

## **FOREWORD**

**This manual is a reference guide for 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. 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 the improvement in the content and format of the manual are welcome.**

# **HAZARDOUS MATERIALS INCIDENT RESPONSE OPERATIONS**

**(165.5)**

This course is designed for personnel who are involved with the investigation and remediation of uncontrolled hazardous waste sites. To a lesser extent, it is designed for personnel who respond to accidents or releases of hazardous materials. It provides basic information needed to meet the requirements of 29 CFR 1910.120, "Hazardous Waste Operations and Emergency Response."

After completing the course, participants will be able to:

- Identify methods and procedures for recognizing, evaluating, and controlling hazardous substances.
- Identify concepts, principles, and guidelines to properly protect site and response personnel.
- Discuss regulations and action levels to ensure the health and safety of the workers.
- Discuss the fundamentals needed to develop organizational structure and standard operating procedures.
- Demonstrate the selection and use of dermal and respiratory protective equipment.
- Demonstrate the use and calibration of direct-reading air monitoring instruments.

The course is designed so that personnel will be more knowledgeable in hazardous waste site operations, team functions, personnel health and safety, and field monitoring equipment.

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**U.S. ENVIRONMENTAL PROTECTION AGENCY  
Office of Emergency and Remedial Response  
Environmental Response Team**

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<b>Section 5:</b>	<b>Supplementary Reading</b>	<b>Hazard Recognition Air Monitoring Instruments Toxicology and Exposure Guidelines Respiratory Protection Chemical Protective Clothing Site Entry and Reconnaissance Decontamination Radiation Response Organization</b>
<b>Section 6:</b>	<b>Appendix A Appendix B Appendix C Appendix D</b>	<b>29 CFR 1910.120 - "Hazardous Waste Operations and Emergency Response" Warning Concentrations of Various Chemicals Hazardous Materials Identification Systems Glossary and Acronym List</b>

## Section 1



## NOTES

### *Hazard Recognition*

#### HAZARDOUS INCIDENT RESPONSE

- *Recognition*
- *Evaluation*
- *Control*

#### *Recognition*

Identification of the substances involved, the associated hazards, and the degree of hazard.

## **NOTES**

### ***Evaluation***

**Assessing impact or risk that the substances pose to public health, response personnