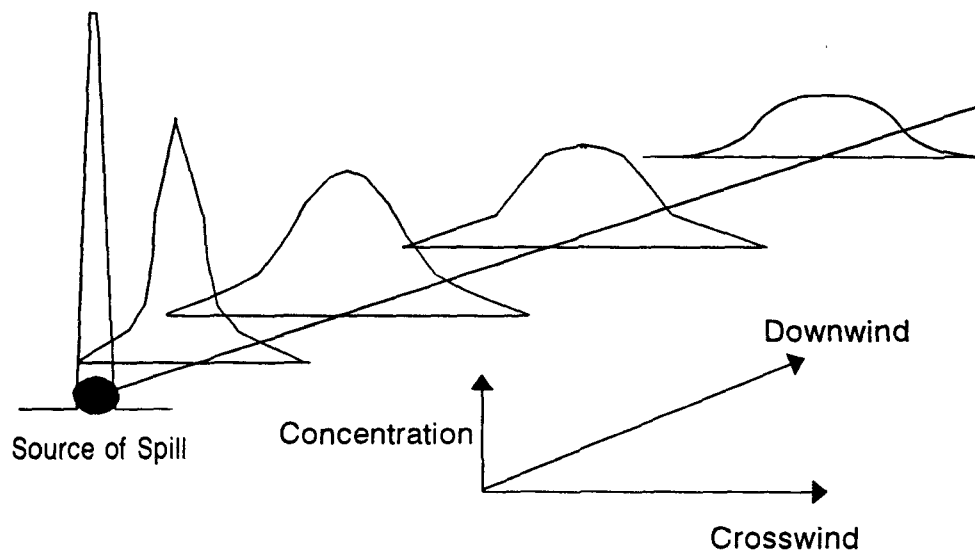


Ground Roughness - Terrain Steering Effects

Areas with hills or valleys may experience wind shifts where the wind actually flows between hills or down into the valleys, turning where these features turn.

Notes:

Gaussian Dispersion

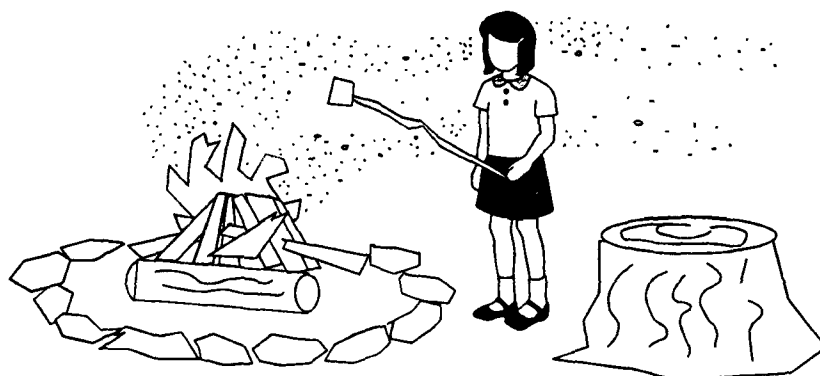


Gaussian Dispersion

In a Gaussian dispersion model, a curve is used to describe how a contaminant will be dispersed in the air after it leaves the source. At the source, the concentration of the contaminant is very high and the Gaussian distribution looks like a spike or a tall column. As the contaminant drifts farther downwind, it spreads out and the "bell shape" gets continually wider and flatter.

Notes:

Near-Field Meandering



Near-Field Meandering

Near-field meandering is caused by individual drifting eddies in the wind that push the plume from side to side. These eddies, or small gusts, are also responsible for much of the mixing that makes the plume spread out. As the plume drifts downward from the spill source, these eddies shift and spread the plume until it takes on the form of a Gaussian distribution.

Notes:

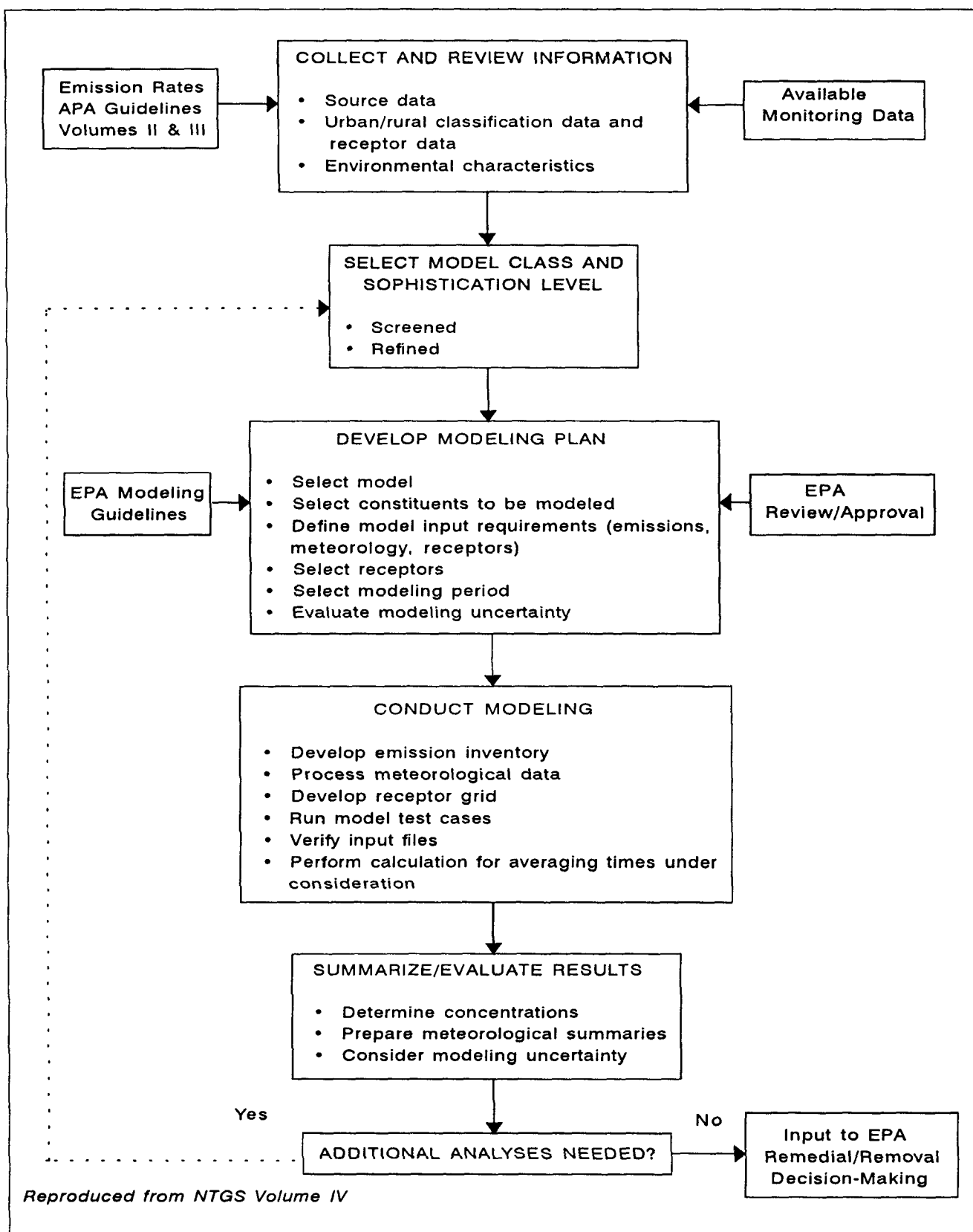


Figure 2. Superfund air impact assessment dispersion modeling protocol.

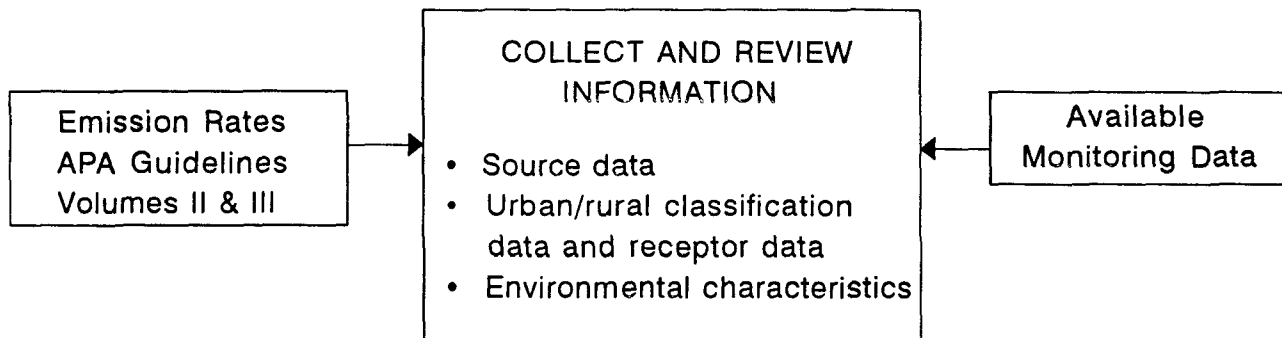
Superfund Air Impact Assessment Dispersion Modeling Protocol

Associated guidance documents:

- National Technical Guidance Study (NTGS) Volumes II and III
- Air quality modeling at Superfund sites factsheet
- Guidelines on air quality models (revised).

Notes:

Dispersion Modeling Protocol



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Step 1:

Step 1 involves collecting and compiling existing information pertinent to air dispersion modeling. This information is obtained during a literature survey. Information that should be collected and compiled includes source data, receptor data, and environmental data (e.g., land use classification, demography, topography, and meteorology). Once the existing data have been collected and compiled, a thorough evaluation will define the data gaps. A coherent dispersion modeling plan can then be developed using site-specific parameters and requirements.

Notes:

Dispersion Modeling Protocol

SELECT MODEL CLASS AND SOPHISTICATION LEVEL

- Screened
- Refined

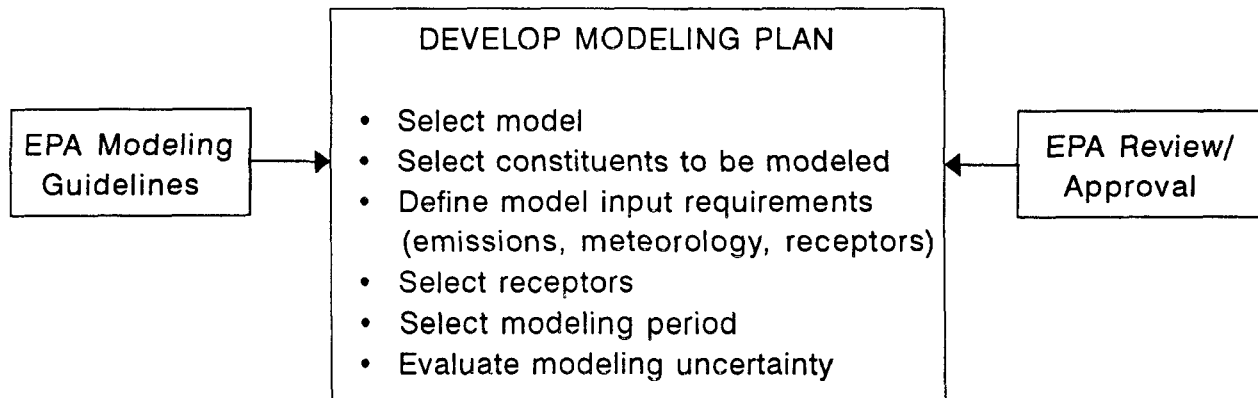
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Step 2:

Step 2 involves the selection of the dispersion modeling sophistication level and screening and refined modeling techniques. The selection process depends on program objectives as well as available resource and technical constraints. Screening models generally use limited and simplified input information to produce a conservative estimate of exposure. Screening models assist in the initial determination of whether the Superfund site, or site activity, will present an air impact problem. The emission source(s) should then be evaluated with either a more sophisticated screening technique or a refined model. When selecting a more sophisticated modeling technique or approach, the following aspects should be considered: availability of appropriate modeling techniques for the Superfund list of toxic constituents; site-specific factors, including source configuration and characteristics; applicability; limitations; performance for similar applications; and comparison of advantages and disadvantages of alternative modeling techniques and approaches.

Notes:

Dispersion Modeling Protocol



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Step 3:

Step 3 involves preparing a dispersion modeling plan. Elements that should be addressed in the plan include overview of the Superfund site area, selection of constituents to be modeled, modeling methodology (emission inventory, meteorology, receptor grid, rural/urban classification, models to be used, concentration averaging time, and special situations such as wake effects), and documentation of the air modeling plan.

Notes:

Dispersion Modeling Protocol

CONDUCT MODELING

- Develop emission inventory
- Process meteorological data
- Develop receptor grid
- Run model test cases
- Verify input files
- Perform calculation for averaging times under consideration

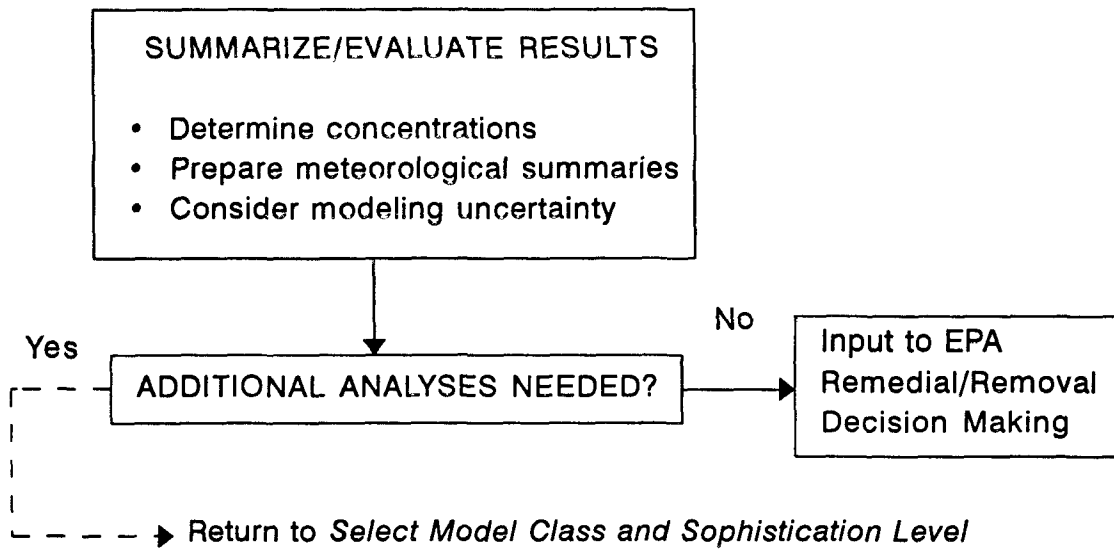
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Step 4:

Step 4 specifies the actual activities involved in conducting air dispersion modeling for a Superfund site. Activities that are performed include developing an emission inventory, preprocessing and verifying modeling, setting model switches, running model test cases, performing dispersion calculations, and obtaining a printout of modeling input and output.

Notes:

Dispersion Modeling Protocol



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Step 5:

Step 5 involves the review and assessment of the dispersion modeling results.

Additional components of this step include preparation of data summaries, concentration mapping (i.e., isopleths), estimation of uncertainties, and assessment.

Notes:

Accidental Release Modeling

- Provides worst-case results
- Results used to determine evacuation of shelter-in-place options
- Cannot account for near-field patchiness
- Examples: ALOHA[™], ARCHIE, CHARM[™], TRACE, and TSCREEN

Accidental Release Modeling

Accidental release modeling is performed when results are needed immediately. Accidental release models that assist in making source-term calculations, or provide probability warnings, are best when real-time solutions are essential.

ALOHA[™], ARCHIE, CHARM[™], TRACE, and TSCREEN are examples of accidental release models.

Each model is a relatively simple estimation technique that provides conservative estimates of air quality impact(s).

Notes:

Accidental Release Models

ALOHA™ (NOAA/EPA)

Areal

Locations

Of

Hazardous

Atmospheres

ALOHA™

The Areal Locations of Hazardous Atmospheres (ALOHA) model was developed through a joint venture between the National Oceanic and Atmospheric Administration (NOAA) and EPA. It is an emission estimation and air quality dispersion model for estimating the emission rate, movement, and dispersion of gases released into the atmosphere. The model estimates pollutant concentrations downwind from the source of a release, taking into account the toxicological and physical characteristics of the material. ALOHA considers the physical characteristics of the release site, the atmospheric conditions, and the initial source conditions.

The model has a built-in database of chemical names and properties that the model uses to calculate emission rates. The program performs buoyant gas dispersion based on Gaussian dispersion equations and heavier-than-air dispersion based on algorithms in the DENSE GAS DISPERSION (DEGADIS) model.

Emission estimations can be made for puddles, tanks, and pipe releases or for direct input of material into the atmosphere. The model uses hourly meteorological data that can be entered by the user or obtained from real-time measurements. The results of the model can be displayed as concentration plots or in text summary screens. The concentration outputs are limited to a 1-hour (or less) exposure.

Notes:

Accidental Release Models

ARCHIE (FEMA/DOT/EPA)

Automated

Resource for

Chemical

Hazard

Incident

Evaluation

ARCHIE

The Automated Resource for Chemical Hazard Incident Evaluation (ARCHIE) model was developed through a joint effort by the Federal Emergency Management Agency (FEMA), the U.S. Department of Transportation (DOT), and EPA. It is an emission estimation and atmospheric dispersion model that can be used to assess the vapor dispersion, fire, and explosion impacts associated with episodic discharges of hazardous materials into the environment. The model can estimate the emissions and duration of liquid/gas releases from tanks, pipelines, and liquid pools, as well as the associated ambient concentrations downwind of these releases. ARCHIE can also evaluate the thermal hazards resulting from the ignition of a flammable release and the consequences of an explosion caused by a flammable gas, tank overpressurization, or ignition of an explosive material. In addition, it can estimate the size of the downwind hazard zone that may require evacuation or other public protection because of the release of a toxic gas or vapor into the atmosphere.

To estimate downwind concentrations, simulated meteorological conditions are input to the model. The user must input chemical properties of the material released from information contained in the material safety data sheets.

Notes:

Accidental Release Models

CHARMTM (Radian Corporation))

Complex

HAzardous

Release

Model

CHARMTM

The Complex Hazardous Release Model (CHARMTM) is a proprietary Gaussian puff model for continuous and instantaneous releases of gases or liquids. The model is configured to handle chemicals that are buoyant, neutrally buoyant, or heavier-than-air. CHARMTM can estimate the emission rates of chemicals using a modification of the SHELL spill model and a multiphase pressurized gas release model. CHARMTM contains a database of chemical information that is used in calculating emission estimates. The program is menu driven and can accept simulated meteorological data for up to 24 hours. The CHARMTM model can simulate the transport of chemicals in spatially and temporally varying wind fields. The results from the program may be displayed graphically on a screen or output to a printer.

Notes:

Accidental Release Models

TRACE (E.I. Dupont de Nemours)

Toxic

Release

Analysis of

Chemical

Emissions

TRACE

The SAFER System TRACE model is an engineering analysis tool for dispersion modeling. It models accidental toxic releases, including those caused by pipe/flange leaks, aqueous spills, hydrogen fluoride spills, fuming acid spills, stack emissions, or elevated dense gas emissions. The program is menu driven and contains several modules to estimate the evaporation and dispersion of chemicals and analyze the effect of certain parameters on downwind concentrations. The program has a built-in database of chemicals and their properties and various source-term modules. The model uses real-time or simulated meteorological data for atmospheric dispersion calculations. These data can vary with time during the release. The results of the modeling analysis can be displayed visually on graphs or stored in tables.

Notes:

Accidental Release Models

TSCREEN (EPA)

- Model for screening toxic air pollutant concentrations

TSCREEN

TSCREEN, a model for screening toxic air pollutant concentrations, is an air quality dispersion model that implements the procedures in *A Workbook of Screening Techniques for Assessing Impacts of Toxic Air Pollutants* (EPA-450-88-009). The TSCREEN model is an atmospheric dispersion model that uses the dispersion algorithms of SCREEN, Release Valve Discharge (RVD), and PUFF models. It automatically selects the worst-case simulated meteorological conditions based on the criteria presented in the workbook. The model contains a data table of chemicals and their associated parameters (limited to two chemicals at this time) that TSCREEN can access. It can calculate the source term for dust particles within a pile of a specified dimension. The model can also simulate the dispersion of gaseous, liquid, and particulate matter releases. TSCREEN outputs graphical and tabular summaries of predicted pollutant concentrations.

Notes:

ACCIDENTAL RELEASE MODELS

CRITERIA	ALOHA ⁽¹⁾	ARCHIE	CHARM	DEGADIS	PUFF	TSCREEN	TRACE ⁽¹⁾
Model Capabilities							
User friendliness	X	X	X			X	X
Hardware/Equipment							
Emission Source Information	DOS/MAC	DOS	DOS	DOS	DOS	DOS	DOS
Constant/variable emission							
Spills	X	X	X	X			X
Tank/pipe leaks	X	X		X			X
Fire/explosions	X	X				X	X
Stack/vents				X			X
Buoyant/dense gas/liquid	X	X		X	X	X	X
Atmospheric Dispersion							
Gaussian dispersion	X			X	X	X	X
Buoyant dispersion	X	X	X		X	X	X
Dense gas	X	X	X	X		X	X
Real-Time Computations							
	X	X	X			X	X
Averaging Periods							
	V		1-24 HOURS		V	1 HOUR	SS
Data Output							
Store to file	X	X	X	X	X	X	X
Display on screen	X		X		X	X	X
Graphic output	X		X		X	X	X
Meteorological Data							
Historical							
Real-time/onsite	X		X				X
Simulated/worst-case	X	X	X	X	X	X	X
Chemical Database							
	X		X			L	X

V = Variable (computer generated)
 SS = Several (by selection)
 L = Limited
⁽¹⁾ = Models most often used
 * = Model using the PUFF algorithm.

Source: Air Quality Modeling at Superfund Sites factsheet.

Notes:

REFERENCES

The following list represents a partial list of background references on the subject of air monitoring and sampling. Although other sources may be available, it is believed that these will provide the reader with a good understanding of the subject.

The references are listed alphabetically by title and include author, publisher, and place of publication. The year of publication is given for governmental sources only. For the remainder, the reader should attempt to obtain the most recent edition. An * after the title indicates that a copy of the document is part of the course library and is available for review.

1. *Advances in Air Sampling**
Lewis Publishers, Inc.
121 South Main Street
P.O. Drawer 519
Chelsea, MI 48118
(Also available through ACGIH. See #4.)
2. Air Methods Database
Available on the Cleanup Information electronic bulletin board (CLU-IN), formerly OSWER BBS. For further information, call 301 589-8366.
3. *Air Monitoring For Toxic Exposures: An Integrated Approach**, 1991
Shirley A. Ness
Van Nostrand Reinhold
115 Fifth Avenue
New York, NY 10003
4. *Air Monitoring Instrumentation: A Manual for Emergency, Investigatory, and Remedial Responders**, 1993
C. Maslonsky and S. Maslonsky
Van Nostrand Reinhold
115 Fifth Avenue
New York, NY 10003
5. *Air Sampling Instruments**
American Conference of Governmental Industrial Hygienists
6500 Glenway Avenue, Building D-E
Cincinnati, OH 45211
513 661-7881
6. Air/Superfund National Technical Guidance Series:
 - *Volume IV—Guidance for Ambient Air Monitoring at Superfund Sites (revised)*. EPA-451/R-93-007, May 1993

- *Compilation of Information on Real-Time Air Monitoring for Use at Superfund Sites.*
EPA-451/R-93-008, May 1993
7. *Atmospheric Analysis: Occupational Health and Safety*, ASTM Standards, Volume 11.03
American Society for Testing and Materials
1916 Race Street
Philadelphia, PA 19103-1187
215 299-5400
 8. *Basic Gas Chromatography*
H.M. McNair and E.J. Bonelli
Varian Instrument Division
Purchase from Supelco, Inc.
Supelco Park
Bellefonte, PA 16823-0048
 9. *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air*,
EPA/600/4-89/017, June 1988
Atmospheric Research and Exposure Assessment Laboratory
U.S. Environmental Protection Agency
Office of Research and Development
Research Triangle Park, NC 27711
 10. *A Compendium of Superfund Field Operations Methods**, EPA/540/P-87/001, December 1987
U.S. Environmental Protection Agency
Office of Emergency and Remedial Response
Office of Waste Programs Enforcement
Washington, DC 20460
 11. *Data Quality Objectives for Remedial Response Activities: Development Process*,
EPA/540/G-87/003, March 1987
U.S. Environmental Protection Agency
Office of Emergency and Remedial Response
Office of Waste Programs Enforcement
Washington, DC 20460
 12. *Fundamentals of Industrial Hygiene*
National Safety Council
444 North Michigan Avenue
Chicago, IL 60611
 13. *Guidance on Applying the Data Quality Objectives Process for Ambient Air Monitoring
Around Superfund Sites (Stages I & II)*, EPA-450/4-89-015; *(Stage III)*, EPA-450/4/90-005
U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Research Triangle Park, NC 27711

14. *Guide to Occupational Exposure Values**
American Conference of Governmental Hygienists
6500 Glenway Avenue, Building D-E
Cincinnati, OH 45211
513 661-7881
15. *Guide to Portable Instruments for Assessing Airborne Pollutants Arising from Hazardous Wastes*
International Organization of Legal Metrology
Paris, France
(Available through ACGIH)
16. *The Industrial Environment - Its Evaluation and Control*, 1973
National Institute for Occupational Safety and Health
Rockville, MD
(Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402 [202 783-3238])
17. *Industrial Hygiene and Toxicology, Volumes I and III*
Frank A. Patty
John Wiley and Sons, Inc.
New York, NY
18. *Manual of Recommendation Practice for Combustible Gas Indicators and Portable Direct Reading Hydrocarbon Detectors*, 1980, 1st edition
John Klinsky (ed)
American Industrial Hygiene Association
Akron, OH
19. *Methods of Air Sampling and Analysis**
Lewis Publishers, Inc.
121 South Main Street
P.O. Drawer 519
Chelsea, MI 48118
(Also available through ACGIH)
20. *NIOSH Manual of Analytical Methods, Editions 1, 2, and 3**
National Institute for Occupational Safety and Health
Rockville, MD
(Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402 [202 783-3238])
21. *OSHA Analytical Methods Manual**
Superintendent of Documents
U.S. Government Printing Office
Washington, DC 20402
202 783-3238

22. *OSHA Technical Manual*, 1990
(See ACGIH)
23. *Removal Program Representative Sampling Guidance: Air*
U.S. Environmental Protection Agency
Office of Emergency and Remedial Response
Emergency Response Division
Environmental Response Branch
Washington, DC
24. *Standard Operating Safety Guides*, June 1992
U.S. Environmental Protection Agency
Environmental Response Team
2890 Woodbridge Avenue
Building 18 (MS-101)
Edison, NJ 08837-3697
908 321-6740
25. *Standard Operating Guide for the Use of Air Monitoring Equipment for Emergency Response*
(See #21)
26. *Standard Operating Guide for Air Sampling and Monitoring at Emergency Responses*
(See #21)
27. *Technical Assistance Document for Sampling and Analysis of Toxic Organic Compounds in Ambient Air*, EPA-600/4-83-027
U.S. Environmental Protection Agency
Environmental Monitoring Systems Laboratory
Research Triangle Park, NC 27711

MANUFACTURERS AND SUPPLIERS OF AIR MONITORING EQUIPMENT

AIR MONITORING EQUIPMENT

Aerosol/Particulate Direct-Reading Monitors:

- Air Techniques Incorporated
- HUND Corporation
- Met One, Inc.
- MIE, Inc.
- MST Measurement Systems, Inc.
- Pacific Scientific (HIAC/ROYCO Instrument Division)
- Particle Measuring Systems, Inc.
- PPM Enterprises
- TSI Incorporated

Calibration Gases: (most manufacturers of instruments provide calibration gases for use with their instruments; these companies provide a variety of calibration gases)

- Airco Industrial Gases
- Alphagaz
- Bryne Specialty Gases
- Digicolor
- Environics, Inc.
- GC Industries
- Kin-Tek laboratories, Inc.
- Liquid Air Corporation
- National Specialty Gases
- Norco, Inc.
- Scott Specialty Gases
- VICI Metronics

Calibrators, Pump:

- Accura Flow Products Co., Inc.
- Air Systems International
- AMETEK
- BGI Incorporated
- BIOS International Corp
- DuPont
- Gillian Instrument Co.
- Sensidyne

- SKC, Inc.
- Spectrex Corporation

Canister Samplers:

- Andersen Samplers Incorporated
- Nutech Corporation
- Scientific Instrumentation Specialists
- Wedding & Associates, Inc.
- Xontech, Inc.

Collection Media:

- Ace Glass Incorporated
- BGI Incorporated
- DACO Products
- Gelman Sciences
- Gilian Instrument Corporation
- Hi-Q Environmental Products Company
- LaMotte Chemical Products Company
- Micro Filtration Systems
- Millipore Corporation
- Mine Safety Appliances Company
- Nuclepore Corporation
- Omega Specialty Instruments Company
- Paliflex, Inc.
- Poretics Corporation
- Schleicher & Schuell
- Sipin, Anatole, J., Co., Inc.
- SKC, Inc.
- Supelco, Inc.

Colorimetric Detectors: (B = badges or dosimeters; DT = regular detector tubes; LT = long term detector tubes)

- American Gas & Chemical Co., Ltd. (B)
- Analytical Accessories International (B)
- Bacharach, Inc. (B)
- Chemsense (B)
- Crystal Diagnostics (B)
- Enmet Corporation (DT, LT)
- GMD Systems, Inc. (B)
- Matheson Safety Products (DT, LT)
- MDA Scientific (B)
- Mine Safety Appliances Co. (B, DT, LT)

- National Draeger, Inc. (B, DT, LT)
- PPM Enterprises (B)
- Sensidyne (DT), Inc.
- SKC, Inc. (B, LT)
- VICI Metronics (B)
- Willson Safety Products (B)

Combustible Gas Meters:

- A.I.M. Safety Company, Inc.
- Astro International Corp.
- Bacharach Instruments
- Biosystems, Inc.
- Chestec, Inc.
- Control Instruments Corp.
- Dynamation Incorporated
- Energy Efficiency Systems, Inc.
- Enmet Corporation
- GasTech, Inc.
- GfG America Gas Detection Ltd.
- Grace Industries, Inc.
- Heath Consultants Incorporated
- Industrial Scientific Corporation
- J and N Enterprises, Inc.
- Lumidor Safety Products e.s.p., Inc.
- Mine Safety Appliances Co.
- National Draeger, Inc.
- Neotronics N.A., Inc.
- Quatrosense Environmental Ltd.
- Scott Aviation
- Sieger Gas Detection
- Sierra Monitor Corporation
- Texas Analytical Controls, Inc.
- TIF Instruments, Inc.

Gas Bags:

- AeroVironment, Inc.
- The Anspec Company, Inc.
- BGI Incorporated
- Calibrated Instruments, Inc.
- Digicolor
- Jensen Inert
- KVA Analytical Systems
- Norton Performance Plastics
- Nutech Corporation

- Plastic Film Enterprises
- Pollution Measurement Corporation
- Science Pump Corporation
- SKC, Inc.

Gas Chromatographs: (types of detectors available: AID = argon ionization; ECD = electron capture; FID = flame ionization; MS = mass spectroscopy; PID = photoionization; SS = chemical specific sensor; TCD = thermal conductivity)

- Bruker Instruments (MS)
- Canaan Scientific Products
- CMS Research Corporation (SS)
- The Foxboro Company (FID)
- GOW-MAC (FID, TCD)
- HNU Systems, Inc. (PID, FID)
- Microsensor Systems Inc.
- Microsensor Technology, Inc. (TCD)
- Photovac Incorporated (PID, FID)
- S-Cubed (ECD)
- Sensidyne (FID)
- Sentex Sensing Technology, Inc. (ECD, PID, PID, TCD)
- Summit Interests (FID, PID, TCD)
- Thermo Environmental Instruments, Inc. (ECD, FID, PID, TCD)
- Viking Instruments (MS)
- XonTech, Inc. (AID, ECD)

Oxygen Meters:

- A.I.M. Safety Company, Inc.
- Bacharach, Inc.
- Biosystems, Inc.
- Dynamation Incorporated
- Energy Efficiency Systems, Inc.
- Enmet Corporation
- GasTech, Inc.
- GC Industries
- GfG America Gas Detection Ltd.
- Industrial Scientific Corporation
- Lumidor Safety Products e.s.p., Inc.
- MDA Scientific, Inc.
- Metrosonics, Inc.
- Mine Safety Appliances Co.
- National Draeger, Inc.
- Neotronics N.A., Inc.
- Rexnord Safety Products
- Scott Aviation

- Sensidyne
- Sieger Gas Detection
- Sierra Monitor Corporation
- Teledyne Analytical Instruments

Passive Dosimeters: (these devices require laboratory analysis; for direct-reading dosimeters see G. Colorimetric Detections)

- Advanced Chemical Sensors
- Air Technology Labs, Inc.
- Assay Technology
- EnSys, Inc.
- Gillian Instrument Corporation
- Landauer, R.S. Jr. & Company
- Mine Safety Appliances Co.
- National Draeger, Inc.
- Pro-Tek Systems, Inc.
- Sensidyne
- SKC, Inc.
- 3M

Sampling Pumps and Accessories: (letters denote primary function of pumps and apparatus: P = Personal; A = Area; B = Bag filling)

- AeroVironment, Inc. (B)
- Air Systems International, Inc. (A)
- AMETFK (P)
- Analytical Accessories International (A,P)
- Andersen Samplers Incorporated (A)
- Arjay Equipment Corporation (A)
- Barnant Company (A)
- BGI Incorporated (P, A)
- BIOS International Corp
- Calibrated Instruments, Inc. (B)
- California Measurements, Inc. (A)
- DuPont (P)
- Environmetrics, Inc. (A)
- General Metal Works, Inc. (A)
- Gillian Instrument Corp. (P)
- LaMotte Chemical Products Company (A)
- Midwest Environics, Inc. (A)
- Mine Safety Appliances Co. (P)
- Omega Specialty Instrument Co. (A)
- Wedding & Associates, Inc. (A)
- Sensidyne (P)
- Sipin, Anatole J., Co., Inc. (P)

- SKC, Inc. (P)
- Spectrex Corporation (P)
- Staplex Air Sampler Division (A)
- Supelco, Inc. (P)
- Thermedics, Inc. (P)
- Wedding & Associates (A)

Toxic Monitors: (direct-reading instruments for low concentrations of contaminants; letters denote types of detectors available; PID = photoionization; FID = flame ionization; IR = infrared spectroscopy; TCD = thermal conductivity; GS = general sensor, e.g., MOS or super-sensitive CGI; SS = sensor for specific chemical, e.g., CO, H₂S)

- A.I.M. Safety Company, Inc. (GS, SS)
- Anacon Detection Technology (SS)
- Analect Instruments (IR)
- Arizona Instrument, Jerome Division (SS)
- Astro International Corp. (SS)
- Bacharach, Inc. (GS, SS)
- Biosystems, Inc. (SS)
- Bruel & Kjaer (IR)
- CEA Instruments, Inc. (GS, SS)
- Dynamation Incorporated (GS, SS)
- Enmet Corporation (SS)
- Environmental Technologies Group (GS)
- The Foxboro Company (FID, IR)
- GasTech, Inc. (GS, SS)
- GfG America Gas Detection Ltd. (SS)
- GMD Systems, Inc. (colorimetric)
- GOW-MAC (TCD)
- Grace Industries, Inc. (GS)
- Graesby Ionics Ltd. (Ion Mobility Spectrometry)
- Heath Consultants Incorporated (FID)
- HNU Systems, Inc. (PID)
- Industrial Scientific Corporation (SS)
- International Gas Detectors, Inc.
- Interscan Corporation (SS)
- J and N Enterprises, Inc. (GS)
- MDA Scientific, Inc. (SS)
- Macurco, Inc. (GS, SS)
- Mast Development Corporation (SS)
- Matheson Safety Products (TCD)
- Metrosonics, Inc. (SS)
- Microsensor Systems, Inc. (SS)
- Mine Safety Appliances Co. (PID, FID, SS)
- National Draeger (SS)
- Neotronics N.A., Inc. (SS)

- Nicolet Instrument Corp. (IR)
- Photovac Incorporated (PID)
- Quatrosense Environmental Ltd. (SS)
- Scott Aviation (SS)
- Sensidyne (SS, FID)
- Sentex Sensing Technology, Inc. (FID)
- Servomax Company (IR)
- Sieger Gas Detection (SS, IR)
- Sierra Monitor Corporation (SS)
- Spectrex Corporation (SS)
- Summit Interests (FID, PID, TCD)
- Tekmar Company (TCD)
- Texas Analytical Controls, Inc. (SS)
- Thermo Environmental Instruments, Inc. (FID, PID, TCD)
- TIF Instruments, Inc. (GS)
- Transducer Research, Inc. (SS)

MANUFACTURERS' AND SUPPLIERS' ADDRESSES

AccuRa Flow Products Co., Inc.
P.O. Drawer 100
Warminster, PA 18974
214 674-4782

Ace Glass Company
P.O. Box 688
Vineland, NJ
609 692-3333

Advanced Chemical Sensors
350 Oak Lane
Pompano Beach, FL 33069
305 979-0958

Advanced Calibration Designs, Inc.
7960 S. Kolb Rd.
Tucson, AZ 85705
602 574-9509

AeroVironment, Inc.
145 Vista Avenue
Pasadena, CA 91107
818 357-9983

A.I.M. Safety Company, Inc.
P.O. Box 720540
Houston, TX 77272-0540
713 240-5020
1-800-ASK-4AIM

Air Systems International
814-P Greenbrier Circle
Chesapeake, VA 23320
1-800-866-8100

Air Techniques Incorporated
1801 Whitehead Road
Air Techniques Incorporated
1801 Whitehead Road
Baltimore, MD 21207
301 944-6037

Airco Industrial Gases
Division of Airco, Inc.
575 Mountain Avenue
Murry Hill, NJ 07974
201 464-8100

Alphagaz
Specialty Gases Division
Liquid Air Corporation
2121 N. California Blvd.
Walnut Creek, CA 94596
415 977-6506

AMETEK
Mansfield & Green Division
8600 Somerset Drive
Largo, FL 34643
813 536-7831

American Gas & Chemical Co., Ltd.
220 Pegasus Avenue
Northvale, NJ 07647
201 767-7300
1-800-288-3647

Anacon Detection Technology
117 South Street
Hopkinton, MA 01748
508 435-6973

Analect Instruments
Division of Laser Precision Corp.
1231 Hart Street
Utica, NY 13502
315 797-4449

Analytical Accessories International
P.O. Box 922085
Atlanta, GA 30092
1-800-282-0073

Anderson Instruments, Inc.
4801 Fulton Industrial Blvd.
Atlanta, GA 30336
404 691-1910

The Anspec Company, Inc.
122 Enterprise Drive
Ann Arbor, MI 48107
313 665-9666
1-800-521-1720

Arizonia Instrument Corp.
P.O. Box 1930
Tempe, AZ 85280
602 731-3400
1-800-528-7411

Arjay Equipment Corp.
P.O. Box 2959
Winston-Salem, NC 27102
919 741-3582

Assay Technology
1070 E. Meadow Cir.
Palo Alto, CA 94303
1-800-833-1258

Astro International Corp.
100 Park Avenue
League City, TX 77573
713 332-2484

BGI, Inc.
58 Guinan Street
Waltham, MA 02154
617 891-9380

BIOS International Corporation
756 Hamburg Turnpike
Pompton Lakes, NJ 07442
201 839-6908

Bacharach, Inc.
625 Alpha Drive
Pittsburgh, PA 15238
412 963-2000

Barnant Company
28W092 Commercial Avenue
Barrington, IL 60010
312 381-7050

Biosystems, Inc.
P.O. Box 158
Rockfall, CT 06481
203 344-1079

Bruel & Kjaer Instruments, Inc.
185 Forest Street
Marlborough, MA 01752
508 481-7000

Bruker Instruments, Inc.
Manning Park
Billerica, MA 01821
617 667-9580

Byrne Specialty Gases, Inc.
118 S. Mead Street
Seattle, WA 98108
206 764-4633

Calibrated Instruments, Inc.
200 Saw Mill River Road
Hawthorne, NY 10502
914 741-5700

CEA Instruments, Inc.
16 Chestnut Street
Emerson, NJ 07630
201 967-5660

CMS Research Corporation
100 Chase Park, Suite 100
Birmingham, AL 35244
205 733-6900

California Measurements, Inc.
150 E. Montecito Avenue
Sierra Madre, CA 91024
818 355-3361

Canaan Scientific Products
P.O. Box 50527
Indianapolis, IN 46250
317 842/1088
1-800-842-8578

ChemSense
3909 Beryl Rd.
Raleigh, NC 27607
919 821-2929

Chestec, Inc.
P.O. Box 10362
Santa Ana, CA 92705
714 730-9405

Compur Monitors
7015 West Tidwell
Suite G111-A
Houston, TX 77092
713 939-1103

Control Instruments Corp.
25 Law Drive
Fairfield, NJ 07006
201 575-9114

Costar/Nucleopore
One Alewife Center
Cambridge, MA 02140
617 868-6200

Crystal Diagnostics, Inc.
600 West Cummings Park
Woburn, MA 01801
617 933-4114

DACO Products, Inc.
12 S. Mountain Avenue
Montclair, NJ 07042
201 744-2453

Digicolor
2770 East Main Street
P.O. Box 09763
Columbus, OH 43209
614 236-1213

Dynamation Incorporated
3784 Plaza Drive
Ann Arbor, MI 48104
313 769-0573

Enmet Corporation
P.O. Box 979
2308 S. Industrial Highway
Ann Arbor, MI 48106-0979
313 761-1270

Energy Efficiency System, Inc.
1300 Shames Drive
Westbury, NY 11590
516 997-2100
1-800-645-7490

EnSys, Inc.
P.O. Box 14063
Research Triangle Park, NC
919 941-5509

Envirometrics, Inc.
1019 Bankton Dr.
Charleston, SC 29406
1-800-255-8740

Environics, Inc.
33 Boston Post Road West
Marlborough, MA 01752
617 481-3600

Environmental Technologies Group
1400 Taylor Avenue
Baltimore, MD 21284-9840
301 635-4598

The Foxboro Company (EMO)
P.O. Box 500
600 N. Bedford St.
East Bridgewater, MA 02333
508 378-5556

GasTech, Inc.
8445 Central Avenue
Newark, CA 94560
415 745-8700

GC Industries, Inc.
8976 Oso Ave., Unit C
Chatsworth, CA 91311
818 882-7852

GfG Gas Electronics, Inc.
6617 Clayton Rd., Suite 209
St. Louis, MO 63144
314 725-9050

GMD Systems, Inc.
Old Route 519
Hendersonville, PA 15339
412 746-3600

Gelman Sciences, Inc.
600 South Wagner Road
Ann Arbor, MI 48106
313 665-0651

General Metal Works, Inc.
145 South Miami
Village of Cleves, OH 45002
513 941-2229

Gilian Instrument Corporation
35 Fairfield Place
West Caldwell, NJ 07006
201 808-3355

GOW-MAC
P.O. Box 32
Bound Brook, NJ 08805
201 560-0600

Grace Industries, Inc.
P.O. Box 167
Transfer, PA 16154
412 962-9231

Graseby Ionics Ltd.
Analytical Division
Park Avenue, Bushey
Watford Herts Wb2 2BW
England
0923 816166

Heath Consultants, Inc.
100 Tosca Drive
P.O. Box CS-200
Stoughton, MA 02072-1591
617 344-1400

Hi-Q Filter Environmental Products
7386 Trade Street
San Diego, CA 92121
619 549-2820

HNU Systems, Inc.
160 Charlemont Street
Newton Highlands, MA 02161
617 964-6690
1-800-527-4566

HUND Corporation
777 Passaic Ave.
Clifton, NY 07012-1804
202 473-5009

Industrial Scientific Corporation
355 Steubenville Pike
Oakdale, PA 15071-1093
412 788-4353
1-800-338-3287

International Gas Detectors, Inc.
11221 Richmond Ave., Suite C-109
Houston, TX 77082
713 558-4099

Interscan Corporation
P.O. Box 2496
21700 Nordoff Street
Chatsworth, CA 91313-2496
1-800-458-6153

J and N Enterprises, Inc.
P.O. Box 108
Wheeler, IN 46393
219 759-1142

Jensen Inert
P.O. Box 660824
Miami, FL 33266-0824
305 871-8839
1-800-446-3781

Kin-Tek Laboratories
2395 Palmer Highway
Texas City, TX 77590
409 945-3627

KVA Analytical Systems
281 Main St.
P.O. Box 574
Galmouth, MA 02541-99811
508 540-0561

LaMotte Chemical Products Co.
P.O. Box 329
Chestertown, MD 21620
301 778-3100
1-800-344-3100

Lumidor Safety Products/E.S.P., Inc.
5364 NW 167th Street
Miami, FL 33014
305 625-6511

Macurco, Inc.
3946 S. Mariposa Street
Englewood, CO 80110
303 781-4062

Mast Development Company
Air Monitoring Division
2212 East 12th Street
Davenport, IA 52803
319 326-1041

Mateson Chemical Corporation
1025 E. Montgomery Avenue
Philadelphia, PA 19125
215 423-3200

Matheson Gas Products, Inc.
30 Seaview Drive
Secaucus, NJ 07096-1587
215 641-2700

MDA Scientific, Inc.
405 Barclay Blvd.
Lincolnshire, IL 60069
312 634-2800
1-800-323-2000

MG Industries
175 Meister Avenue
North Branch, NJ 08876
201/231-9595

MIE, Inc.
213 Burlington Road
Bedford, MA 01730
617 275-5444

MST Measurement Systems, Inc.
327 Messner Drive
Wheeling, IL 60090
708 808-2500

Met One, Inc.
481 California Avenue
Grants Pass, OR 97526
503 479-1248

Metrosonics, Inc.
P.O. Box 23075
Rochester, NY 14692-3075
716 334-7300

Micro Filtration Systems
6800 Sierra Court
Dublin, CA 94568
415 828-6010

Microsensor Systems, Inc.
6800 Versar Center
Springfield, VA 22151
703 642-6919

Microsensor Technology, Inc.
47747 Warm Springs Blvd.
Fremont, CA 94539
415 490-0900

Midwest Environics, Inc.
10 Oak Glen Court
Madison, WI 53717
608 833-0158

Millipore Corporation
Lab Products Division
80 Ashby Road
Bedford, MA 01730
617 275-9200

Mine Safety Appliances
P.O. Box 427
Pittsburgh, PA 15230
412 967-3000
1-800-MSA-INST

National Draeger, Inc.
P.O. Box 120
101 Technology Drive
Pittsburgh, PA 15230-0120
412 787-8383

National Specialty Gases
630 United Drive
Durham, NC 27713-9985

Neotronics N.A., Inc.
P.O. Box 370
411 North Bradford Street
Gainesville, GA 30503
404 535-0600
1-800-535-0606

Nicolet Instrument Corp.
5225 Verona Rd.
Madison, WI 53711
608 271-3333

Norco, Inc.
1121 W. Amity
Boise, ID 83705
208 336-1643

North Performance Plastics
150 Dey Road
Wayne, NJ 07470-4699
1-800-526-7844

Nutech Corporation
2806 Cheek Road
Durham, NC 27704
919 682-0402

Omega Specialty Instruments Company
4 Kidder Road, Unit 5
Chelmsford, MA 01842
508 256-5450

Pacific Scientific
HAIC-ROYCO Instruments Division
141 Jefferson Drive
Menlo Park, CA 94025

Paliflex, Inc.
125 Kennedy Drive
Putnam, CT 06260
203 929-7761

Particle Measuring Systems
1855 South 57th Court
Boulder, CO 80301-2886
303 443-7100

Photovac International, Inc.
25-B Jefryn Blvd. W.
Deer Park, NY 11729
516 254-4199

Plastic Film Enterprises
2011 Bellaire Avenue
Royal Oak, MI 48067
313 399-0450

Pollution Measurement Corporation
P.O. Box 6182
Chicago, IL 60680
708 383-7794

Poretics Corporation
151 I Lindbergh Avenue
Livermore, CA 94550-9412
415 373-0500
1-800-922-6090

PPM Enterprises
11428 Kingston Pike
Knoxville, TN 37922
615 966-8796

Pro-Tek Systems, Inc.
64 Genung Street
Middletown, NY 10940
914 344-4711

Quatrosense Environmental Ltd.
5935 Ottawa Street
P.O. Box 749
Richmond, Ontario, Canada KOA 2Z0
613/838-4005

S-Cubed
P.O. Box 1620
La Jolla, CA 92038-1620
619/453-0060

Schleicher & Schuell, Inc.
10 Optical Street
Kenne, NH 03431
603/352-3810
800/245-4024

Scientific Instrumentation Specialists
P.O. Box 8941
Moscow, ID 83843
208/882-3860

Science Pump Corporation
1431 Ferry Avenue
Camden, NJ 08104
609/963-7700

Scott Aviation
225 Erie Street
Lancaster, NY 14086
716/683-5100

Scott Specialty Gases
Route 161 North
Plumsteadville, PA 18949
215/766-8861

Sensidyne, Inc.
16333 Bay Vista Dr.
Clearwater, FL 34620
813/530-3602
800/451-9444

Sentex Sensing Technology, Inc.
553 Broad Avenue
Ridgefield, NJ 07657
201/945-3694

Servomax Company
90 Kerry Place
Norwood, MA 02062
617 769-7710

Sieger Gas Detection
405 Barclay Blvd.
P.O. Box 1405
Lincolnshire, IL 60069-1405
1-800-221-1039

Sierra Monitor Corporation
1991 Tarob Court
Milipitas, CA 95035
408 262-6611

Anatole J. Sipin Co., Inc.
505 Eighth Avenue
New York, NY 10018
212 695-5706

SKC, Inc.
334 Valley View Road
Eighty Four, PA 15330-9614
412 941-9701
1-800-752-8472

Spectrex Corporation
3580 Haven Avenue
Redwood City, CA 94063
415 365-6567

Staplex Company
Air Sampler Division
777 Fifth Avenue
Brooklyn, NY 11232-1695
212 768-3333
1-800-221-0822

Summit Interests
P.O. Box 1128
Lyons, CO 80540
303 444-8009

Supelco, Inc.
Supelco Park
Bellefonte, PA 16823-0048
814 359-3441

3M OH & ESD
3M Center
Building 220-3E-04
St. Paul, MN 55144-1000
612 733-5608

TIF Instruments Inc.
9101 NW 7th Avenue
Miami, FL 33150
305 757-8811

TSI Incorporated
500 Cardigan Road
P.O. Box 43394
St. Paul, MN 55164
612 483-0900

Tekmar Company
P.O. Box 371856
Cincinnati, OH 45222
1-800-543-4461

Teledyne Analytical Instruments
16830 Chestnut Street
City of Industry, CA 91749
213 283-7181

Texas Analytical Controls, Inc.
P.O. Box 42520
Houston, TX 77242
713 240-4160

Thermedics, Inc.
470 Wildwood Street
Woburn, MA 01888
617 938-3786

Thermo Environmental Instruments, Inc.
8 West Forge Parkway
Franklin, MA 02038
508 520-0430

Transducer Research, Inc.
999 Chicago Ave.
Naperville, IL 60540
708 357-0004

VICI Metronics
2991 Corvin Drive
Santa Clara, CA 95051
408 737-0550

Viking Instruments Corp.
12007 Sunrise Valley Drive
Reston, VA 22091-3406
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AIR MONITORING FOR HAZARDOUS MATERIALS WORKBOOK

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EXERCISE 1

Oxygen Monitors, Combustible Gas Indicators, and Specific Chemical Monitors

OBJECTIVE

In this exercise, students will calibrate or check the calibration of a variety of combustible gas indicators (CGIs), combination CGI/O₂ monitors, and combination CGI/O₂/toxic monitors. The instruments will then be used to sample a variety of test atmospheres and the results will be interpreted.

PROCEDURE

The exercise is divided into three different stations. Each station is equipped with an air monitoring instrument or group of instruments.

Station 1: MSA Model 260/261 combination CGI/O₂ monitor

Station 2: MSA Model 360 combination CGI/O₂/carbon monoxide monitor

Station 3: GasTech Model 1314 combination CGI/O₂/toxic monitor

There may be more than one of each numbered station to reduce crowding. Follow the instructions given for each instrument. Sample the indicated gas bags and record your results. At the end of the exercise, answer the questions. The instructor will then hold a brief discussion.

The instructions given for each instrument are based on the manufacturers' operating manuals. However, some steps may have been added for illustration purposes and some may have been shortened for purposes of time or space. As with any instrument, consult the operator's manual before using in the field.

STATION 1

MSA Model 260/261 Combination CGI/O₂ Monitor

The MSA Model 260/261 is a combination combustible gas and oxygen monitor. There are meter displays for both indicators. Visual and audible alarms for a % LEL reading and a low oxygen reading are included. The Model 261 also has a high oxygen reading alarm. The audible alarm can be deactivated. Air is drawn into the instrument by a battery-operated pump.

SETUP

1. Record the instrument serial number or ID number on the data sheet.
2. Attach the sampling hose to the instrument. Make sure that the connection is hand tight.

STARTUP

3. Turn the center "ON-OFF" control clockwise to the "HORN-OFF" position. Both meter pointers will move, both alarm lights will light, and the center green lamp will blink on and off. (*Note:* On the Model 261, the light will not turn on until after the reset button is pushed.) The green light indicates alarms status. When it glows continuously, the audible alarm is operable. When it blinks on and off, it indicates that the audible alarm has been deactivated.
4. Adjust the meter pointer on the % oxygen monitor by pulling and turning the "O₂ CALIBRATE KNOB." The knob is supplied with a clutch to prevent accidental field decalibration. Adjust the pointer to read 20.8%, which is the hatch mark below the 21% mark.
5. Adjust the meter pointer on the %LEL meter by pulling and turning the "LEL ZERO KNOB." Adjust the pointer to read 0%.
6. Press the red alarm "RESET" button to reset the alarms. Both red lights should stop flashing. (*Note:* The "RESET" button will not reset the alarms if the meter pointers exceed the alarm levels.)
7. Press the black "CHECK" button and observe the pointer on the %LEL meter. The pointer should move above 80% LEL into the BATTERY zone of the meter. This indicates that the battery is okay. If it does not reach the BATTERY zone, inform an instructor/technician.

LEAK TEST

8. Momentarily hold a finger over the sample inlet or end of sample probe. Observe that the flow indicator float (lower right hand corner of instrument face) drops out of sight, indicating

no flow. If the float does not drop out of sight, check the system for leaks. If the instrument does not pass the leak test, inform an instructor/technician.

ALARM CHECK

The purpose of these steps is to check the meter readings at which the alarms will sound.

9. Turn the O₂ CALIBRATE knob counterclockwise (decreasing the % oxygen reading) while watching the % oxygen meter and the oxygen alarm light. Note the reading at which the alarm sounds and the light starts flashing. Adjust the reading back to 20.8% and press the reset button. Record the reading on the data sheet. The lower alarm reading should be 19.5%.
10. (MSA 261 only) Turn the O₂ CALIBRATE knob clockwise (increasing the % oxygen reading) while watching the % oxygen meter and the oxygen alarm light. Note the reading at which the alarm sounds and the light starts flashing. Adjust the reading back to 20.8% and press the reset button. Record the alarm reading on the data sheet. The upper alarm reading should be 25%.
11. Turn the zero LEL knob clockwise until the alarm is activated. Record this reading. Return the meter pointer to zero and press the reset button. The alarm should have activated at 25% LEL.
12. If any of the alarm points are not what they should be, inform an instructor/technician.
13. The instrument is ready for calibration.

CALIBRATION

14. Open the clamp to the gas bag labeled "**PENTANE 0.75%**" and attach the sample line to the bag. Draw a sample into the instrument until a constant reading is obtained.
15. Record your reading on the data sheet. The instrument should give a reading of 50% LEL. Inform the instructor if it does not.
16. Disconnect the sample line and clamp the bag. Allow fresh air to flow through the instrument until the reading returns to zero. Rezero the instrument, if needed.

SAMPLING

17. Please note that the **Model 261** has a latching mechanism that engages the %LEL meter pointer if it reaches or exceeds 100. To disengage the lock, the instrument must be turned

off and then turned back on in an area where the LEL readings are less than 100%. Room air will do.

18. For field monitoring, the alarm should be in the operable mode. For this exercise, you may keep the audible alarm deactivated to reduce noise levels.
19. Sample each of the gas bags listed on the data sheet. Record the readings.

SHUTDOWN

20. When sampling is complete, flush fresh air through the instrument. Turn the instrument OFF.

STATION 2

MSA Model 360 Combination CGI/O₂/CO Monitor

The MSA Model 360 is a combination combustible, oxygen, and carbon monoxide (CO) monitor. It has a digital display that shows only one reading. It has alarms for a specific % LEL reading, low and high oxygen, and a specific carbon monoxide reading. If the alarm levels are reached for any of these responses, there will be a visual and audible indication. This will occur no matter what function is being displayed at the time. The audible alarm can be deactivated. Air is drawn into the instrument by a battery-powered pump.

SETUP

1. Record the instrument serial number or ID number on the data sheet.
2. Attach the sampling hose to the instrument. Make sure the connection is hand tight.

STARTUP

3. Turn the FUNCTION control to the "HORN-OFF" position. Alarm signals will flash for all three chemicals, the "HORN OFF" green/yellow lamp will be off and % LEL will show in the readout.
4. A low battery condition is indicated by a BATT sign in the readout or by a steady horn. Inform an instructor/technician if this occurs.
5. Set the readout to zero (00) by lifting and turning the LEL ZERO knob. This must be done within 30 seconds of turning ON to prevent the possibility of activating the off-scale, LEL latching alarm.
6. Press the SELECT button firmly to obtain % OXY on the readout. Then set the readout to 20.8% by adjusting the OXY CALIBRATE knob.
7. Press the SELECT button firmly to obtain PPM TOX on the readout. Then set the readout to zero (00) by adjusting the TOX ZERO knob.
8. Press the RESET button. (*Note:* The "RESET" button will not reset the alarms if the exceed the alarm levels.) The "HORN OFF" green/yellow lamp will start flashing. The light indicates alarm status. When it glows continuously, the audible alarm is operable. When it blinks on and off, as it does now, it indicates that the audible alarm has been deactivated.

LEAK TEST

9. Momentarily hold a finger over the sample inlet or end of sample probe. Observe that the flow indicator float (lower right hand corner of instrument face) drops out of sight, indicating no flow. If the float does not drop out of sight, check the system for leaks. If the instrument does not pass the leak test, inform an instructor/technician.

ALARM CHECK

The purpose of these steps is to check the meter readings at which the alarms will sound.

10. Press the SELECT button until % LEL is displayed. Adjust the LEL ZERO knob until the alarm sounds. Record the % LEL reading. Set the reading back to zero and press the RESET button. The alarm should activate at 25%.
11. Press the SELECT button until OXY is displayed. Turn the OXY CALIBRATE knob counterclockwise (decreasing the % oxygen reading) until the alarm sounds. Record the % OXY reading. Adjust the reading back to 20.8% and press the RESET button. The lower alarm reading should be 19.5%.
12. Turn the OXY CALIBRATE knob clockwise (increasing the % oxygen reading) until the alarm sounds. Record the % OXY. Adjust the reading back to 20.8% and press the RESET button. The upper alarm reading should be 25%.
13. Press the SELECT button until TOX is displayed. Turn the TOX ZERO knob clockwise until the alarm is activated. Record this reading. Adjust the reading back to zero and press the RESET button. The alarm should have activated at 35 ppm.
14. If any of the alarm points are not what they should be, inform an instructor/technician.
15. Turn the FUNCTION control to MANUAL for continuous readout of any one gas or to SCAN for automatic scanning of the three gas readings. *Note:* All alarm functions operate in either position.
16. The instrument is ready for sampling.

CALIBRATION

17. Open the clamp to the gas bag labeled "PENTANE 0.75%" and attach the sample line to the bag. Draw a sample into the instrument until a constant reading is obtained.
18. Record your readings on the data sheet. The instrument should give a reading of 50% LEL. Consult the instructor for proper oxygen and carbon monoxide readings.
19. Disconnect the sample line and clamp the bag. Allow fresh air to flow through the instrument until the reading returns to zero. Rezero the instrument, if needed.

SAMPLING

20. For field monitoring, the alarm should be in the operable mode (SCAN or MANUAL setting). For this exercise, you may keep the audible alarm deactivated to reduce noise levels.
21. *Note:* The **Model 360** has a latching mechanism that engages if the % LEL exceeds 100. To disengage the lock, the instrument must be turned off and then turned back on in an area where the LEL readings are less than 100%. Room air will do.
22. Sample each of the gas bags listed on the data sheet. Record the readings.

SHUTDOWN

23. When done sampling, flush fresh air through the instrument. Turn the instrument OFF.

STATION 3

Gastech Model 1314 Gastechtor

The GasTech Model 1314 is a combination combustible, oxygen, and toxic monitor. There is no separate toxic sensor. The "toxic" response is provided by an amplification of the combustible sensor (supersensitive CGI). Thus the toxic response is actually ppm combustible. The readout is an analog meter that only displays one reading. The readout being displayed depends on the position of the buttons on the side of the instrument. It has a specific % LEL, low and high oxygen, and toxic level alarms. The oxygen alarm will sound even if % LEL is being displayed and vice versa. The toxic alarm, however, will only sound if in the "PPM" mode. The unit has a battery-powered pump for drawing air.

STARTUP

1. Attach the hose to instrument by means of the quick release fitting.
2. Put the PPM/LEL switch in the LEL (out) position, with the black indicator showing, and OXY/LEL switch also in the LEL (out) position.
3. Press the POWER switch to turn the instrument on, with orange indicator dot showing. The meter will normally rise upscale and a pulsing or steady alarm signal may sound. Audible hum of pump will be noticed. The cause of the alarm condition (combustibles, oxygen, or both) can be identified by the blinking lights.
4. Press the BATT CK button and note the meter reading. If reading is close to or below the BATT CHECK mark on the meter, consult an instructor/technician.
5. Allow the instrument to warm up until the meter stabilizes (about a minute). If a pulsed oxygen alarm continues to sound, turn the OXY CAL potentiometer clockwise to stop it. If the sound is steady, turn the potentiometer counterclockwise.
6. With the hose inlet in a clean air location, turn the ZERO LEL potentiometer to bring the meter to "0" indication. If this is not possible, consult an instructor/technician.
7. Put the OXY/LEL switch in the OXY (in) position, so that the orange indicator shows. Turn the OXY CAL potentiometer to bring the meter to the O₂ CAL mark (21%).
8. As a quick check, gently breathe into hose inlet and allow instrument to sample exhaled air. Reading should come down to about 16%, and alarm should sound at 19.5%. Allow it to return to 21%, then put switch back in LEL position.
9. These particular units have a high oxygen alarm that will sound in a steady tone and the amber alarm lights will blink when reading reaches or exceeds 25%.

10. The instrument will automatically test for oxygen whenever it is used, and will give a pulsed audible and an amber light alarm if oxygen content drops to 19.5%. It is not necessary to use the instrument with the switch in the OXY position unless oxygen measurements are of primary interest. If both abnormal gas conditions exist simultaneously, both lights will blink in their normal pattern, but alarm will sound continuously.
11. For readings in the 0-100% LEL range, hold inlet at point to be tested. Watch meter and observe maximum reading as taken from the upper set of graduations, 0-100% scale. If reading rises above the alarm setting (20% LEL), a pulsed red light and an audible alarm will commence, and will continue as long as reading remains above alarm point.
12. If the reading on the 0-100% range is imperceptible or very small, use the sensitive range, 0-500 ppm. First allow to warm up in the LEL range, and then push range switch to put circuit in PPM range (colored indicator showing). Rezero carefully with the ZERO LEL potentiometer.

Because of the very high sensitivity of this range, the meter will tend to drift until instrument is thoroughly warmed up. Always let it run for 5 minutes or more, whenever possible, before operating on the PPM range. Take the reading immediately after zeroing, and observe maximum deflection as taken from the middle set of graduations, 0-500 PPM scale. The alarm will sound whenever the reading rises above the preset alarm level - 100 ppm.

CALIBRATION

13. Put the PPM/LEL switch in the LEL (out) position.
14. Unclamp the bag labeled "HEXANE 0.55%" and attach it to the sample inlet. Record the reading when it has stabilized. The reading should be 50%. If not, please inform the instructor.

SAMPLING

15. Sample each of the gas bags listed on the data sheet. Record the readings. **DO NOT USE THE PPM SETTING UNLESS THE LEL RESPONSE IS VERY LOW.**

SHUTDOWN

16. When sampling is complete, flush fresh air through the instrument. Turn the instrument OFF.

DATA SHEET

	STATION 1			STATION 2			STATION 3		
SAMPLE BAGS	MSA 260/261			MSA 360			GASTECH 1314		
	ID #:			ID #			ID #		
	O ₂	LEL		O ₂	LEL	CO	O ₂	LEL	PPM
ALARM LEVELS*									
PENTANE CAL GAS									
HEXANE CAL GAS									
BAG 1									
BAG 2									
BAG 4									
BAG 5									
BAG 6									

*The two spaces under O₂ are for the low and high level alarm readings.

QUESTIONS

1. Did the alarms activate at the appropriate readings? Which instruments did not?
2. Why do the different instruments give different responses to similar combustible gases?
3. What are the hazards (if any) associated with each unknown bag?

4. List the limitations and advantages of each instrument for monitoring an unknown atmosphere.

MSA 260/261:

MSA 360:

GasTech 1314:

EXERCISE #2

Photoionization Detectors - Survey

OBJECTIVE

Participants will learn how to calibrate and operate the HNU Model PI-101 Photoionization Detector.

PROCEDURE

Students will divide into groups as directed by the laboratory instructor. Each group will have an HNU PI-101 Photoionization Detector with either a 10.2 eV or 11.7 eV lamp, and eight gas bags. Also, five containers with unknown chemicals will be placed around the room.

STATION 1:	Bag A	100 parts per million (ppm) toluene
	Bag B	100 ppm acetone
	Bag C	100 ppm toluene/100 ppm acetone
	Bag D	800 ppm acetone
	Bag E	250 ppm acetone
	Bag F	50 ppm acetone
	Bag G	50 ppm hexane
	Bag CH ₄	100 ppm methane

STATION 2: Five containers with unknowns

By following the instructions, sample each station and record your results. A discussion of your findings will be held at the end of the exercise.

SETUP

1. Record the instrument serial number or ID number on the data sheet.
2. Record the lamp energy.

STARTUP

Refer to **Figure 1** for location of instrument controls.

3. Connect the probe.
4. Turn the FUNCTION SWITCH to the BATTERY CHECK position. The needle should deflect within or above the green arc. If not, inform the instructor. If the red indicator light (low battery) comes on, do not use the instrument.
5. To ensure that the lamp will light, turn the FUNCTION switch to any RANGE setting and place a solvent based marker near the sample intake on the probe. A needle deflection should occur, thus indicating that the lamp is on.
6. There are two methods of zeroing an instrument. For this lab, use METHOD 1.
 - METHOD 1 - Turn the FUNCTION SWITCH to the STANDBY position and zero the instrument using the ZERO knob. This procedure is used to zero the instrument electronically. If the SPAN setting is altered, the zero should be rechecked and adjusted. Wait fifteen to twenty seconds to ensure that the zero reading is stable. If necessary, readjust the zero.
 - METHOD 2 - Turn the FUNCTION SWITCH to the range being used and rotate the ZERO knob until the meter reads zero. Now you have zeroed out background. If the SPAN setting is changed after the zero is set, the zero should be rechecked and adjusted.

You are now ready to calibrate your instrument.

CALIBRATION

7. The instructor will assist the students in the calibration procedure. A compressed gas cylinder containing isobutylene will be used to calibrate the instrument. Set the FUNCTION SWITCH to the 0-200 RANGE setting.
8. Connect the probe to the tubing from the ISOBUTYLENE cylinder. Unlock the SPAN knob by moving the black lock handle counter clockwise. By adjusting the SPAN setting between 0-100, obtain the appropriate instrument reading. The instructor will tell you the

appropriate reading. Do not lock the SPAN knob at all during this lab exercise. Record the SPAN setting at calibration on the data sheet.

SAMPLING

9. When taking readings, adjust the FUNCTION SWITCH to get the maximum on scale needle deflection. If the reading exceeds the meter range, adjust the FUNCTION SWITCH.
10. Measure for contaminants in BAGS A, B, C, G, and CH₄ and record the results.
11. Take readings over the openings of each of the unknown containers. Record the readings.

CALIBRATION CHANGE

12. By adjusting the SPAN, calibrate the instrument to BAG B (acetone). Measure the concentration of BAGS C, D, E, and F and record your results. Then plot the instrument readings vs. actual concentration from BAGS B, D, E, and F on **Graph 1**.

SHUTDOWN

13. Turn the FUNCTION SWITCH to the OFF position.

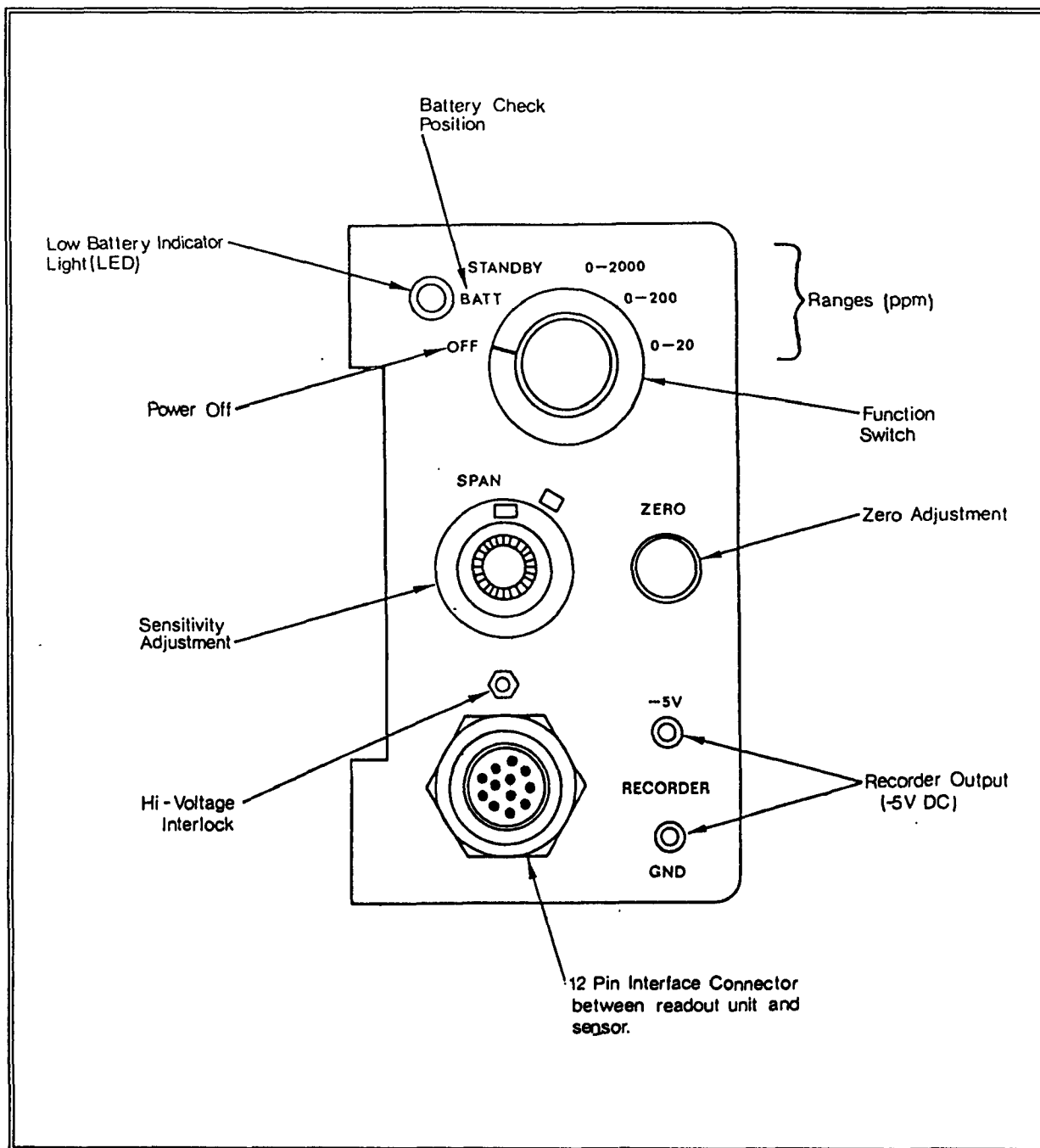


FIGURE 1. HNU PI 101 CONTROLS

Source: *Instruction Manual for Model PI 101 Photoionization Analyzer*, 1975, HNU Systems, Inc. Used with permission of HNU Systems, Inc.

DATA SHEET

TABLE 1	
INSTRUMENT MODEL	
I.D. NUMBER	
LAMP ENERGY	
CALIBRATION	
GAS	
CONCENTRATION	
INSTRUMENT READING	
SPAN SETTING	

TABLE 2			
BAG	CONCENTRATION	INSTRUMENT READING	RELATIVE RESPONSE*
A - TOLUENE	100 ppm		
B - ACETONE	100 ppm		
C - TOLUENE/ ACETONE	100/100		
G - HEXANE	50 ppm		
CH ₄ - METHANE	100 ppm		

* Relative Response = Instrument Reading ÷ Actual Concentration. Multiply by 100% to get % Relative Response.

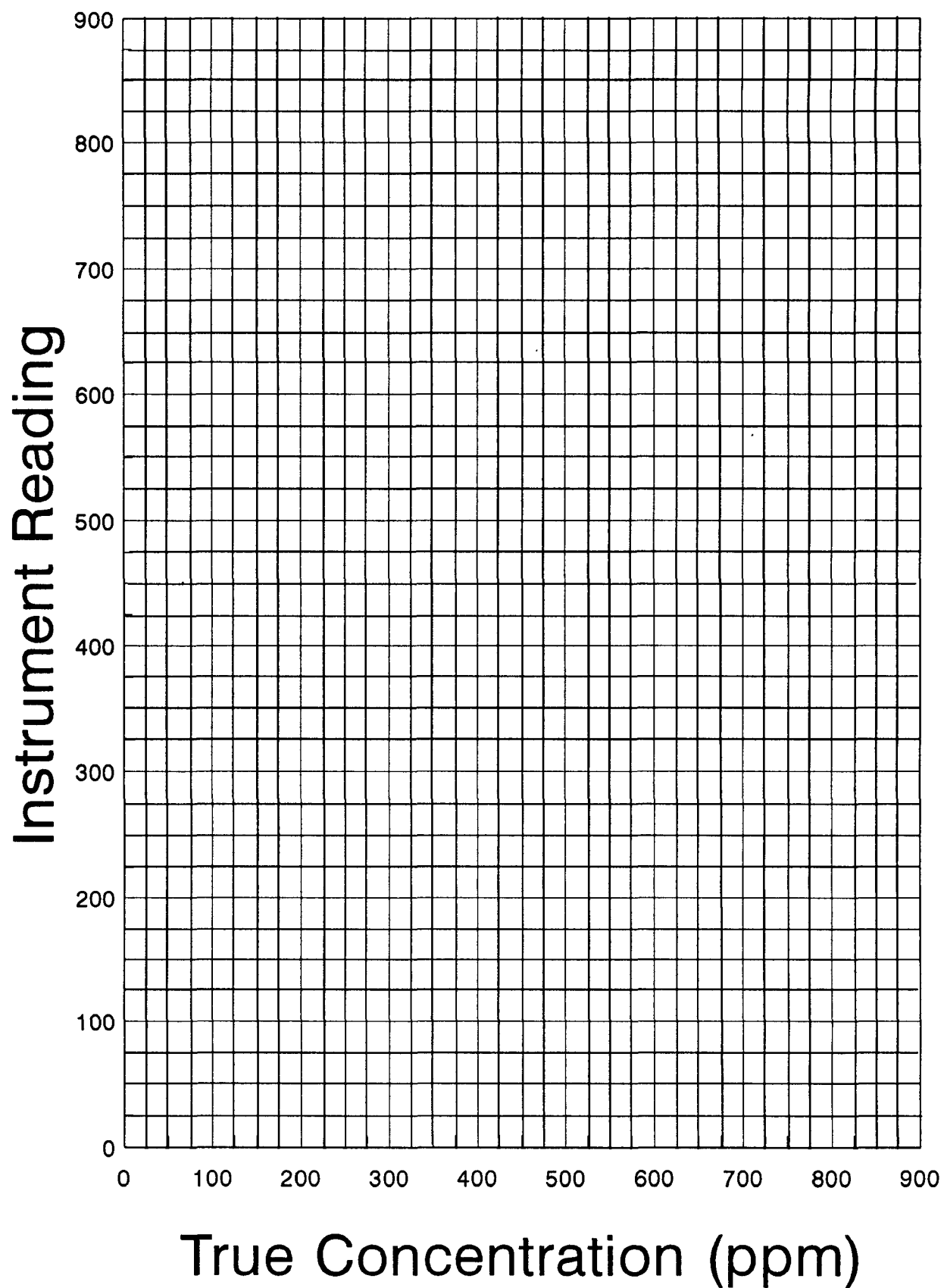
DATA SHEET

TABLE 3	
SAMPLE LOCATION*	READING
1	
2	
3	
4	
5	

*Add information about location of probe when taking the reading.

TABLE 4 ACETONE CALIBRATION			
BAG	ACTUAL CONCENTRATION	INSTRUMENT READING	SPAN SETTING
B	100 ppm		
C	100/100		
D	800 ppm		
E	250 ppm		
F	50 ppm		

GRAPH 1. INSTRUMENT READING VS. TRUE CONCENTRATION



QUESTIONS

1. Calculate and record the relative response for each of the chemicals in **Table 2**.
2. Why is the reading for Bag C in **Table 2** different from the reading in **Table 4**?
3. From **Graph 1**, does the instrument accurately measure all four concentrations? If you were going to measure acetone vapors at concentrations of 0–10 ppm, would this calibration curve be of value to you?
4. Unknown 2 is found to be acetone. Develop a method(s) using the HNU to determine the concentration of acetone at the location.
5. You are using an HNU to survey a site and obtain a reading of 200. How do you report your findings and what additional information would you like recorded?

EXERCISE #3

Flame Ionization Detectors - Survey

OBJECTIVE

Participants will learn how to calibrate and operate the Foxboro Organic Vapor Analyzer OVA-128 in the survey mode.

PROCEDURE

Students will divide into groups as directed by the laboratory instructor. Each group will have an Foxboro OVA-128 plus eight gas bags. Also, five containers with unknown chemicals will be placed around the room.

Station 1:	Bag A	100 parts per million (ppm) toluene
	Bag B	100 ppm acetone
	Bag C	100 ppm acetone/100 ppm toluene
	Bag D	800 ppm acetone
	Bag E	250 ppm acetone
	Bag F	50 ppm acetone
	Bag G	50 ppm hexane
	Bag CH ₄	100 ppm methane

Station 2: Five sampling containers

By following the instructions, sample each station and record your results. A discussion of your findings will be held at the end of the exercise.

Please read each paragraph completely before following the directions and proceeding to the next paragraph.

SETUP

1. Record the instrument serial number or ID number on the data sheet.

STARTUP

2. Turn off the charger and disconnect the charger cable from the instrument.
3. Unlock the GAS SELECT dial and adjust it to 300 (i.e., a 3 in the window and 00 on the dial).
4. Turn the VOLUME knob fully counter clockwise.
5. Ensure that the SAMPLE INJECT VALVE and BACK FLUSH VALVE are in the full out position.
6. The toggle switches on this instrument have a lock to prevent accidental changes. To move the toggle switch, lift and then move the lever.
7. Move the INSTRUMENT switch to ON and allow 5 minutes for warm-up.
8. Move the PUMP switch to ON. You should hear the pump running. Place the instrument in a vertical position and look at the SAMPLE FLOW RATE (rotameter at lower left of panel). The flow rate (read at center of ball) should be 2.0 (liters/minute). A reading between 1.5 and 2.5 is considered adequate.
9. Set the CALIBRATE switch to X10. Adjust the CALIBRATE knob until the meter reads 0.
10. Open the H₂ TANK VALVE and H₂ SUPPLY VALVE one and one-half turns counter clockwise. The TANK gauge should be 500 psi or higher. The SUPPLY gauge should read between 10 and 12 psi. If they do not, inform the instructor.
11. Wait about 1 minute. Depress the red IGNITER BUTTON (on the side of the pack) until the flame ignites or until 6 seconds have passed. Flame ignition is indicated by a sharp meter needle deflection towards 10 along with a small "pop" sound. Also, the meter needle should return to a reading above 0 instead of 0. Do not depress the button longer than 6 seconds. If the flame does not ignite on the first try, wait a minute, and try again. If it does not ignite on a second try, check that steps 1 through 10 have been completed. Then consult an instructor or technician for assistance.
12. Use the CALIBRATE knob to adjust the meter reading to zero. Move the CALIBRATE switch to X1 and rezero.

CALIBRATION

13. Set the CALIBRATE switch to X10.
14. Locate the METHANE calibration gas bag. Methane is the normal calibration gas for the OVA.
15. Open the bag clamp and attach the methane bag to the probe inlet. It is important that the bag be open before attaching it so that a "flame out" does not occur from oxygen starvation.
16. Unlock and adjust the GAS SELECT knob so that the meter reading is equal to the bag concentration divided by the CALIBRATE switch setting. For example, if the bag concentration is 90 ppm, then the reading should be 9 (90 divided by 10).
17. Disconnect the gas bag and close the clamp.
18. The GAS SELECT setting should be about 300. 300 is the "ideal" setting, but your instrument may have a different reading. If the setting must be adjusted above 400 or below 200, internal calibration may be advisable.
19. The instrument is now calibrated to methane and ready for survey purposes.

SAMPLING

20. During the next two steps, change the CALIBRATE switch setting as necessary to get the maximum on-scale reading. If the meter reads above 10 on the X100 setting, report the reading as greater than 1000.
21. Take readings of bags A, B, C and G. Record the data.
22. Take readings at the five containers. Record the readings and locations.

CALIBRATION

23. Change the CALIBRATE switch to X10.
24. Open and connect Bag B to the probe inlet. Adjust the GAS SELECT knob until the instrument reads 10 on the X10 range.
25. Disconnect and close the bag. Use the CALIBRATE ADJUST knob to rezero, if needed.
26. Take readings of bags C, D, E, and F. Record the readings. Plot the readings from bags B, D, E, and F on GRAPH 1.

SHUTDOWN

27. Close the H₂ SUPPLY valve, then the H₂ TANK valve.
28. Move the INSTRUMENT switch to OFF.
29. When the SUPPLY pressure gauge falls to zero, move the PUMP switch to OFF.

DATA SHEET

TABLE 1	
INSTRUMENT MODEL	
I.D. NUMBER	
CALIBRATION	
GAS	
CONCENTRATION	
INSTRUMENT READING	
GAS SELECT SETTING	

TABLE 2			
BAG	CONCENTRATION	INSTRUMENT READING	RELATIVE RESPONSE*
A - TOLUENE	100 ppm		
B - ACETONE	100 ppm		
C - TOLUENE/ ACETONE	100/100		
G - HEXANE	50 ppm		

*Relative Response = Instrument Reading ÷ Actual Concentration. Multiply by 100% to get % Relative Response.

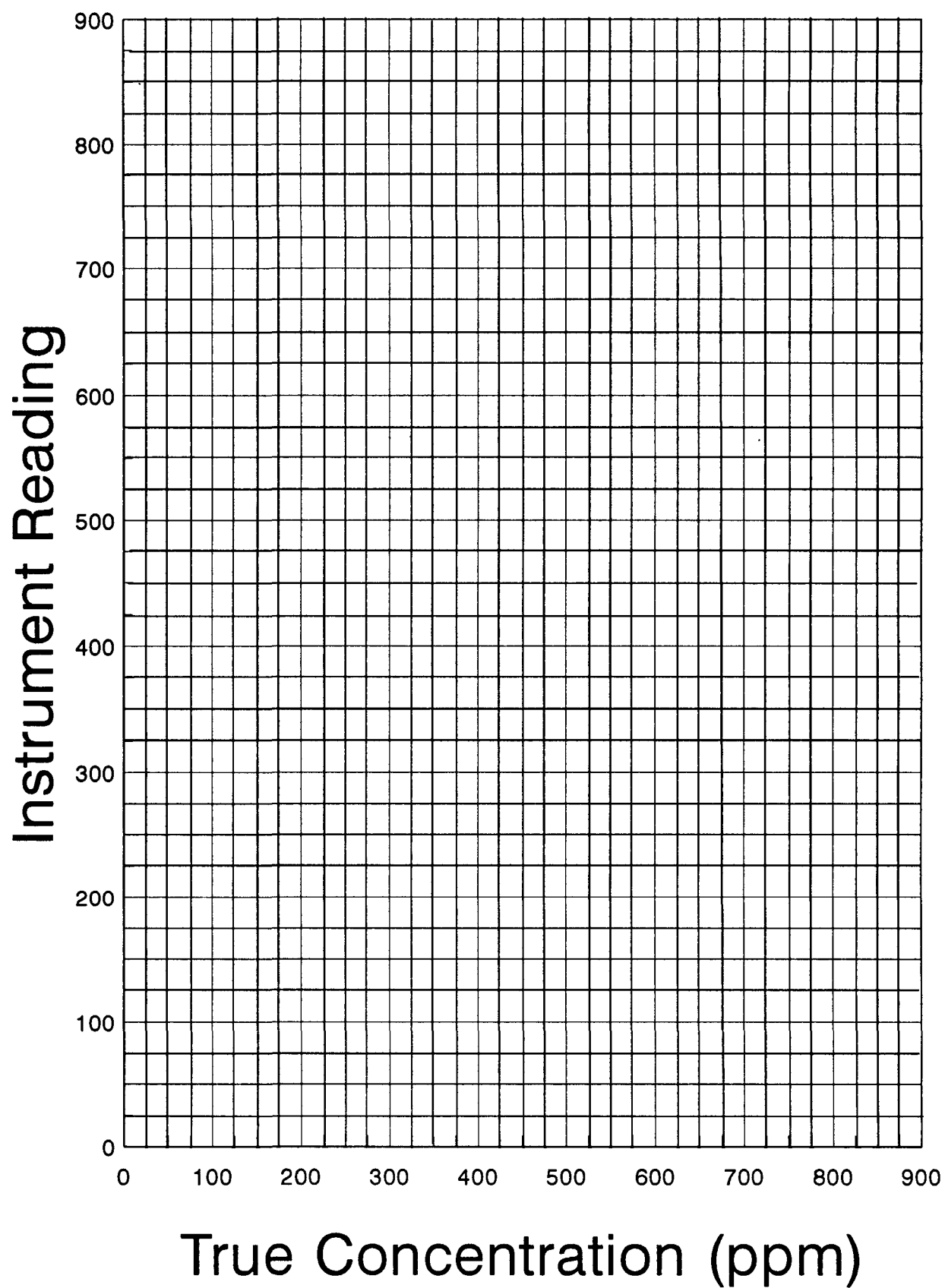
DATA SHEET

TABLE 3	
SAMPLE LOCATION*	READING
1	
2	
3	
4	
5	

* Add information about location of probe when taking the reading.

TABLE 4 ACETONE CALIBRATION			
BAG	ACTUAL CONCENTRATION	INSTRUMENT READING	GAS SELECT SETTING
B	100 ppm		
C	100/100		
D	800 ppm		
E	250 ppm		
F	50 ppm		

GRAPH 1. INSTRUMENT READING VS. ACTUAL CONCENTRATION (from Table 4)



QUESTIONS

1. Calculate the relative response for each of the chemicals in **Table 2**.
2. Why is the reading for Bag C in **Table 2** different from the reading in **Table 4**?
3. From **Graph 1**, does the instrument accurately measure all four concentrations? If you were going to measure acetone vapors at concentrations of 0–10 ppm, would this calibration curve be of value to you?
4. Unknown 2 is found to be acetone. Develop a method(s) using the OVA to determine the concentration of acetone at the location.
5. You are using an OVA to survey a site and obtain a reading of 200. How do you report your findings and what additional information would you like recorded?

EXERCISE #4

Gas Chromatography - Organic Vapor Analyzer

OBJECTIVE

Participants will learn how to operate the Foxboro OVA-128 with gas chromatograph option as a portable gas chromatograph.

PROCEDURE

The students will divide into groups as directed by the laboratory instructor. Each group will have a Foxboro OVA-128 with gas chromatograph option and three gas bags.

Bag CH ₄ :	Calibration gas
Bag C:	Standard of 100 ppm toluene and 100 ppm acetone
Unknown #1	

By following the instructions of the lab manual and instructor, each group will produce a gas chromatograph for each bag. By comparing the results from the standard to the unknown, the group will try to determine what chemicals are present and at what concentrations. The results will be recorded and discussed at the end of the exercise.

Please read each paragraph completely before following the directions and proceeding to the next paragraph.

SETUP

1. Record the instrument serial number or ID number on the data sheet.

STARTUP

2. For gas chromatograph use, the charger can remain on and connected to the OVA.
3. Unlock the GAS SELECT dial and adjust it to 300 (i.e., a 3 in the window and 00 on the dial).
4. Turn the VOLUME knob fully counter clockwise.
5. Ensure that the SAMPLE INJECT VALVE and BACK FLUSH VALVE are in the full out position.
6. The toggle switches on this instrument have a lock to prevent accidental changes. To move the toggle switch, lift and then move the lever.
7. Move the INSTRUMENT switch to ON and allow 5 minutes for warm-up.
8. Move the PUMP switch to ON. You should hear the pump running. Place the instrument in a vertical position and look at the SAMPLE FLOW RATE (rotameter at lower left of panel). The flow rate (read at center of ball) should be 2.0 (liters/minute). A reading between 1.5 and 2.5 is considered adequate.
9. Set the CALIBRATE switch to X10. Adjust the CALIBRATE knob until the meter reads 0.
10. Open the H₂ TANK VALVE and H₂ SUPPLY VALVE one and one-half turns counter clockwise. The TANK gauge should be 500 psi or higher. The SUPPLY gauge should read between 10 and 12 psi. If they do not, inform the instructor.
11. Wait about 1 minute. Depress the red IGNITER BUTTON (on the side of the pack) until the flame ignites or until 6 seconds have passed. Flame ignition is indicated by a sharp meter needle deflection toward 10 along with a small "pop" sound. Also, the meter needle should return to a reading above 0 instead of 0. Do not depress the button longer than 6 seconds. If the flame does not ignite on the first try, wait a minute, and try again. If it does not ignite on a second try, check that steps 1 through 10 have been completed. Then consult an instructor or technician for assistance.
12. Use the CALIBRATE knob to adjust the meter reading to zero. Move the CALIBRATE switch to X1 and rezero.

CALIBRATION

13. Set the CALIBRATE switch to X10.
14. Locate the METHANE calibration gas bag. Methane is the normal calibration gas for the OVA.
15. Open the bag clamp and attach the methane bag to the probe inlet. It is important that the bag be open before attaching it so that a "flame out" does not occur from oxygen starvation.
16. Unlock and adjust the GAS SELECT knob so that the meter reading is equal to the bag concentration divided by the CALIBRATE switch setting. For example, if the bag concentration is 90 ppm, then the reading should be 9 (90 divided by 10).
17. Disconnect the gas bag and close the clamp.
18. The GAS SELECT setting should be about 300. 300 is the "ideal" setting, but your instrument may have a different reading. If the setting must be adjusted above 400 or below 200, internal calibration may be advisable.

GAS CHROMATOGRAPH SETUP

19. Connect the strip chart recorder to the OVA. Move the HI/LO switch (on the side of the recorder) to the LO position. The chart paper should start moving and you should hear a clicking sound. If the chart does not operate, check the cable connections. Inform the instructor if the chart doesn't work.
20. Turn the ZERO knob on the recorder (next to HI/LO switch) completely clockwise.
21. Turn the OVA CALIBRATE knob to adjust the baseline (black line produced by the pin) on the chart. Do not use the ZERO knob on the recorder. The baseline should be about 1/4 inch (two thin brown lines) above the thick brown line next to the sprocket holes.
22. Locate the stopwatch. Practice with the stopwatch until you can do lap counting. The instructor will demonstrate. Lap counting involves stopping the readout without stopping the stopwatch timing. This is useful for timing more than one peak.

STANDARD CHROMATOGRAM

23. Open and connect the STANDARD (Bag C: Acetone/Toluene) bag to the probe inlet. Watch the meter needle. When the needle has deflected to its highest point, depress the SAMPLE INJECT VALVE and start the stopwatch. Disconnect and close the gas bag. If the needle passes 10, wait 3 seconds, then depress the INJECT VALVE.

Keep the SAMPLE INJECT VALVE depressed until the end of the chromatogram. The instructor will discuss how to determine when the chromatogram is done.

24. Strike a line across the chart with a pen or pencil to indicate the start of a chromatogram. Write the OVA CALIBRATE SWITCH setting (X1, X10, X100) and the recorder HI/LO setting on the chart paper.
25. Watch the chart paper or meter face for an upward needle deflection. When the needle reaches a maximum reading and starts to drop, note the time. This is the top of the peak and the time is the **retention time** for the peak. Do this for each peak. Record the retention times for each peak.
26. If a peak is too small or goes off scale, you will need to rerun the standard at a different CALIBRATE SWITCH setting and/or different HI/LO setting. **Table 1** shows the relationship between peak size and instrument settings. For example, if a peak is off scale on a HIX10 setting, changing the settings to LOX10 or HIX100 would make the peaks 1/2 or 1/10 the size of the original peaks.

TABLE 1		
RECORDER RANGE FACTOR	OVA SCALE	RELATIVE PEAK SIZE
HI	X1	1
LO	X1	1/2
HI	X10	1/10
LO	X10	1/20
HI	X100	1/100
LO	X100	1/200

27. When a chromatogram is done (i.e, the last peak is out and the baseline is back to normal), lift the SAMPLE INJECT VALVE. The instrument is ready for another run.

SAMPLE CHROMATOGRAM

28. Repeat steps 22 through 26 using the UNKNOWN sample bag.

SHUTDOWN

29. Close the H₂ SUPPLY valve, then the H₂ TANK valve.
30. Move the INSTRUMENT switch to OFF.

31. Move the RECORDER RANGE SETTING switch to OFF.
32. When the SUPPLY pressure gauge falls to zero, move the PUMP switch to OFF.

CALCULATIONS FOR QUALITATIVE EVALUATION

27. (Optional) Tear off the strip chart and measure the distance from the injection point to the middle of the peak in mm (see Figure 1 below).

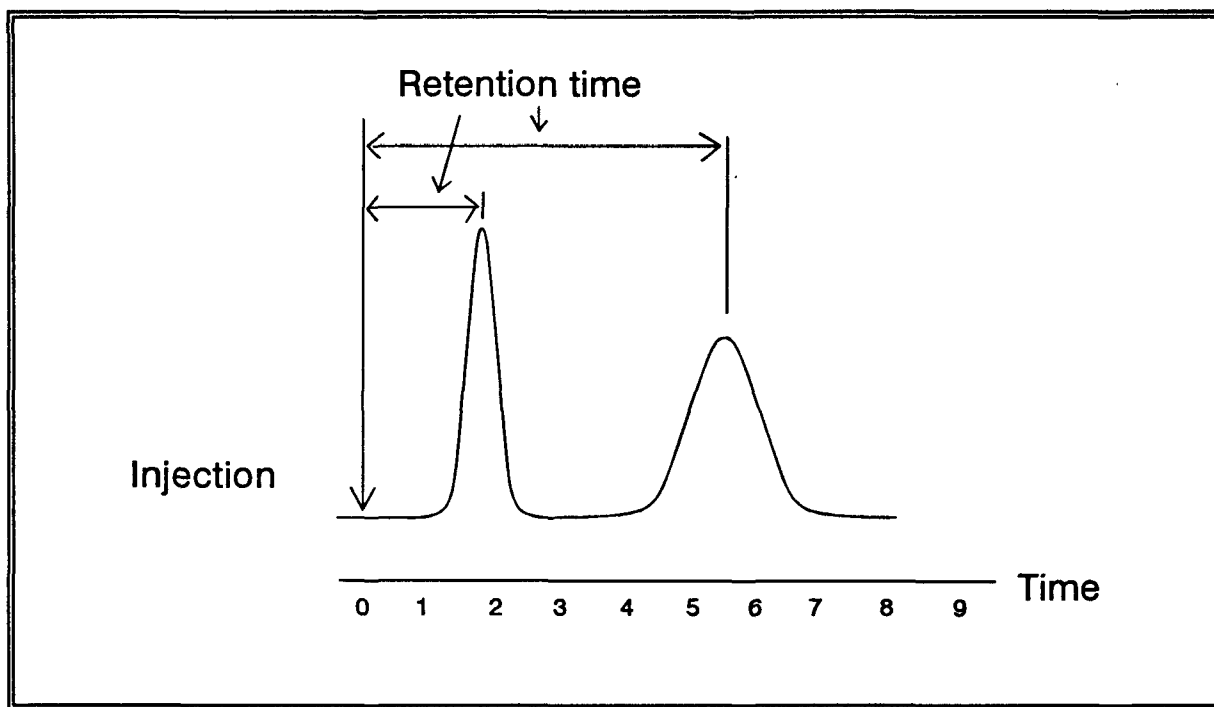


FIGURE 1. RETENTION TIME (DISTANCE) ILLUSTRATION

28. Compare the retention times of the known standard and the unknown. If the retention times are relatively close, then the unknown can possibly be identified through comparison to the known. For example, if a standard of **acetone** released at 144 seconds and a peak on our unknown was at 136 seconds, then we can assume that the peak was acetone.

QUANTITATIVE ANALYSIS

29. To find the concentration of a chemical that has been identified with a standard, you will need a ruler, a calculator, and a pencil.
30. Draw a triangle that approximates the area of the curve similar to the example (Figure 2) below.

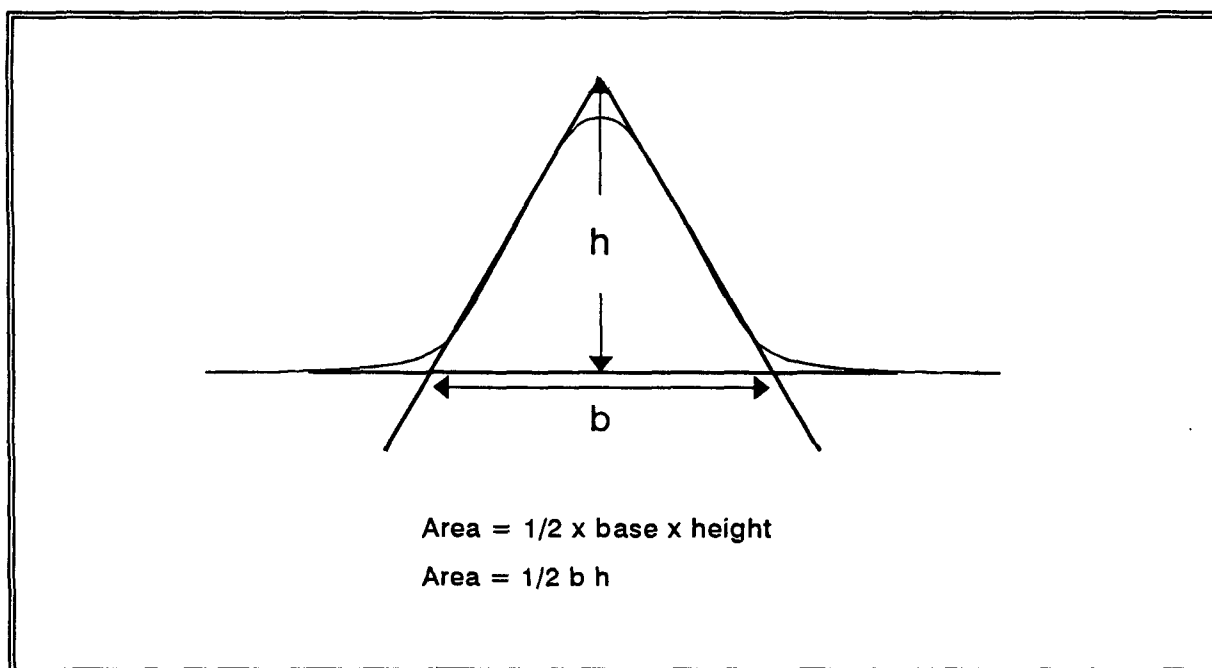


FIGURE 2. PEAK AREA ILLUSTRATION

31. Calculate the area of the triangle for the standards and unknowns by using the following formula:

$$\text{Area} = \frac{1}{2}(b)(h)$$

32. To compensate for the different instrument settings a **corrected area** formula must be used:

$$\text{Corrected Area} = \text{OVA Setting} \times \text{Recorder Range Factor} \times \text{Area of Triangle}$$

X100
 X10
 X1

HI = .5
 LO = 1.0

33. To obtain the actual concentration of the unknown, divide the corrected area of the unknown by the corrected area of the standard and multiply by the standard concentration.

$$\text{Concentration of unknown} = \frac{\text{Corrected Area}_{\text{unknown}}}{\text{Corrected Area}_{\text{standard}}} \times \text{Standard concentration}$$

TABLE 2					
	STANDARD BAG C		UNKNOWN #1		
	ACETONE	TOLUENE	PEAK 1	PEAK 2	PEAK 3
CONCENTRATION					
RETENTION TIME					
RETENTION DISTANCE (mm)					
PEAK BASE (mm)					
PEAK HEIGHT (mm)					
PEAK AREA (mm ²)					
OVA SCALE SETTING					
RECORDER SETTING					
CORRECTED AREA (mm ²)					

CALCULATIONS



QUESTIONS

1. Identify the peaks in Unknown #1. For the peaks that can not be positively identified, list the possible candidates.
2. What are the concentrations of the identified peaks? Compare your numbers with the actual concentrations (from the instructor). Give reasons why your results may vary from the actual concentrations.

CHROMATOGRAPHY AND SURVEY GUIDE
FOXBORO CENTURY ORGANIC VAPOR ANALYZERS

COMPOUND	T-12 COLUMN				G-24 COLUMN				SYNONYM
	TWA ppm	RR %	IR sec	a	IR sec	a			
ACETONE	750	82	118	2.23	36	0.29			2-PROPANONE
ACETONITRILE	40	64	384	7.25	39	0.32			
ACRYLONITRILE	2	98	252	4.75	45	0.37			VINYL CYANIDE
ALLYL ALCOHOL	2	27	623	11.75	98	0.80			
ALLYL CHLORIDE	1	45	36	0.68	38	0.31			
BENZENE	1	185	116	2.19	142	1.15			
BROMOETHANE	200	72	23	0.43	35	0.28			ETHYL BROMIDE
BROMOMETHANE	5	23	13	0.25	14	0.11			METHYL BROMIDE
BROMOPROPANE	*	73	51	0.96	100	0.81			PROPYL BROMIDE
BUTADIENE, 1,3-	1000	36	3	0.06	7	0.06			BUTADIENE
BUTANE	800	58	12	0.23	3	0.02			
BUTANOL	100	46	725	13.68	243	1.98			BUTYL ALCOHOL
BUTANOL, 2-	100	55	340	6.42	131	1.07			sec-BUTYL ALCOHOL
BUTANONE, 2-	200	75	203	3.83	93	0.76			METHYL ETHYL KETONE
BUTENE	*	43	5	0.09	12	0.10			
BUTYL ACETATE	150	67	572	10.79	782	6.36			
BUTYL ACRYLATE	10	60	1099	20.74	1577	12.82			
BUTYL ACRYLATE, tert-	*	75	293	5.53	567	4.61			2-BUTYL ACRYLATE / PROPYLENE
BUTYL FORMATE	*	48	338	6.38	319	2.59			
BUTYL FORMATE, tert-	*	64	111	2.09	112	0.91			2-BUTYL FORMATE
BUTYL METHACRYLATE	*	60	1600	30.19	3950	32.11			
BUTYL METHYL ETHER, tert-	*	57	21	0.40	70	0.57			
CARBON TETRACHLORIDE	10	8	41	0.77	143	1.16			
CHLOROBENZENE	75	179	713	13.45	866	7.04			MONOCHLOROBENZENE
CHLOROFORM	2	57	122	2.30	91	0.74			TRICHLOROMETHANE
CHLOROMETHANE	50	56	4	0.08	5	0.04			METHYL CHLORIDE
CHLOROPROPANE	*	79	25	0.47	48	0.39			PROPYL CHLORIDE
CHLOROPROPANE, 2-	*	55	13	0.25	26	0.21			ISOPROPYL CHLORIDE
CUMENE	50	18	690	13.02	1910	15.53			ISOPROPYL BENZENE
CYCLOHEXANE	300	92	16	0.30	161	1.31			HEXAMETHYLENE
CYCLOHEXANONE	25	43	—	0.00	1256	10.21			
DECANE	*	69	225	4.25	—	0.00			
DIACETONE ALCOHOL	50	56	950	17.92	1017	8.27			4-HYDROXY-4-METHYL-2-PENTANON
DIBROMOETHANE, 1,2-	20	56	1168	22.04	536	4.36			ETHYLENE DIBROMIDE
DICHLOROBENZENE, 1,2-	50	119	4060	76.60	—	0.00			o-DICHLOROBENZENE
DICHLOROETHANE, 1,1-	100	70	66	1.25	66	0.54			
DICHLOROETHANE, 1,2-	1	89	289	5.45	124	1.01			ETHYLENE DICHLORIDE
DICHLOROETHYLENE, 1,1-	1	49	11	0.21	36	0.29			VINYLDIENE CHLORIDE
DICHLOROETHYLENE, trans-1,2	200	40	37	0.70	55	0.45			
DICHLOROMETHANE	100	84	73	1.38	43	0.35			METHYLENE CHLORIDE
DICHLOROPROPANE, 1,2-	75	96	258	4.87	203	1.65			PROPYLENE DICHLORIDE
DICHLOROPROPANE, 1,3-	*	76	677	12.77	397	3.23			
DIOXANE, p-	25	28	760	14.34	242	1.97			DIETHYLENE DIOXIDE

COMPOUND	T-12 COLUMN				G-24 COLUMN		SYNONYM
	TWA ppm	RR %	tR' sec	α	tR' sec	α	
ENFLURANE	*	146	79	1.49	29	0.24	2-CHLORO-1,1,2-TRIFLUOROETHYL-DI-
ETHANE	*	77	1	0.02	1	0.01	FLUOROMETHYL ETHER / ETHRANE
ETHANETHIOL	0.5	28	24	0.45	31	0.25	ETHYL MERCAPTAN
ETHANOL	1000	20	178	3.36	45	0.37	ETHYL ALCOHOL
ETHENE	*	47	1	0.02	1	0.01	ETHYLENE
ETHER	400	47	13	0.25	38	0.31	DIETHYL ETHER
ETHYL ACETATE	400	67	143	2.70	108	0.88	
ETHYL ACRYLATE	5	71	263	4.96	254	2.07	
ETHYL BENZENE	100	111	495	9.34	1054	8.57	
ETHYL BUTYRATE	*	91	398	7.51	588	4.78	
ETHYL FORMATE	100	44	78	1.47	43	0.35	
ETHYL METHACRYLATE	*	73	375	7.08	514	4.18	
ETHYL PROPIONATE	*	83	241	4.55	274	2.23	
ETHYLENE OXIDE	1	49	31	0.58	35	0.28	EPOXYETHANE
FREON-11	1000	7	4	0.08	24	0.20	FLUOROTRICHLOROMETHANE
FREON-113	1000	91	8	0.15	43	0.35	TRICHLOROTRIFLUOROETHANE
FREON-114	1000	110	3	0.06	8	0.07	1,2-DICHLORO-1,1,2-TETRAFLUOROETH.
FREON-123	100	86	19	0.36	22	0.18	2,2-DICHLORO-1,1,1-TRIFLUOROETHANE
FREON-12	1000	13	3	0.06	5	0.04	DICHLORODIFLUOROMETHANE
FREON-21	10	71	20	0.38	17	0.14	DICHLOROFLUOROMETHANE
FREON-22	1000	67	5	0.09	3	0.02	CHLORODIFLUOROMETHANE
HALOTHANE	*	49	53	1.00	51	0.41	2-BROMO-2CHLORO-1,1,1-TRIFLUOROETH.
HEPTANE	400	80	16	0.30	232	1.89	
HEXADECANE	*	52	1764	33.28	—	0.00	
HEXAFLUOROPROPENE	*	81	1	0.02	2	0.02	PERFLUOROPROPENE
HEXANE	50	70	7	0.13	88	0.72	
ISOBUTANE	*	70	3	0.06	14	0.11	2-BUTANE / 2-METHYL PROPANE
ISOBUTENE	*	64	2	0.04	10	0.08	ISOBUTYLENE / 2-METHYL PROPENE
ISOPRENE	*	59	9	0.17	32	0.26	2-METHYL-1,3-BUTADIENE
ISOPROPYL ACETATE	250	71	155	2.92	180	1.46	
METHANE	*	100	1	0.02	1	0.01	
METHANOL	200	10	139	2.62	64	0.52	METHYL ALCOHOL
METHYL ACETATE	200	46	93	1.75	49	0.40	
METHYL ACRYLATE	10	39	197	3.72	107	0.87	
METHYL CYCLOHEXANE	400	67	20	0.38	280	2.23	
METHYL CYCLOPENTANE	*	81	9	0.17	114	0.93	
METHYL ISOBUTYL KETONE	50	82	468	8.83	353	2.87	4-METHYL-2-PENTANONE / HEXONE
METHYL METHACRYLATE	100	54	291	5.49	266	2.16	
METHYL SULFIDE	*	20	27	0.51	35	0.28	DIMETHYL SULFIDE
NITROMETHANE	100	35	1053	19.87	73	0.59	
NITROPROPANE	25	65	1893	35.72	285	2.32	
NITROPROPANE,2-	10	71	1030	19.43	191	1.55	
NONANE	200	85	103	1.94	1939	15.76	
OCTANE	300	87	44	0.83	748	6.08	
PENTANE	600	65	3	0.06	29	0.24	
PENTANOL	*	39	1771	33.42	728	5.92	PENTYL ALCOHOL
PENTANONE,2-	200	76	365	6.89	227	1.85	METHYL PROPYL KETONE

COMPOUND	T-12 COLUMN				G-24 COLUMN		SYNONYM
	TWA ppm	RR %	tR' sec	a	tR' sec	a	
PENTANONE,3-	200	61	355	6.70	257	2.09	DIETHYL KETONE
PROPANE	1000	70	1	0.02	5	0.04	
PROPANOL	200	35	351	6.62	102	0.83	PROPYL ALCOHOL
PROPANOL,2-	400	60	153	2.39	57	0.46	ISOPROPANOL
PROPYL ACETATE	200	60	283	5.34	286	2.33	
PROPYL ETHER	*	56	36	0.68	217	1.76	
PROPYL FORMATE	*	58	157	2.96	111	0.90	
PROPYLENE	*	36	2	0.04	4	0.03	
PROPYLENE OXIDE	20	66	46	0.87	40	0.33	1,2-EPOXYPROPANE
PYRIDINE	5	109	—	0.00	—	0.00	
STYRENE	50	92	1384	26.11	1355	11.02	
TETRACHLOROETHANE,1,1,1,2	*	81	956	18.04	810	6.59	
TETRACHLOROETHYLENE	25	67	141	2.66	603	4.90	PERCHLOROETHYLENE
TETRAHYDROFURAN	200	47	106	2.00	125	1.02	
TOLUENE	100	126	262	4.94	391	3.18	METHYL BENZENE
TRICHLOROETHANE,1,1,1-	350	101	53	1.00	123	1.00	METHYL CHLOROFORM
TRICHLOROETHANE,1,1,2-	10	95	1158	21.85	378	3.07	
TRICHLOROETHYLENE	50	54	104	1.96	222	1.80	
TRIETHYLAMINE	10	59	—	0.00	34	0.28	
TRIMETHYLPENTANE,2,2,4-	*	91	14	0.26	221	1.80	ISOOCTANE
VINYL ACETATE	10	40	116	2.19	77	0.63	
VINYL CHLORIDE	1	38	5	0.09	9	0.07	
XYLENE,m-	100	107	563	10.62	1135	9.23	1,3-DIMETHYL BENZENE
XYLENE,o-	100	106	804	15.17	1366	11.11	1,2-DIMETHYL BENZENE
XYLENE,p-	100	106	545	10.28	1140	9.27	1,4-DIMETHYL BENZENE

KEY:

* No TWA levels available.

TWA 8 Hour Time Weighted Average for
Maximum allowable exposure.

RR Relative Response to METHANE in Percent =
(Measured Response / Prepared Concentration) x 100.

— tR data not available

tR = Solute Retention Time from point of injection

tR' = Adjusted Retention Time in seconds

tM = Gas Hold-Up, or Dead Time

tR' = tR - tM

a = Relative Retention as compared to a Reference
Reference Compound is 1,1,1-Trichloroethane

Data collected at a chart speed = 1 cm/min. at
concentrations of 50 or 100 ppm, and at ambient
temperature

HOW TO USE THIS CHART FOR IDENTIFICATION OF UNKNOWN BY GC

1. Calculate the Adjusted Retention time of the Unknown solutes and of the Reference compound for the selected column. This can be accomplished by either running the reference compound separately, under similar conditions as the unknown will be run, or along with the questioned sample by introducing it into the sample stream via direct injection, dilutor accessory, or other like means. The t_R' for any solute is equal to the time elapsed from the point of injection to the projection of the peak maximum, minus the gas hold-up time of the column. The gas hold-up time is the time elapsed from the point of injection to the maximum deflection of the air peak. (NOTE: approximate hold-up times are 5 secs for a T-12 column and 10 secs for a G-24 column.)
2. In order to minimize the effects of minor variation in operating conditions and in the stationary phase loading of the columns, the parameter of Relative Retention (α) is used. To calculate α , for a particular solute on a given column, divide the t_R' of the solute by the t_R' of the reference compound. If the value of α falls within $\pm 10\%$ of the chart value, then the chances are good that the questioned solute is one of the compounds in this range.
3. To increase the probability of identifying an unknown solute, this chart provides the user with the option of Two-Column dimensional chromatography. By utilizing a second type column, one can calculate a second α value for the questioned solute. If this value of α falls within $\pm 10\%$ of the chart value, and the value of α for the previous column falls within $\pm 10\%$ of that chart value, then there is a high probability that the unknown has been identified.
4. Laboratory GC analysis and standard preparation may be required for confirmation, depending upon the application.

EXERCISE #5

Detector Tubes

OBJECTIVE

During this exercise, participants will learn how to do a leak check and a volume check of both a Draeger and a Sensidyne detector tube pump and how to use detector tubes quantitatively and qualitatively.

INTRODUCTION

There are chemical indicators that use the reaction of a chemical reagent with the airborne chemical of interest to produce a color change. The intensity of the color change or the length of color change is used to determine the amount of airborne chemical present. The chemical reagent may be impregnated on a piece of paper or tape and the color change read by eye or by an electronic device. The chemical could also be placed in a glass tube called a colorimetric indicator tube or detector tube.

PRINCIPLE OF OPERATION

Colorimetric indicator tubes or detector tubes (**Figure 1**) consist of glass tube impregnated with an indicating chemical. A known volume of contaminated air passes through or into the tube. The contaminant reacts with the indicator chemical in the tube, producing a change in color whose length or intensity is proportional to the contaminant concentration.

The tubes may have a preconditioning filter preceding the indicating chemical to:

- Remove contaminants (other than the one in question) that may interfere with the measurement. Many have a prefilter for removing humidity.
- React with a contaminant to change it into a compound that reacts with the indicating chemical.

TYPES OF TUBES

Detector tubes can be classified by the way air is drawn into the tube:

- Short-term tubes use a hand pump to draw air through the tube for a sample duration of a few seconds to a few minutes. This is used to give an instantaneous sample. The hand pump may be a **piston** or **bellows** type pump. This exercise will use both types. A piston pump has a handle that is pulled to evacuate a cylinder of known volume. Air is pulled through the tube to equalize the pressure in the cylinder.

MSA, Sensidyne, Enmet, and Matheson manufacture piston pumps. In a bellows pump, the bellows is squeezed and released. Air is pulled through the tube as the bellows expands. Draeger and MSA manufacture bellows-type pumps.

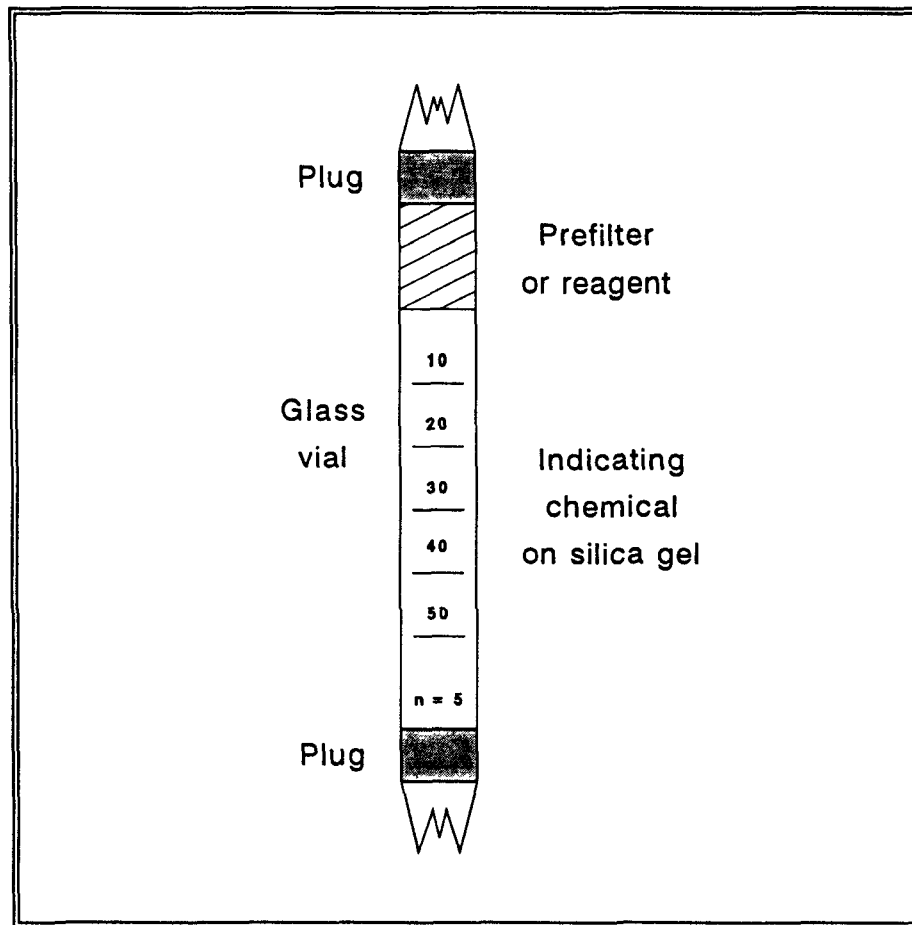


FIGURE 1. DETECTOR TUBE EXAMPLE

- Long-term tubes (pump) use a battery-operated pump to draw air through the tube over a longer period of time, usually 8 hours. These are used to determine 8-hour, time-weighted average exposures.
- Long-term tubes (dosimeter) do not use a pump. Contaminants diffuse into the tube over a long period of time, usually 8 hours. These also are used for 8-hour, time-weighted average exposure determination. However, a pump is not required for operation.

The three types of tubes are not interchangeable. They are calibrated for their specific applications. There are many more short-term tubes than there are long-term tubes.

Detector tubes can also be classified by the information generated the results:

- **Chemical groups**—Some tubes will react to a class of chemicals (e.g., alcohols or hydrocarbons). They will only indicate that a chemical of a certain class is present.
- **Specific chemicals**—There are a few tubes that only react to that specific chemical. Most tubes have a specific chemical listed for the tube, but can react to other chemicals (interferences).
- **Concentration ranges**—There may also be different concentration ranges for the same chemical. For example, there are tubes for carbon monoxide with concentration ranges of 5–150 ppm, 10–300 ppm, 0.1–1.2% and 0.3–7%.

DETECTOR TUBE CONSIDERATIONS

There are several factors that determine the effective use of detector tubes. These factors can be found in the instructions issued with each box of tubes.

Chemical Group: Some tubes are for a specific chemical and some are for a group of chemicals.

Lot #: The instructions for the tubes may change with different model numbers or different lots. Thus, the instructions should be matched with the proper tubes.

Expiration Date: The chemicals used in the tubes deteriorate over time. Because of this, the tubes are assigned a shelf life and the expiration date is printed on the box. This varies from 1 to 3 years.

Pump Strokes/Volume/Time: The total volume of air to be drawn through the tube varies with the type of tube. The volume needed is given as the number of pump strokes needed, i.e., the number of times the piston or bellows is manipulated. Also, the air does not instantaneously go through the tube. It may take 1 to 2 minutes for each volume (stroke) to be completely drawn. Therefore, sampling times can vary from 1 to 30 minutes per tube. This can make the use of detector tubes time consuming.

Color Change: The instructions will give the appropriate color change for indicating the chemical of concern. Other color changes may be noted for interferences. This information can be used to check for the presence of other chemicals.

Interferences: As mentioned previously, not every tube is specific. For example, an acetone tube will also respond to other ketones. Thus, methyl ethyl ketone would be considered an interference if one were checking for acetone. The instructions will give known interferences or color changes that are not for the chemical of interest.

Temperature/Humidity/Pressure: The length of color change (stain) can be affected by temperature, humidity and barometric pressure. If this is a problem, the instructions will note it and may give correction factors. Cold weather slows the chemical reaction in the tube and reduces the reading. Hot temperatures increase the reaction and can cause a problem by discoloring the indicator even

when a contaminant is not present. This can happen even in unopened tubes. Therefore, the tubes should be stored at a moderate temperature or even be refrigerated during storage.

Reusable?: Most tubes can only be used once, even if there is a negative result. There are some tubes, however, that can be reused the same day until a positive result is obtained.

Accuracy: The accuracy of detector tubes vary. Some studies have reported error factors of 50% and higher for some uncertified tubes. Some tubes are certified to be $\pm 25\%$ accurate at readings from 1 to 5 times the OSHA Permissible Exposure Limit (PEL) and $\pm 35\%$ at concentrations one-half the PEL. Only a few tubes are presently certified. Certification of detector tubes is being done by a private organization - Safety Equipment Institute (SEI).

One factor that affects accuracy is the interpretation of the end of the color change. Some color changes are diffused and the endpoint is not definite; others may have an uneven endpoint (**Figure 2**). When in doubt, use the highest value that would be obtained from reading the different aspects of the tube.

APPLICATIONS

Although there are many limitations and considerations for using detector tubes, detector tubes allow the versatility of being able to measure a wide range of chemicals with a single pump. Also, there are some chemicals for which detector tubes are the only direct-reading indicators.

They can be used to get a reading for a specific chemical in an atmosphere where a total vapor survey instrument would response to all the chemicals in the atmosphere. They also give an immediate response. Laboratory analysis (see the *Air Sample Collection* section) that can identify and quantify a chemical in a mixture takes time.

Manufacturers use general tubes for identification in their HazMat kits. These kits identify or classify the contaminants as a member of a chemical group such as acid gas, halogenated hydrocarbon, etc. This is done by sampling with certain combinations of tubes at the same time by using a special multiple tube holder or by using tubes in a specific sampling sequence. All manufacturers of detector tubes have some kind of system for hazard categorization. Detector tube manufacturers are listed in the *Manufacturers and Suppliers of Air Monitoring Equipment* section of this manual.

SAFETY

Do not directly inhale the contents of the bags and keep the bags closed when not in use. The contents of the gas bags, if released into the room, will not pose a hazard to the occupants.

Breaking the tips off the detector tubes can create a hazard. Please ensure that the glass tips are discarded into the containers provided and not onto the table or floor. The tube breakers built into the pumps can propel bits of glass. Direct the glass into the container provided. The instructor will demonstrate proper procedures. The ends of the detector tubes are also sharp, so handle them carefully.

Eating or drinking is not allowed during this exercise because it is nearly impossible to prevent small shards of glass from being deposited on the desk, table, or floor. Also, check the work area so that you do not pick up glass on your hands or arms.

PUMP CHECK - DRAEGER

Leak Test

The purpose of this test is to ensure that air is going through the tube and not around it or through a leaky valve.

1. Insert an unopened tube into the socket of the pump. Do not use your finger to seal the orifice. The instructor will demonstrate why not.
2. Squeeze the pump completely and release. If the indicator mark has not appeared in 15 minutes, the pump passes the test. You may want to go to the Sensidyne pump check while this is taking place.
3. If the pump fails the test, inform the instructor.
4. Remove tube from the socket.
5. (New model pump) Press counter reset button with a ball point pen or end of unopened tube to set at zero.

Volume Check

The purpose of this step is make sure that the pump is drawing the specified volume (100 cubic centimeters or milliliters). The tubes are calibrated for this volume. If the volume is not within limits, the tubes can not be used quantitatively.

6. Break off the tips of a tube or use a previously opened tube.
7. Connect the detector tube and pump to the apparatus as shown in **Figure 2**.

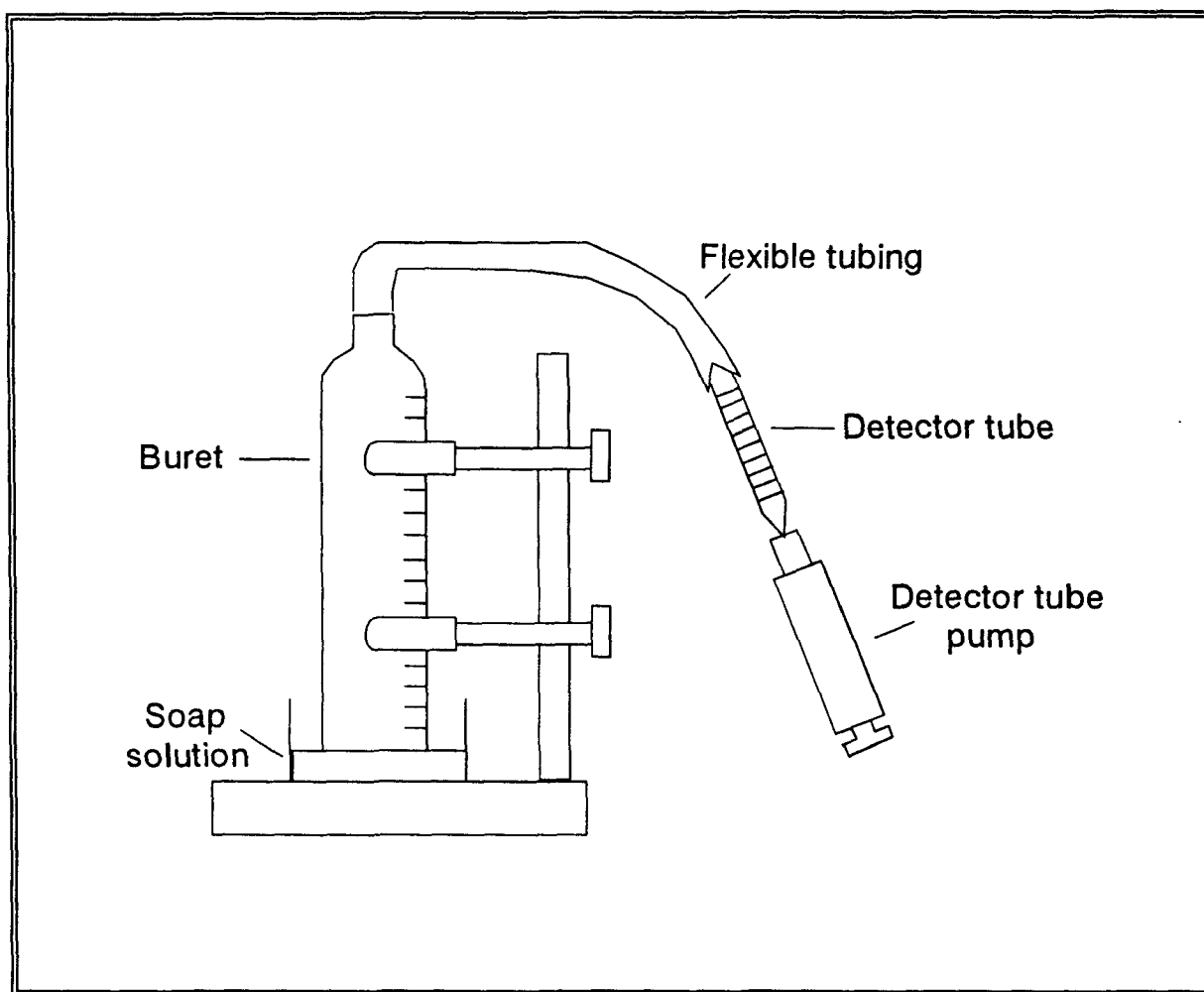


FIGURE 2. DETECTOR TUBE PUMP VOLUME CHECK APPARATUS

8. Start a bubble at the mouth of the inverted buret by just touching the soap solution to the mouth of the buret.
9. Squeeze the bellows pump in order to pull the bubble up the buret. Continue to squeeze and release the pump until the bubble stops above the "0" mark on the buret. This maneuver may require disconnecting the flexible tubing after the bubble passes the "0" mark.
10. Start with the bellows fully expanded. Reconnect the detector tube to the tubing. Record the start point (ml) in **Table 1**.
11. Squeeze and release the pump.
12. When the bubble stops, record the stopping point (ml).
13. The difference in the two points (the travel volume) is the volume pulled by one stroke of that pump. This volume should be between 95 and 105 ml (100 ml \pm 5%).
14. You may repeat the test to see whether the results are consistent.

PUMP CHECK - SENSIDYNE

Leak Test

1. Insert an unbroken tube into the orifice of the pump.
2. Align the index marks on the pump handle and the pump cap. Pull the handle straight out as far as it will go. It should lock in place.
3. Wait 1 minute. Turn the handle 1/4 turn and release the handle. Hold the pump barrel firmly as the handle will pop back rapidly if the pump does not leak. The handle should return to within 1/4 inch of the cap. If the pump is equipped with a "Flow Finish Indicator," the red button will remain down if there is no leak.
4. If the pump fails the test, inform the instructor.

Volume Check

5. Break off the tips of a tube or use a previously opened tube.
6. Connect the detector tube and pump to the apparatus as shown in **Figure 2**. An adapter may be needed because of the small diameter of the tube.
7. Start a bubble at the mouth of the inverted buret by just touching the soap solution to the mouth of the buret.
8. Pull the handle back in order to pull the bubble up the buret. Continue to pull the handle until the bubble stops above the "0" mark on the buret. This maneuver may require disconnecting the flexible tubing after the bubble passes the "0" mark.
9. Start with the piston empty (handle fully in). Reconnect the detector tube to the tubing. Record the start point (ml) in **Table 1**.
10. Pull back the pump handle all the way.
11. When the bubble stops, stop the stopwatch. Record the time and the stopping point (ml).
12. The difference in the two points (the travel volume) is the volume pulled by one stroke of that pump. This volume should be between 95 and 105 ml ($100 \text{ ml} \pm 5\%$).
13. You may repeat the test to see if the results are consistent.

QUANTITATIVE RESULTS - DRAEGER AND SENSIDYNE

The pumps and detector tubes will be used to determine the concentration of two chemicals. The Draeger pump and tube will be used to determine the concentration of carbon dioxide in the gas bag. The Sensidyne pump and tube will be used to determine the concentration of isopropyl alcohol in the air above a beaker of liquid.

1. Read the instructions for the detector tube.
2. Determine the number of pump strokes needed; the color change expected; and any adjustments to the reading.
3. Use a fresh tube. Break off both ends of the tube. Insert the opened tube into the pump orifice with the arrow on the tube pointing towards the pump. Sample the bag (carbon dioxide) and the air above the liquid (isopropyl alcohol). Do not pull liquid into the tube. (This is air, not water, monitoring.) Liquid drawn into the tube can produce a change even if the chemical is not present.
4. Record your results on **Table 1**.

CHEMICAL CLASSIFICATION - DRAEGER

In this step, a series of Draeger tubes will be used to determine the types of chemicals in an unknown mixture. The flow chart on the next page will be used to determine the mixture's components. The chart was provided by National Draeger, Inc. Other manufacturers have similar systems for chemical classification.

This sample taking schedule refers to a selection of substances which occur frequently in practice. Other situations may necessitate another sequence of measurements and, the case being, the use of additional detector tubes, or measurements according to other procedures must be carried out. (from National Draeger, Inc.)

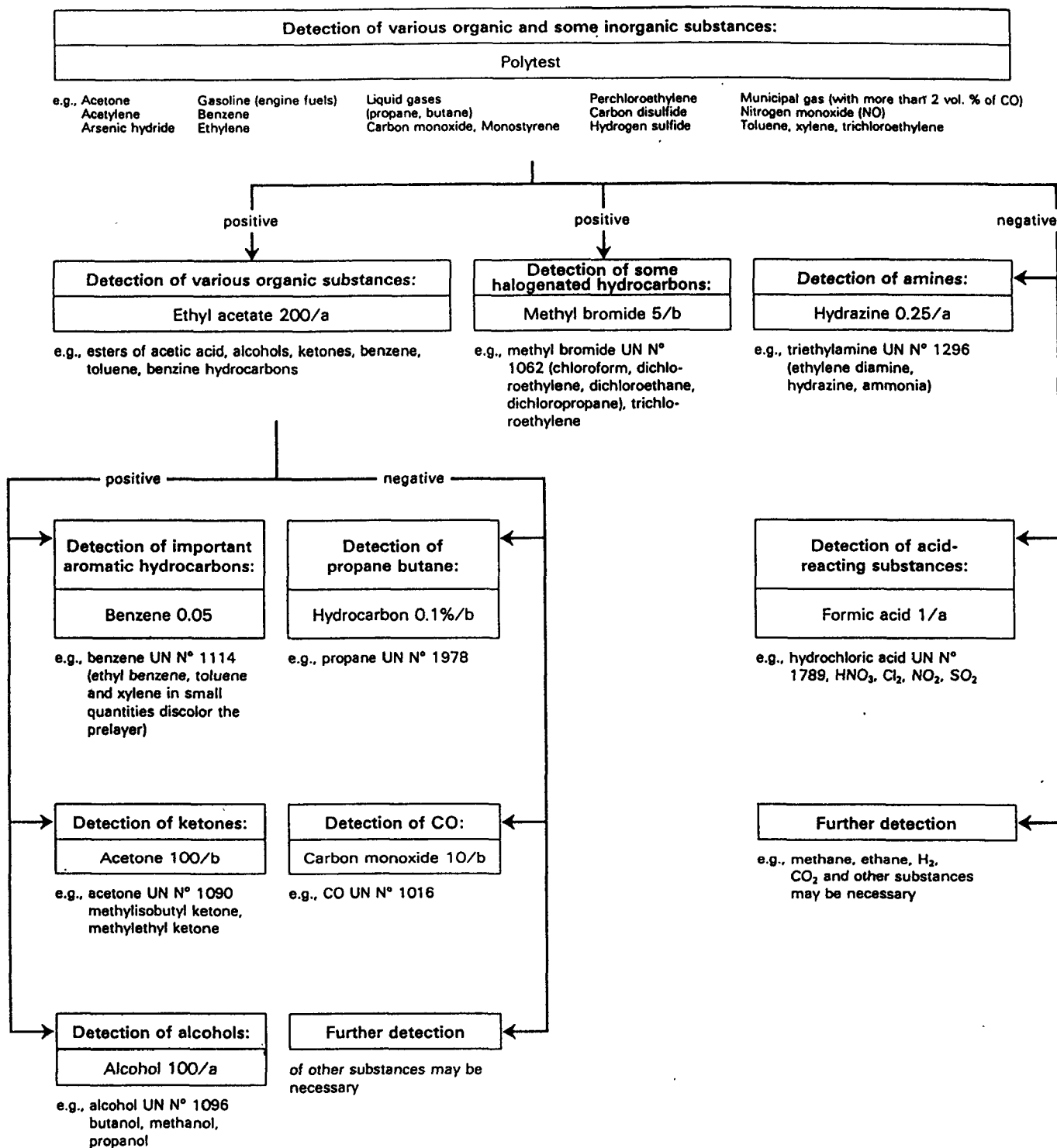
The information on the next two pages has been reprinted with the permission of National Draeger, Inc., Pittsburgh, PA. This information can also be found in their Haz Mat Kit. Similar flow charts/decision logics have also been developed by MSA and Sensidyne for use with their detector tubes.

1. Read the instructions for the tubes.
2. Use the tubes to sample the unknown atmosphere.
3. Record the result in the appropriate space in **Table 2**.
4. Repeat process with all the tubes provided.
5. Extra space is provided should any special tubes be used.

Safety Tips

The POLYTEST and HYDROCARBON tubes use sulfuric acid as a reagent. When the bellows is squeezed, an aerosol (smoke-like) containing the acid will be emitted. Avoid breathing the "smoke." If you think you may have some problems with the aerosol, please inform your instructor. You should not have any problems unless you are more sensitive than the average person.

Detection of unknown substances by means of DRAEGER detector tubes*



*Important: This sample taking schedule refers to a selection of substances which occur frequently in practice. Other situations may necessitate another sequence of measurements and, the case being, the use of additional detector tubes, or measurements according to other procedures must be carried out.



National Draeger, Inc.

101 Technology Drive (Shipping) • P.O. Box 120 (Mailing) • Pittsburgh, PA 15230 • 412/787-8383 • Telex: 86-6704

Examples for the (qualitative) indication response of the DRAEGER Polytest tubes

The results were obtained under the following test conditions:

Temperature 20°C; Humidity 50% relative; All tests carried out with pure substances

Substance	Concentration	Number of strokes of the bellows pump	Length of Discoloration	Notes on the indication
Acetone	5000 ppm	5	approx. 10 mm	brownish green
Acetone	above liquid	5	completely colored	brownish
Acetylene	200 ppm	5	approx. 10 mm	brownish green
Acetylene	high conc. (over 1 %)	5	completely colored	brownish
Arsine	10 ppm	5	approx. 10 mm	brownish green
Arsine	high conc. (over 1 %)	5	completely colored	brownish
Benzine (Gasoline)	50 ppm	5	approx. 10 mm	brownish green
Benzine (Gasoline)	above liquid	5	completely colored	brownish
Benzene	100 ppm	5	approx. 10 mm	brownish
Benzene	above liquid	5	approx. 10 mm	brownish
Butane	100 ppm	5	approx. 10 mm	faded green (spotty)
Butane	high conc. (over 1 %)	5	completely colored	brownish green
Carbon disulfide	10 ppm	5	approx. 10 mm	greenish
Carbon disulfide	above liquid	5	completely colored	brownish green
Carbon monoxide	100 ppm	5	approx. 10 mm	brownish green
Carbon monoxide	high conc. (over 1 %)	5	completely colored	brownish
Ethylene (ethene)	500 ppm	5	approx. 10 mm	brownish green
Ethylene (ethene)	high conc. (over 1 %)	5	completely colored	brownish
Nitrogen monoxide (NO)	50 ppm	5	approx. 10 mm	brownish green
Nitrogen monoxide (NO)	high conc. (over 1 %)	5	completely colored	brownish with bleaching effect
Perchloroethylene	50 ppm	5	approx. 10 mm	greenish
Perchloroethylene	above liquid	5	completely colored	brownish green
Propane	500 ppm	5	approx. 10 mm	faded green (spotty)
Propane	high conc. (over 1 %)	5	completely colored	brownish green
Styrene (monostyrene)	500 ppm	5	approx. 10 mm	brownish
Styrene (monostyrene)	above liquid	5	approx. 10 mm	brownish
Toluene	200 ppm	5	approx. 10 mm	brownish
Toluene	above liquid	5	approx. 10 mm	brownish
Trichloroethylene	50 ppm	5	approx. 10 mm	brownish green
Trichloroethylene	above liquid	5	completely colored	faded yellow
Xylene	500 ppm	5	approx. 10 mm	brownish
Xylene	above liquid	5	approx. 10 mm	brownish

Examples for the (qualitative) indication response of the DRAEGER tubes for ethyl acetate 200/a

The results were obtained under the following test conditions:

Temperature 20°C; Humidity 50% relative; All tests carried out with pure substances

Substance	Concentration	Number of strokes of the bellows pump	Length of Discoloration	Notes on the indication
Acetone	3000 ppm	5	approx. 10 mm	greenish
Acetone	above liquid	5	completely colored	greenish
Benzene	500 ppm	5	completely colored	very pale grey
Benzene	above liquid	5	completely colored	greenish grey
Ethyl alcohol	2000 ppm	5	approx. 5 mm	greenish
Ethyl alcohol	above liquid	5	approx. 20 mm	greenish
Octane	100 ppm	5	approx. 10 mm	grey-brown-greenish
Octane	above liquid	5	completely colored	greenish
Toluene	500 ppm	5	approx. 10 mm	greenish grey
Toluene	above liquid	5	completely colored	greenish grey
Xylene	500 ppm	5	approx. 10 mm	greenish brown
Xylene	above liquid	5	completely colored	greenish brown



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TABLE 1		
	SENSIDYNE	DRAEGER
ID NUMBER		
LEAK CHECK	PASS FAIL	PASS FAIL
VOLUME CHECK		
BURET STOP POINT (ml)		
BURET START POINT (ml)		
TOTAL VOLUME		
SAMPLE TIME		
ACCEPTABLE VOLUME? ^a	PASS FAIL	PASS FAIL
SAMPLES	ISOPROPYL ALCOHOL	CARBON DIOXIDE
UNADJUSTED READING		
READING ADJUSTED FOR TEMPERATURE		
READING ADJUSTED FOR BAROMETRIC PRESSURE ^b		

^a The acceptable volume for a full pump stroke is 100 ml \pm 5% (i.e., between 95 and 105 ml).

^b Assume the sampling conditions were 30°C and 720 mm barometric pressure.

TABLE 2	
NAME OF TUBE	READING/INDICATION
POLYTEST	
METHYL BROMIDE	
ETHYL ACETATE	
BENZENE	
ACETONE	
ALCOHOL	
HYDROCARBON	
CARBON MONOXIDE	
HYDRAZINE	
FORMIC ACID	

What types of chemicals are present in the mixture?

QUESTIONS

1. Based on your test results, how long should you wait between pump strokes for the MSA?
2. What factors could affect the detector tube results?
3. Does the CO₂ concentration exceed the PEL? REL? TLV? IDLH?
4. Does the isopropyl alcohol concentration exceed the PEL? REL? TLV? IDLH?

EXERCISE #6

Direct-Reading Aerosol Monitors

OBJECTIVE

Participants will learn how to operate the MIE Real-Time Aerosol Monitor Model RAM-1 and the MIE MINIRAM Personal Monitor Model PDM-3.

DESCRIPTION OF EQUIPMENT

The RAM-1 and the MINIRAM are portable, self-contained aerosol monitors. Their detection system is based on the detection of near-forward, scattered, near-infrared radiation.

The RAM-1 uses a pump to draw air into the unit to the sensors. It uses an air screen to prevent contamination of the sensors. The MINIRAM does not require a pump. Air passes through the sensing volume by convection, circulation, ventilation and personnel motion. The sensors are also in direct contact with the environment. Thus, there is a chance the sensors may get covered with dust. The MINIRAM sensors require cleaning on a regular basis.

Both units indicate the aerosol concentration in milligrams per cubic meter (mg/m^3). Both use a digital display. The MINIRAM's displayed reading is updated every 10 seconds. The RAM-1 has a variable time display.

The RAM-1 has a range of 0.000–200.0 mg/m^3 . The readout range is selected by the operator. The MINIRAM normally operates in the 0.00 to 9.99 mg/m^3 range. Whenever a 10-second concentration exceeds 9.99 mg/m^3 , the MINIRAM automatically switches to the 0.0 to 99.9 mg/m^3 range and remains in that range as long as the measured 10-second concentration exceeds 9.99 mg/m^3 . Otherwise the MINIRAM reverts to its lower range display.

The RAM-1 only displays real-time concentrations. A output device can be connected to record data. The MINIRAM can store data for later output and for TWA calculations. Thus, it can be used as a direct-reading monitor and a dosimeter.

Both instruments can be powered by internal batteries or an external AC source.

It is important to remember that these instrument only give total or respirable quantities of aerosols. They do not give the composition of the aerosol. To determine the composition of the aerosol, a sample must be taken and analyzed. Refer to the *Air Sample Collection* section of the course manual.

MIE MINIRAM PERSONAL MONITOR MODEL PDM-3

Before using the instrument without the charger, charge the MINIRAM for a minimum of 8 hours.

Initial Condition

- Blank display—Indicates that the MINIRAM has not been in the measurement mode for 48 hours or more, and is in the minimum power off mode.
- "OFF" display—MINIRAM has been in the off mode for less than 48 hours.
- Concentration display that changes or "blinks" once every 10 seconds: the MINIRAM is in the measurement mode.

Controls (refer to Figure 1)

"MEAS" When this button is pressed, the measurement mode will start. Once the MEAS mode has been entered, this sequence can only be interrupted by pressing OFF. Pressing ZERO, TWA, SA, TIME, or ID# only affects the display during the time the keys are pressed.

The readout will first display "GO" (or "CGO" if TIME is also pressed) followed by the last concentration reading or ".00."

Approximately 36 seconds later, the first new 10-second-averaged concentration reading is displayed. The reading will be updated and displayed every 10 seconds.

The MINIRAM will now run in the measurement mode for 500 minutes (8 hours and 20 minutes), after which time it will stop, displaying the OFF reading. It will retain in storage the concentration average and elapsed time information.

If both MEAS and TIME are pressed at the same time (press TIME first and while depressing it actuate MEAS) the MINIRAM will display "CGO," and will then operate as above (i.e., pressing MEAS only), except that after the first 8.3-hour run, it will restart automatically and continue to measure for an indefinite number of 8.3-hour runs, (with the battery charger) until the OFF key is pressed, or until the batteries are exhausted. Concentration averages and timing information for the last seven 8.3-hour runs will remain in storage at any give time.

"ZERO" When instrument displays "OFF," pressing this button initiates the ZERO procedure.

"TIME" During the measurement mode, if TIME is pressed, the display will show the elapsed time, in minutes, from the start to the last measurement run. The MINIRAM will automatically return to concentration display after the TIME key is released.

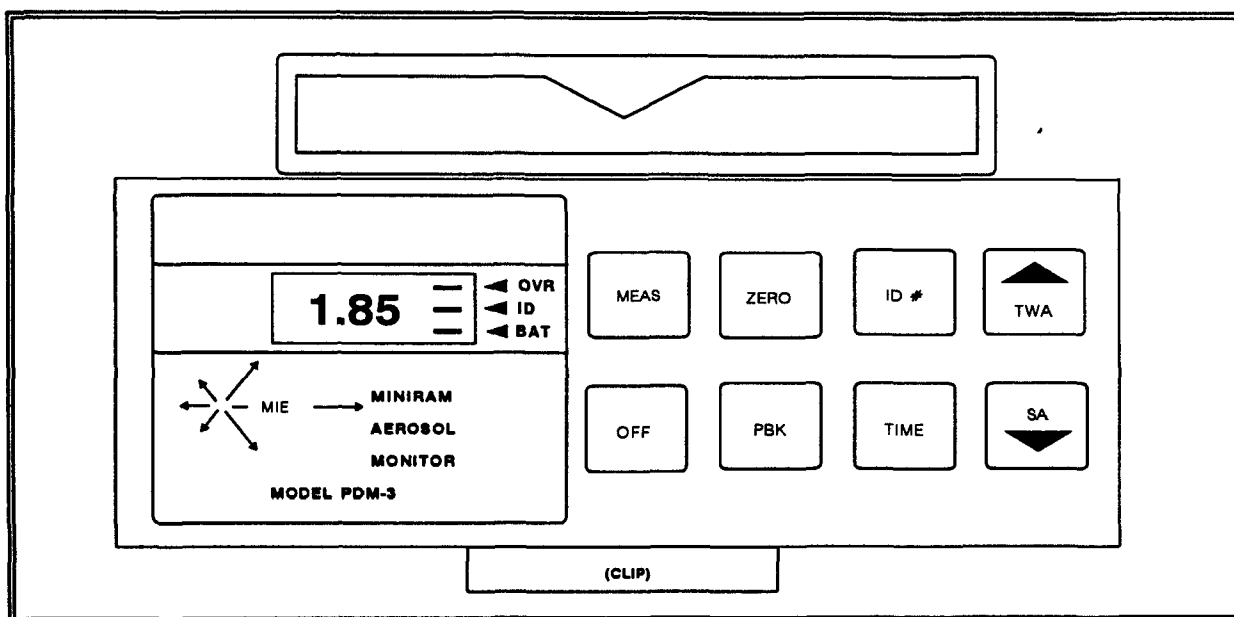


FIGURE 1. FRONT PANEL OF MINIRAM

- "TWA"** During the measurement mode, if the time-weighted average (TWA) is pressed, the display will indicate the average concentration in milligrams per cubic meter (mg/m^3) up to that instant, from the start of the last run. The value of TWA is updated every 10 seconds. After releasing the TWA key, the MINIRAM display returns to the 10-second concentration display.
- "SA"** During the measurement mode, pressing SA (Shift-Average) will provide a display of the aerosol concentration, up to that moment, averaged over an 8-hour shift period.
- "PBK"** With the MINIRAM in the off mode, the stored information can be played back by pressing PBK (Play Back). Pressing the PBK key for more than 1 second will cause stored data to be automatically played back through the MINIRAM display: First, the identification number is displayed with the ID indicator bar on; next the shift or run number (i.e., 7 through 1, starting with the last run) is shown (with the OVR indicator bar on as identification); followed by the sampling time in minutes, for that run; followed by the off-time between the last and next run (in tens of minutes; finally, the average in mg/m^3 . This sequence is repeated seven times. An average reading of 9.99 indicates that a significant overload condition occurred during that run. The total time required for the complete automatic playback on the MINIRAM display is approximately 70 seconds.
- "OFF"** When this key is pressed, the MINIRAM will discontinue whatever mode is underway displaying "GCA" followed by the display segments check ("8.8.8=") and finally "OFF." The MINIRAM will then remain in this reduced power condition (displaying "OFF").

Display

During the measurement mode, the display indicates the present concentration in mg/m^3 . If one of the function buttons is pushed, the information indicated in **CONTROLS** is displayed. If a bar appears in the display, the bar's location indicates one or more of the following:

- "OVR" The concentration exceeds the range of the instrument or there is an overload due to reflected line (e.g., sunlight).
- "ID" This indicates that the ID number is being displayed and not a concentration.
- "BAT" This indicates a low battery.

Zero Procedure

1. Zeroing must be performed in a clean-air environment. This can be done by using a clean room or clean-bench, flowing clean air through the sensing chamber, or using an air-conditioned office (without smokers).
2. Press OFF and wait until the display indicates "OFF."
3. Depress the ZERO button. Wait until the display again indicates "OFF." The average of four consecutive 10-second zero level measurements will then be stored by the MINIRAM as the new ZERO reference value. The ZERO reference value will be subtracted from subsequent readings. When operating the MINIRAM in high particle concentration environments ($>5 \text{ mg}/\text{m}^3$) the zero value should be updated approximately every 8 hours. At aerosol concentrations below approximately $1 \text{ mg}/\text{m}^3$ this update may only be required once a week.

Start Measurement Cycle

4. Place the MINIRAM in the area to be monitored. The instrument should be placed vertically (i.e., display/control panel facing upwards) by clipping it to a belt, shoulder strap, etc.
5. If the MINIRAM shows a blanked display, press OFF and wait until the display reads "OFF" (approximately 5 seconds after pressing OFF) before pressing MEAS to initiate measurement cycle.
6. If the MINIRAM shows "OFF," press MEAS directly to initiate measurement cycle (there is no need to press OFF first, in this case).
7. Press MEAS.
8. Observe the readings for 1 minute to verify that the levels change every 10 seconds and that the OVR bar is not displayed.

9. Avoid objects being placed in the sensing chamber. Also avoid direct sunlight scattering in the sensing chamber.
10. At the end of the sampling period, press "TIME." Record the sample duration in **Table 1**.
11. Press the TWA button. Record the reading in **Table 1**.
12. Press OFF.

TABLE 1	
INFORMATION	RESULTS
INSTRUMENT SERIAL #	
START TIME	
TWA	
SHIFT AVERAGE (SA)	
OFF TIME	

MIE REAL-TIME AEROSOL MONITOR MODEL RAM-1

In the following procedure, the numbered buttons, displays, and switches refer to the illustration of the RAM-1 in **Figures 2 and 3**.

Startup

1. Lift up protective cover of control panel.
2. Place selector switch (1) in battery (BATT) position.
3. Place inlet valve (2) in CLEAR position (horizontal).
4. Replace sealed cap on inlet valve with the restrictor orifice.
5. Switch instrument on (3) and check battery voltage. The digital readout (4) should indicate between 6.0 and 6.6 volts. If not, inform the instructor. The reading should be identified by a display of VDC (volts DC). Low battery voltage is indicated by a flashing "VDC" on the right-hand side of the display, whenever the selector switch is not in the BAT position.

Zeroing

6. Check that the inlet valve is in the CLEAR position (horizontal). Place the selector switch in the 0-200 position. The letter "m" should appear to the right of the display reading, indicating that the instrument is set to read concentration measurements.
7. Place the time constant switch (5) in the 2-second position.
8. Allow 1 minute for instrument to stabilize (warm-up). **IMPORTANT!**
9. If necessary, lift the cover over the ZERO control (6) and adjust the control until a reading of 00.0 is obtained.
10. Switch the selector to the 0-20 position and repeat step #9.
11. Switch the selector to the 0-2 position and repeat step #9. Readings may fluctuate. Try to obtain an average reading of 0 ± 0.005 .

Secondary Calibration

12. Keep inlet valve in its CLEAR position.
13. Set the range selector to the 0-20 position.
14. Unlock the hinged flow chamber cover and place in the horizontal position.

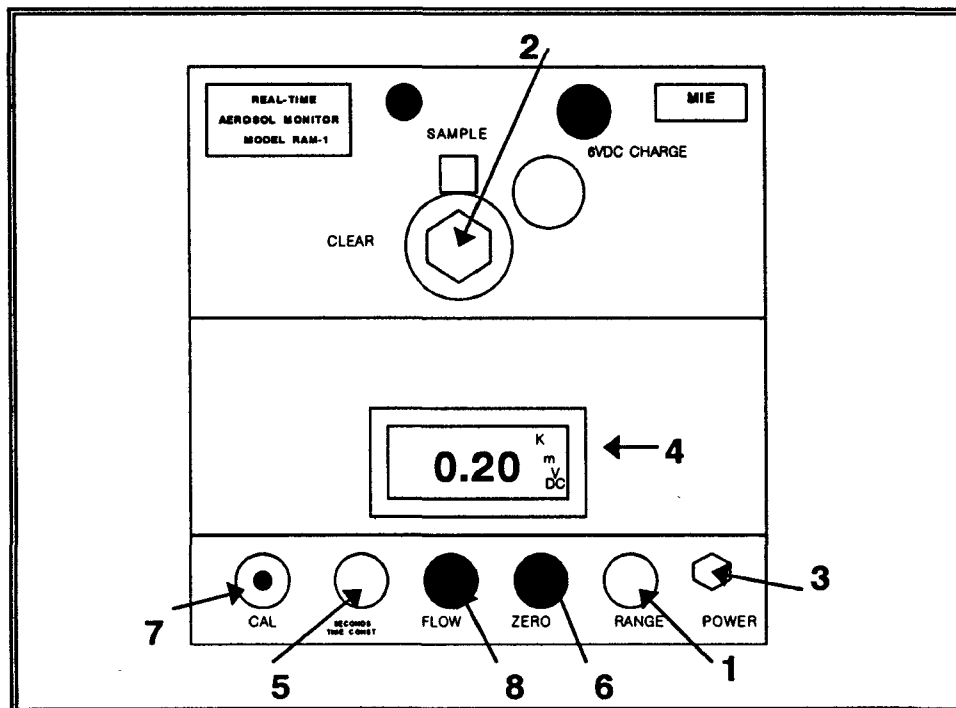


FIGURE 2. RAM-1 TOP VIEW

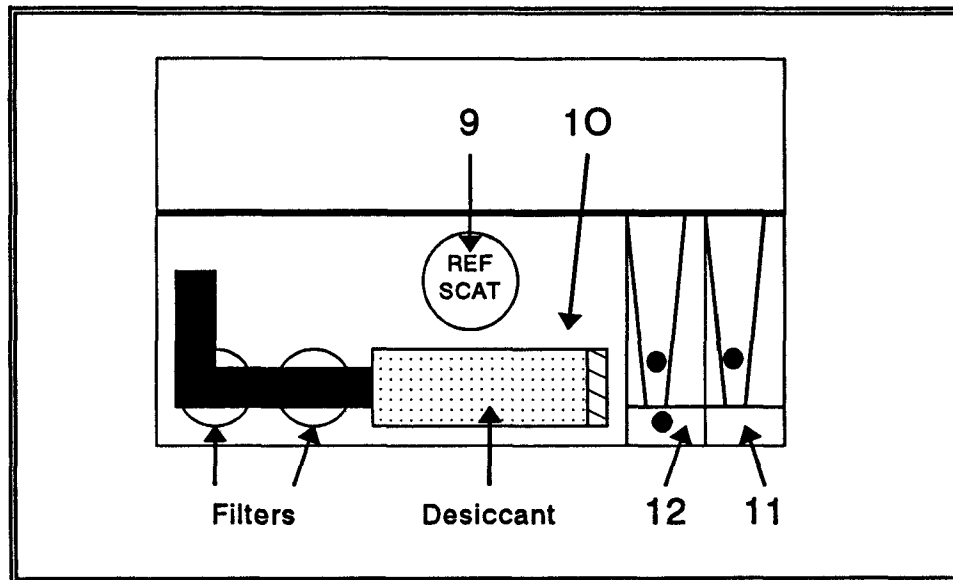


FIGURE 3. RAM-1 SIDE VIEW

15. Push the reference scatterer knob (REF SCAT) (9) inward until a positive stop is detected. The pump will automatically shut off. The letter "K" should be flashing in the upper right side of the display. Allow the reading to stabilize for 30 seconds.
16. See if the instrument reading corresponds with the factory calibration label (10) by the (REF SCAT).
17. If the indicated readings differ by more than 5%, adjust the CAL control (7) as required. The CAL control has a lock that must be disengaged before attempting to turn the knob. Allow to stabilize and repeat if required. Relock the CAL control.
18. Pull the REF SCAT back out.
19. Close the flow chamber cover and tighten thumb-screws.

Measurement Procedures

20. Switch RAM on.
21. Select measurement range (usually the 0-20 position).
22. Select desired time constant (usually 2 seconds).
23. Place inlet valve in SAMPLE position (vertical downwards).
24. Check the flow meters. The TOTAL (11) should read about 2 and the PURGE (12) should read about 0.2 (or 10% of TOTAL). Adjust the total flow rate with the flow adjust screw

(8). Adjust the purge flow with the black valve on the rotameter. If the rotameter is pegged, check that the inlet valve is in the SAMPLE position.

25. Measure the aerosol concentrations in the areas designated by the instructor.
26. If the aerosol concentration exceeds the maximum selected range, the RAM-1 will indicate 1 with all zeros blanked out. If this occurs, change the range selection to higher ranges as needed.
27. Check and update zero periodically.
28. **BEFORE SHUTTING OFF THE RAM-1, CLOSE THE INLET VALVE (CLEAR POSITION) AND OPERATE FOR 3 MINUTES TO ALLOW PURGING OF THE DUSTS INSIDE THE OPTICAL CAVITY.**
29. When sampling and purging is complete, turn the instrument OFF.

QUESTIONS

1. Discuss the advantages and disadvantages of these instruments.

2. Analysis of the site soil or analysis of a filter sample shows the soil composition to be 5% lead. You obtain a reading of 1.35 mg/m^3 with the RAM-1. Determine (approximately) the airborne lead concentration based on your reading.

3. The action level for lead at your site has been determined to be $1.5 \text{ } \mu\text{g/m}^3$. The soil on the site is 5% lead. a) What instrument reading would be equivalent to your lead action level?
b) What reading would you be concerned about if your action level was $50 \text{ } \mu\text{g/m}^3$?

a)

b)

EXERCISE #7

Gas Chromatography - PID

OBJECTIVE

The student will learn the basic operation of the Photovac 10S50 portable gas chromatograph and analyze several air samples.

PROCEDURE

The instructor will describe and illustrate the different parts of the Photovac 10S50 and their functions. Since the 10S50 needs a certain amount of warm-up time, the student will not be able to go through start-up of the instrument. After the introduction, students will run a calibration standard and an unknown sample. Students will also collect an air bag sample and analyze it.

OPERATING INSTRUCTIONS FOR THE PHOTOVAC 10S50 (CAPILLARY COLUMN OPERATION)

Preparation for Use

Refer to the Photovac 10S50 instrument panel and **Figure 1.**

Recharge the Carrier Gas

1. Connect the fill line for the Photovac 10S50 to a cylinder of "Ultra-Zero Air" (contents <0.1 ppm hydrocarbon).
2. Attach the "Quick-Connect" from the fill line to the REFILL receptacle on the upper right-hand corner of the Photovac 10S50.
3. Turn on the cylinder and rotate the valve for the fill line so that the pointed end points toward the cylinder. Be sure not to stand directly in front of the regulator.
4. The reservoir in the instrument will be filled to the maximum pressure of the supply cylinder. The pressure is indicated on the CONTENTS gauge on the upper left of the instrument panel. (The maximum pressure at which the instrument can be filled is 1750 psi.) The delivery pressure is indicated on the DELIVERY gauge. This pressure should be 40 psi. When the reservoir is filled, the excess air will be expelled at the fritted outlet on the supply cylinder regulator. This will be indicated by a "hissing" sound. Turn off the supply cylinder valve and then turn off the valve on the fill line.
5. Disconnect the fill line.

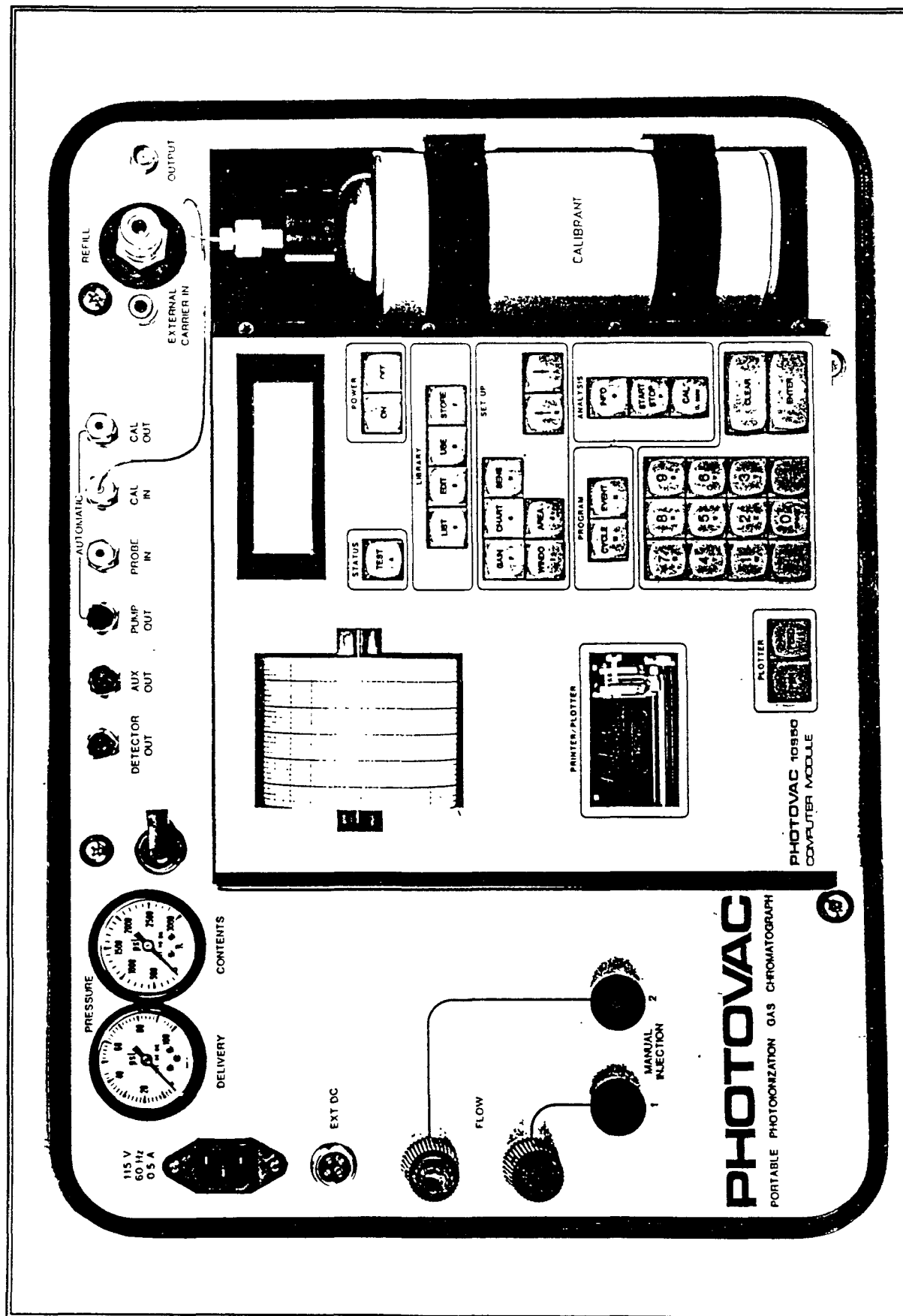


FIGURE 1. PHOTOVAC 10S50 INSTRUMENT PANEL

Source: *Photovac 10S50 Operating Manual*, Photovac Incorporated.

Set the Carrier Gas Flow Rate

6. The pieces of tubing to the flow meter are attached to the ports on the instrument panel.
7. Attach the line on the left side of the meter to the DETECTOR OUT port.
8. Attach the line on the right side of the meter to the needle valve marked AUX OUT.
9. Connections should be secured with a 7/16 inch open-ended wrench (1/4 turn past tight).
10. Adjust the flow rates on the meter.
 - a. If the instrument is being set up to stabilize overnight, set the DETECTOR OUT FLOW using the red FLOW adjustment knob on the left side of the panel to 5 ml/min. *Note:* Turn knob clockwise to decrease the flow or counterclockwise to increase the flow. Set AUX OUT flow using the needle valve to 0 ml/min. Allow to stabilize overnight.
 - b. If the instrument is being set up for analysis, set the DETECTOR OUT flow using the red FLOW adjustment knob to 10 ml/min. Set AUX OUT flow using the needle valve to 10 ml/min.

Activate the Power Source

11. When the instrument is ready for use, attach the power cord for the instrument to the 3-prong socket in the upper left-hand corner of the instrument. The cord is then plugged into an AC outlet.
12. Press the ON key. The instrument will respond with "LAMP NOT READY, PLEASE WAIT."
13. Wait until the display reads "READY ENTER COMMAND."

Set Instrument Parameters

14. Locate the LIBRARY block and press the USE key. The instrument will respond with "LIBRARY IN USE?" There are four libraries numbered 1 to 4. Library #1 is the default. We will use #1 for this exercise. Press the 1 key and then the ENTER key.
15. The instrument will prompt for "DAY" (1-31). Press the appropriate value for the day of the month and then press the ENTER key.

16. The following information is entered in the same manner:
 - a. MONTH (1-12), then press ENTER
 - b. YEAR (e.g., 1993), then press ENTER
 - c. HOUR (0-23), then press ENTER
 - d. MINUTE (0-59), then press ENTER.
17. The instrument will read: "READY ENTER COMMAND."

Obtain a Status Report

18. Locate the STATUS block and press the TEST key. The instrument will respond with "FUNCTION, USE < >, STATUS REPORT." Respond by pressing the ENTER key.
19. The instrument will print a status report containing the following information:
 - a. Current field date and time.
 - b. Field: The # represents the detector field in volts/10.
 - c. Power: The # indicates the current lamp consumption at mA/10.
 - d. EVENT settings show the ON and OFF times of the 10S50 sample pump and solenoid valves. The instructors will have set the following EVENT values:

SAMPLE	(EVENT #1)	0	10
CAL	(EVENT #2)	0	0
EVENT #3		10	60*
EVENT #4		0	10
EVENT #5		13	60*
EVENT #6		0	0
EVENT #7		0	0
EVENT #8		0	0

* Some units may have a longer time (e.g., 80) instead.

20. Allow the instrument to stabilize for approximately 45 minutes. The instrument has been stabilizing prior to the exercise so we may continue.

Select the Analytical Parameters

21. Locate the SETUP block on the instrument panel.

22. Press the GAIN key. The gain controls the amplification from the detector. The default value is "2" For higher values, press the UP ARROW key until the desire value appears. For this exercise, choose a gain setting of "5" and then press ENTER.
23. Press the CHART key. The instrument will respond with "CHART ON" or some other readout. "CHART ON" means the chromatogram will be displayed along with identification information and some instrument settings (e.g., GAIN). "CHART OFF" means that the chromatogram will not be displayed, but identification information and some instrument settings will be displayed. "CHART ON WITH BASELINE" prints out the same information as "CHART ON," but also shows the baseline the instrument uses to calculate peak area. "CHART ON WITH SETUP" prints out the same information as "CHART ON WITH BASELINE" but also includes the setup information (e.g., SENS, WINDO). Use the UP ARROW or DOWN ARROW key until "CHART ON WITH SETUP" is displayed. Press ENTER. The next display is the chart speed. The default is 0.1 cm/min. Press the UP ARROW key until 0.5 appears. Press ENTER.
24. Press the SENS key. The key controls the instrument integrator. The following settings specify the minimum response that will be recognized as a peak on the chromatogram.

SLOPE UP; Use the arrow keys to display 18 mv. Then ENTER.
SLOPE DOWN; Use the arrow keys to display 16 mv. Then ENTER.
PW (Peak Width) at 4 minutes; Use the arrow keys to display 6 (sec). Then ENTER.
25. Press the WINDO key. This key adjusts the 10S50's tolerance to retention time drift. A peak must be within a specified percentage of a stored retention to be identified as that chemical by the instrument. Choose a value of "10" (i.e., 10%) and press ENTER.
26. Press the AREA key. This key sets a peak size threshold. All peaks smaller than the AREA setting are deleted from the "PEAK INFORMATION" listing at the end of the analysis. (However, these peaks will still be numbered on the chromatogram.) Set the minimum area at "50" and ENTER.
27. Locate the PROGRAM block and press the CYCLE key. The instrument will prompt for the following information:
 - a. "TIMER DELAY." This setting determines the delay in time from when the START/STOP key is pressed and when the instrument will start looking for peaks. Choose "10" seconds and ENTER.
 - b. "ANALYSIS TIME." The duration of the analysis is dependent upon the types of compounds that are being considered for analysis. Select an analysis time of 600 seconds for this exercise. Press ENTER.
 - c. "CYCLE TIME." These times refer to the mode for continuous monitoring. This mode will not be used in this exercise. Choose "0" min and ENTER. The instrument will respond with "CYCLING DISABLED, COUNTERS RESET."

Establish a Baseline for the Chromatogram

28. The baseline will be established by analyzing a bag of ultrazero air (a BLANK sample). Connect the "zero" bag to the PROBE IN CONNECTION. Open the bag. To initiate the analysis, locate the ANALYSIS block and press the START/STOP key. The instrument will respond: "PROBE IN?" Press ENTER.
29. As soon as the ENTER key is pressed, the pump should start and run 10 seconds. If the pump does not start, inform the instructor.
30. Allow the chromatogram to be generated. Examine the baseline for significant drift or extraneous peaks. The baseline should be flat and smooth. Repeat this procedure until a stable (zero slope) baseline is obtained or until the instructor informs you to stop.

Analyze the Standard Gas Bag

31. For this exercise, we will use the chemicals in Library 1 as the standard. The "standard gas bag" will be used to check retention times and allow you to see a chromatogram.
32. Connect the "sample bag" bag to the PROBE IN CONNECTION. Open the bag. To initiate the analysis, locate the ANALYSIS block and press the START/STOP key. The instrument will respond: "PROBE IN?" Press ENTER.
33. Allow the chromatogram to be generated. This will take 600 seconds (the analysis time we selected).
34. At the end of the chromatogram, the printout will print the peak numbers that exceed the area setting, the identity of the peaks (if they match the retention times in the library) and the concentration of identified peaks. Consult the instructor for the expected results. If the peaks are not properly identified, a update adjustment or calibration run will be necessary. See *Updating the Library* and *Creating a Library* before analyzing any samples.

Updating the Library

35. If library does not recognize all of chemicals in the standard, the library should be updated.
36. Select a peak (one that you can identify) as a reference point. Press the CAL key. The instrument will request a plotter peak number. Enter the peak number you have selected. Press ENTER.
37. The instrument will request an ID number. Look at the previous printout of the library. Enter the number for the chemical that matches the peak. Press ENTER.
38. The instrument will request a concentration. Enter the concentration of the compound corresponding to the plotter peak used. Press ENTER.

39. The plotter will print out a listing of the peaks from the recent analysis and hopefully identify the peaks using retention times and peak areas adjusted by the reference peak.

Creating a Library

40. Connect the "sample bag" bag to the PROBE IN CONNECTION. Open the bag. To initiate the analysis, locate the ANALYSIS block and press the START/STOP key. The instrument will respond: "PROBE IN?" Press ENTER.
41. Allow the chromatogram to be generated.
42. The information from the chromatogram must be stored in the library **IMMEDIATELY FOLLOWING** completion of the analysis. **IF ANY OTHER KEY IS PRESSED BEFORE STEP #43, THE STANDARD CHROMATOGRAM WILL NEED TO BE GENERATED AGAIN TO UTILIZE ITS INFORMATION.**
43. Locate the LIBRARY block and press the STORE key. The instrument will prompt for:
- PLOTTER PEAK #: Select the number of the first peak of interest on the chromatogram and press ENTER.
 - CHEMICAL NAME: Select the name of the compound using the alpha-numeric keys on the key pad. After the name is complete press ENTER. (To change to numbers, press the CAL (NUM) key. This key must also be pressed again to return to letters.)
 - CONCENTRATION (in ppm): Select the actual concentration of the compound in ppm. Press ENTER.
 - LIMIT VALUE: The limit value is the concentration, which if exceeded, causes the plotter to print the concentration value in red instead of green. This "flags" the compound. Press ENTER. This will instruct the instrument to use 0 as the limit, so all concentrations will be in red.
 - This procedure is repeated for subsequent compounds in the chromatogram by pressing the STORE key and following steps a through d.
 - To check the contents of the library, press CAL. The instrument prompts with "PLOTTER PEAK #?" ENTER TO RELIST. Press ENTER. The plotter will print out the added compounds and their concentrations.

Note: DO NOT enter a value here or the instrument will prompt for recalibration.

Editing the Library

44. A compound can be added to the library after any analysis. A compound can be added to the library even if it is already in the library. However, the new entry will not replace the old entry. There will be two listings for the compound.
45. To remove a compound from the library, first press EDIT.
46. The instrument will prompt with "ID NUMBER." Enter the ID number for the compound in the library. The instrument will list the name of the compound.
47. Press CLEAR, then press ENTER. The instrument will respond with "COMPOUND REMOVED FROM LIBRARY."
48. Repeat for any additional compounds.

Analyze the Samples

49. Using steps 31 through 34, analyze the unknown samples provided.
50. **IMPORTANT! DO NOT USE ANY GAS BAGS**, other than those provided by the instructors, **WITHOUT THE PERMISSION OF THE INSTRUCTORS**. High concentrations can contaminate the column.

Exercise Shutdown

51. When sample analysis is complete, do **not** turn the instrument off.

Shutdown (Overnight)

52. Generate a chromatogram of the baseline to ensure that there are no residual materials in the column.
53. Locate the POWER block and press the OFF key. The instrument will respond with "ENTER=OFF." Press ENTER.
54. Adjust the flow rate for the DETECTOR OUT to 5 ml/min. Make sure the air supply is adequate for overnight operation.

Shutdown (Long Term)

55. Follow the same steps as in *Shutdown (Overnight)*.
56. Disconnect the power cord from the AC source.
57. Before shipping, drain the carrier gas supply reservoir.

EXERCISE #8

Sampling Pumps and Collection Media

OBJECTIVE

Participants will assemble a variety of sampling trains and calibrate them using an electronic bubble meter. They will also check the pump's flow compensator. The students will review sample results and evaluate exposure levels.

PROCEDURE

The class will be divided into teams. Each team will be given a Gilian® HFS 113UT air sampling pump.

The instructor will explain the operation of the Gilian® HFS 113UT sampling pump.

The students will calibrate the Gilian® sampling pump using different media and an electronic bubble meter.

Demonstration: Calibration of Gilian® pump with filter media using a bubble-meter (page 82).

Station 1: Calibration of Gilian® pump with filter media and with sorbent tube media using an electronic bubble-meter (page 85).

Station 2: Check flow compensator of Gilian® pump using Gilian® Calibrator Pack (page 92).

Note: The procedures shown here apply only to this specific sampling pump. The actual procedures for other pumps may vary. Consult the manufacturer's instructions for the pump you use in the field.

After calibrating their sampling pump, the students will look at sampling results and calculate concentration levels (page 94).

OPERATION AND CONTROLS OF GILIAN® HFS 113UT SAMPLER

The Gilian® HFS 113UT sampler is a lightweight, battery-powered air sampling pump. It has a high flow range—0.5–3.5 liters per minute (lpm) and a low flow range—1–500 cubic centimeters per minute (cc/min). It has a built-in timer to shut off the pump after a preset time. The pump is equipped with a flow compensation control that provides for constant air flow from the pump at any preset flow within its performance limits.

The following is a brief description of the controls for operating the pump.

1. **ON - OFF Switch.** This turns pump on and off.
2. **PRESS TO TEST Button.** When the pump is on, pressing this button gives battery power indication and also gives an elapsed time indication in TIME MIN window. If the pump has stopped because of end of time or fault, pressing this button before turning the pump off gives the pump run time.
3. **PROGRAMMABLE TIMER.** Allows operator to set sample time from 10 minutes to 990 minutes in ten minute increments. Note: The pump will not start if the timer is set at 00. When setting the timer, the dials should be turned clockwise past the zero point several times.
4. **BAT CK - Battery Check.** Turn on pump and press the test button. If the BAT CK illuminates, then the battery is fully charged.
5. **FAULT.** This light illuminates and the pump shuts down, if the pump is unable to maintain the preset flow rate.
6. **TIME OUT.** This illuminates when the pump stops at the programmed time.
7. **FLOW ADJUST.** Turning clockwise increases flowing; turning counterclockwise decreases flow.
8. **PUMP INLET.** Inlet to pump. Point where tubing and sampling media are connected.
9. **DISCHARGE AIR CAP SCREW.** Removing this screw provides access to discharge port. Inserting adapter allows pump to be used to fill gas bag.
10. **REGULATOR SHUTOFF CAP SCREW.** Removing screw provides access to the regulator shutoff valve. The valve is used to switch the pump from high to low flow.
11. **FLOW METER.** Rotameter used to show flow. Read center of flow meter ball. Reading is $\pm 20\%$ of true flow.

DEMONSTRATION: CALIBRATING GILIAN® PUMP USING A BUBBLE METER

During this demonstration, the Gilian® pump will be calibrated for lead particulate sampling. The NIOSH analytical method for lead sampling (Method 7802) uses a 0.8- μ cellulose ester membrane filter. The appropriate filter is provided with the calibration setup. The recommended flow rate is between 1 and 4 liters per minute. For this exercise, calibrate the pump to about 2 liters per minute (between 1.8 and 2.2 is okay). The important thing is to know the actual flow rate of your pump. Step 4 explains how to convert the pump to the high flow range.

BUBBLE METER PREPARATION

During this step, the Gilian® pump will be calibrated using an inverted buret and soap bubbles (bubble meter). This method is considered a primary calibration method because the buret volume and the stopwatch time can be traced to an original standard.

1. Check the calibration set-up (Figure 1). It should contain all the parts shown in the figure. If not, inform the instructor.
2. Wet the buret by pouring a small amount of soap solution into it, and tilting it up and down while rotating. Seal the outlet end to prevent soap from getting into the tubing.
3. Reassemble the calibration setup.

PUMP PREPARATION

4. Remove the Pump Regulator Shutoff Protective Cap. Turn the exposed screw clockwise until closed - **DO NOT OVERTIGHTEN**. Replace the protective cap.
5. Using the small screwdriver provided, set the programmable timer to 240 minutes. Turn each dial clockwise past zero several times before setting the time.
6. Turn the pump on.
7. Press the test button. The BAT CK light should illuminate or flicker.

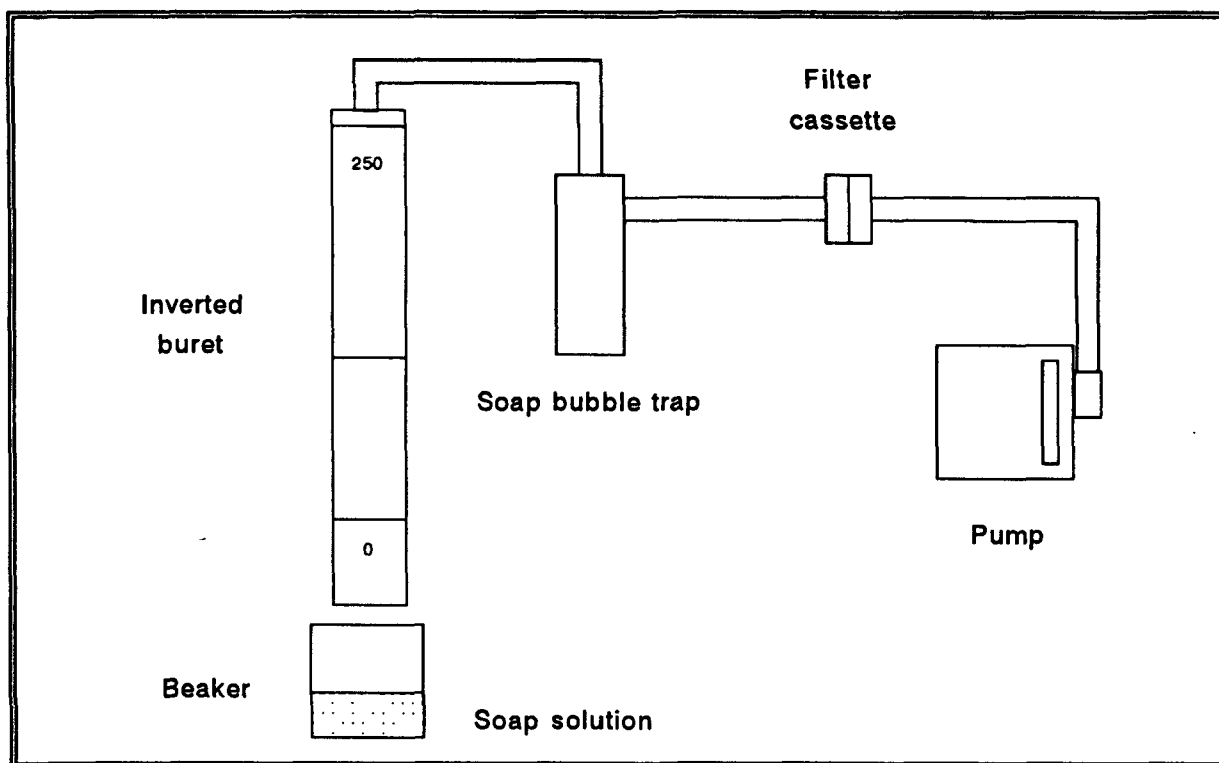


FIGURE 1. BUBBLE METER CALIBRATION SETUP

8. Connect the tubing and filter to the pump. The filter pad should be nearest to the pump. Connect the filter to the tubing attached to the bubble meter.
9. Start a bubble in the buret by briefly touching the surface of the soap solution to the open end of the buret. When the bubble passes the "0" mark, start the stopwatch. Stop the stopwatch when the bubble passes the "250" mark.
10. Flow rate is calculated using the following formula:

$$FLOW RATE (L/min) = \frac{VOLUME TRAVELED (ml)}{TIME (sec) \times BUBBLE TRAVELED} \times \frac{60 \text{ sec/min}}{1000 \text{ ml/L}}$$

11. Use *Data Sheet 1* to record your calibration data.

DATA SHEET 1

1. PUMP MFG. AND MODEL: _____
2. PUMP IDENTIFICATION #: _____
3. BATTERY CHECK _____ YES _____ NO
4. LOCATION/TEMP & BAROMETRIC PRESSURE: _____

5. CALIBRATION METHOD: _____
6. FLOW RATE CALCULATIONS

$$FLOW\ RATE\ (L/min) = \frac{VOLUME\ TRAVELED\ (ml)}{TIME\ (seconds)} \times \frac{60\ seconds/minute}{1000\ ml/L}$$

VOLUME TRAVELED	TIME	FLOW RATE	AVERAGE
_____	_____	_____	
	_____	_____	
	_____	_____	_____
	_____	_____	_____
	_____	_____	_____

(Continue calibration until three consecutive flow rates are within $\pm 5\%$ of the average.)

7. FLOW RATE: _____
8. ROTAMETER SETTING: _____
9. SIGNATURE: _____
10. DATE/TIME: _____

STATION 1: CALIBRATING THE GILIAN® PUMP USING AN ELECTRONIC BUBBLE METER

The Gilibrator™ is an example of an electronic bubble meter. It is a primary calibration method. A fixed volume is located in the center tube of the flow cell. A quartz-controlled timer is used to measure the travel time for a bubble between two sensors. A microprocessor calculates the volume per unit time. The flow rate is displayed in cc/min for this model.

The control unit will display the actual flow for each sample and will accumulate and average each successive reading.

AVERAGE - To display average and number of samples, depress and hold the AVERAGE BUTTON. Releasing the button will display the last flow reading. Pressing the button again and the number of reading made will be displayed. Release and the display returns to the last flow reading.

DELETE - To delete obvious false readings, push the DELETE BUTTON. This will delete the false information from the average and reset the average and sample number back to the previous reading.

RESET - To reinitiate the sequence, hit the RESET BUTTON. This will zero out all sample and average registers within the Control Unit. The Reset Button is also used if a malformed bubble is generated and has not been subtracted from the average by use of the DELETE Function.

GILIBRATOR™ PREPARATION

1. Remove the storage tubing between the air inlet and air outlet of the Gilibrator™. Pour a small amount of soap through the BOTTOM AIR INLET of the Gilibrator™ to thoroughly cover the bottom of the flow cell. Skip this step if already done.
2. Connect a pump to the UPPER AIR OUTLET using the piece of tubing provided.
3. Turn the regulator shutoff valve on the Gilian® pump (the screw under the brass cap on top of the pump) fully clockwise. **DO NOT OVERTIGHTEN**. Turn on the pump. Initiate soap film up the flow tube by rapidly pressing the CALIBRATOR BUTTON down and releasing. Repeat this procedure until a bubble travels the length of the tube without breaking.
4. After the Flow Tube walls have been "primed" (Step 3), turn on the Power switch of the Control Unit. Wait approximately 10 seconds while the system runs through its check sequence. The RUN LED will light at this time as well and a LO Battery indication and a series of five dashes will be displayed on the LCD Readout. Do not operate the Gilibrator until the RUN LED signal extinguishes. Ready operation is indicated by a series of 4 dashes.
5. Calibrate the pump using the following steps.

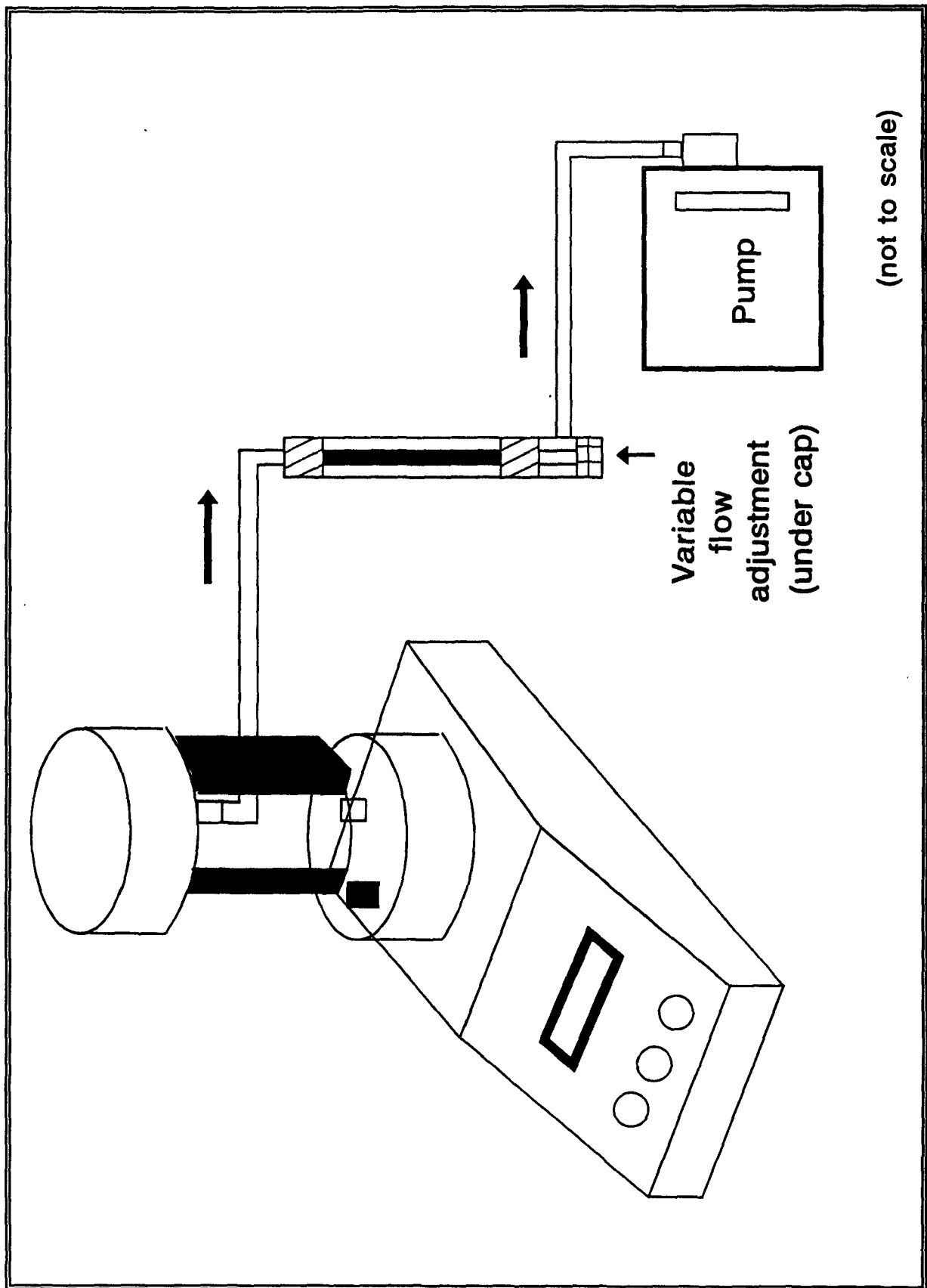


FIGURE 2. SAMPLE PUMP AND GILBRATOR™ SETUP

HIGH-FLOW CALIBRATION (1 to 4 liters/min)

6. Insert a filter cassette and tubing between the pump and the tubing attached to the calibrator.
7. Turn on the pump.
8. Depress the BUBBLE INITIATE BUTTON and hold to initiate 1 bubble up the Flow Tube. Release the button to initiate a second bubble up the flow tube. At low flow rates, the button can be depressed and released quickly for a single bubble.
9. After a bubble completes passage up the FLOW TUBE, a flow reading will appear on the LCD display.
10. Adjust the flow rate (pump adjustment) and repeat Steps 8 and 9 until you have a flow rate of about 2 liter/min.
11. RESET the calibrator.
12. Repeat Steps 8 and 9 until you have three consecutive readings that are within 5% of their average.
13. If the first set of 3 readings are not within the 5% allowable range, press the RESET Button. Then repeat step 15 for 3 more readings. The Reset Button is used because the Gilibrator™ averages all readings and not just the last 3. If the first reading was outside the 5% limits, you wouldn't know till readings 2 and 3 were made. Readings 2, 3, and 4 may be within the limits, but you would not be able to check because reading 1 would still be in the average.
14. If a bubble breaks before completing the timing sequence, timing will continue until another bubble is generated to trip the second sensor. This will cause an erroneous reading and should be subtracted from the average by hitting the Delete Button.
15. Record each run, the average, and other pertinent information on *Data Sheet 2*

LOW-FLOW CALIBRATION (20–500 cc/min)

16. Connect the pump to the Gilibrator™ with a piece of tubing.
17. Turn on the pump.
18. Using the steps above, adjust the pump to about 1 liter/min.
19. Open the regulator shutoff valve (located under the brass cap on top of the pump) by turning it counterclockwise at least 5 turns.

20. Put a carbon tube in the sorbent tube holder. Connect the inlet side of the holder to the upper outlet of the calibrator (Figure 2). Connect the outlet side of the holder to the pump inlet.
21. Depress the Bubble Initiate Button to initiate a bubble up the Flow Tube. After the bubble completes passage up the Flow Tube, a flow reading will appear on the LCD display.
22. Remove the knurled cap from the end of the tube holder. Repeat Step 21 and adjust the variable flow controller screw to get the desired flow rate. For this exercise, try to obtain about 50 cc/min.
23. RESET the calibrator after each run if not at the desired flowrate. Reset after each flow adjustment. Do three runs at the desired flow rate. Record your results on *Data Sheet 3*.

SHUTDOWN

24. Turn off the pump.
25. Turn off the calibrator.
26. Remove the air sampler from the Gilibrator™. Replace the Storage Tubing between the upper and lower cell chambers.
27. Disconnect the pump from the tube holder.
28. Replace the cap on the tube holder.

DATA SHEET 2

1. PUMP MFG. AND MODEL: _____
PUMP IDENTIFICATION #: _____
BATTERY CHECK _____ PASS _____ FAIL
2. CALIBRATOR MFG. AND MODEL: _____
CALIBRATOR IDENTIFICATION #: _____
3. COLLECTION MEDIA: _____
4. LOCATION/TEMP & BAROMETRIC PRESSURE: _____

5. FLOW RATES: (Continue calibration until three consecutive flow rates are within $\pm 5\%$ of average.)

FLOW RATE	AVERAGE	FLOW RATE	AVERAGE
_____		_____	_____
_____		_____	
_____	_____	_____	
_____		_____	_____

6. ROTAMETER SETTING: _____
7. FLOW RATE: _____
8. SIGNATURE: _____
9. DATE/TIME: _____

DATA SHEET 3

1. PUMP MFG. AND MODEL: _____
PUMP IDENTIFICATION #: _____
BATTERY CHECK ____ PASS ____ FAIL
2. CALIBRATOR MFG. AND MODEL: _____
CALIBRATOR IDENTIFICATION #: _____
3. COLLECTION MEDIA: _____
4. LOCATION/TEMP & BAROMETRIC PRESSURE: _____

5. FLOW RATES: (Continue calibration until three consecutive flow rates are within $\pm 5\%$ of average.)

FLOW RATE	AVERAGE	FLOW RATE	AVERAGE
_____		_____	_____
_____		_____	
_____	_____	_____	
_____		_____	_____

6. FLOW RATE: _____
7. SIGNATURE: _____
8. DATE/TIME: _____

STATION 2: CHECKING GILIAN® PUMP WITH CALIBRATOR PACK

The Gilian® Calibrator Pack has precision rotameters that can be used to calibrate a pump. A rotameter is considered a secondary calibration standard since it needs to be calibrated or checked with a primary calibration method periodically. The pack also has a magnehelic to produce a pressure drop along the flow of a pump. This, in combination with the rotameters, can be used to check the constant flow compensator on the Gilian® pump.

In this step, the precision rotameter will be used to check the constant flow compensator.

COMPENSATOR CHECK

1. Remove the Regulator Shutoff Protective Cap on the pump. Turn the exposed screw clockwise until closed - **DO NOT OVERTIGHTEN**. Replace the protective cap.
2. On the Calibrator pack, move the BYPASS/CAL switch to the BYPASS position.
3. Move the CAL SELECT (V2) switch to the upward position (3 liters/minute).
4. Connect the pump to the PUMP SUCTION (B1) outlet on the calibrator pack.
5. Turn on the pump.
6. Adjust (on the pump) the flow rate so that precision rotameter on the calibrator (not the pump rotameter) reads "3.0" (3 liters/min or 3000 cc/min). The flow rate is read at the center of the rotameter ball.
7. Move the CAL/BYPASS switch to the CAL position.
8. Turn the V3 knob until the magnehelic dial reads 10 inches of back pressure.
9. Read the flow rate on the rotameter. If the difference in flow rates with and without back pressure is more than $\pm 5\%$ (i.e., if the flow rate is not between 2850 and 3150), the pump needs adjustment. Consult the instructor.
10. Move the BYPASS/CAL switch to the BYPASS position.
11. Move the CAL SELECT (V2) switch to the downward position (1 liter/minute).
12. Adjust the flow rate to "1.0" (1 liter/min or 1000 cc/min) - reading the precision rotameter on the calibrator.
13. Move the BYPASS/CAL switch to the CAL position.
14. Turn the V4 knob until the magnehelic dial reads 20 inches of back pressure.

15. Read the flow rate on the rotameter. If the difference in flow rates with and without the back pressure is more than $\pm 5\%$ (i.e., if the flow rate is not between 950 and 1050), the pump needs adjustment. Consult the instructor.

SHUTDOWN

16. When completed with the compensator check, turn off the pump and disconnect the pump from the pack.

QUESTIONS AND CALCULATIONS

1. Calculate the concentrations in the sampled atmospheres based on the following information.

Units: 1000 liter = 1 m³
 1000 ml = 1000 cc = 1 liter
 1 mg = 1000 micrograms

- (A) Lead samples. Pump flow rate = 2.0 liters per minute.

SAMPLE DURATION	LAB ANALYSIS	AVERAGE CONCENTRATION
4 HR	0.041 mg	
2 HR	0.029 mg	
2 HR	0.008 mg	

To calculate the Average Concentration (for each sample):

$$C = \frac{\text{mg chemical}}{\text{sample volume (m}^3\text{)}}$$

where:

$$\text{sample volume (m}^3\text{)} = \text{pump flow rate (liters/minute)} \times \text{sample time (minutes)} \times \frac{1 \text{ m}^3}{1000 \text{ liters}}$$

To calculate an 8-hour TWA:

$$8 \text{ hour TWA} = \frac{C_1 T_1 + C_2 T_2 + \dots + C_n T_n}{8 \text{ hours}}$$

where T is sample time in hours. Minutes can be used for T if 480 minutes is used instead of 8 hours in equation.

(B) Solvent vapor sampling. Flow rate = 50.0 cc/min.

SAMPLE TIME	CONCENTRATION (ppm)		
	TOLUENE	XYLENE	ACETONE
1 HR	10	5	ND
2 HR	32	11	ND
1 HR	21	8	100
15 MIN	175	70	300
15 MIN	140	50	1000
15 MIN	100	67	820
30 MIN	93	40	1000
15 MIN	85	30	50
30 MIN	54	10	45
2 HR	10	ND	30

- Calculate an 8-hour TWA exposure for the three chemicals.
- Calculate an 8-hour TWA exposure for the mixture. Is this calculation valid?

(C) Do any of the concentrations in (A) and (B) exceed an exposure limit?

2. Calibration of a pump prior to sampling gave a flow rate of 2.0 liters/minute. Calibration after sampling gives a flow rate of 1.8 liters/minute. What do you do?

EXERCISE #9

Field Exercise

OBJECTIVE

Using the instruments and information provided, participants will:

1. Perform a survey of the zones on the "hazardous waste site."
2. Characterize the "hazards" present at each "zone" on the site.
3. Identify as completely as possible the materials present on the site.
4. Quantify the airborne concentrations in each "zone" and evaluate the risk associated with these concentrations.

PROCEDURE

The class will be divided into teams. Each team will select a leader/spokesperson. Each team will receive the same equipment. The equipment available is the same equipment used earlier in the week. Before each entry, the team must submit plan of action for that entry to an instructor.

The "site" simulates a much larger site. It is divided into six zones. A description of each zone is on the next page. A "map" of the site also follows. Treat the readings obtained with the instruments taken inside the containers as representing the average airborne concentrations in the "zone."

DESCRIPTION OF EXERCISE AREA

ZONE 1:

100 to 200 drums. Some with "FLAMMABLE" labels.

ZONE 2:

About 100 drums. Some with "CORROSIVE" labels.

ZONE 3:

Box trailer containing drums. Records indicate that the following chemicals were in the load. (*Note:* This zone can be treated as a transportation incident separate from the site.)

- Acetone
- Methyl ethyl ketone
- Methyl isobutyl ketone
- Ethyl alcohol
- Butyl alcohol
- Toluene
- Benzene
- Xylenes
- 1,1,1-Trichloroethane
- Trichloroethylene
- Tetrachloroethylene

Readings taken in the drum represent readings at the trailer.

ZONE 4:

About 50 drums with "Waste Cleaner" labels.

ZONE 5:

Opening to underground vault. The vault could contain many drums. Readings inside container are equivalent to readings taken inside vault (using extended probes).

ZONE 6:

50 to 100 drums. Some with hand-painted labels reading "Paint Waste."

"SITE" MAP

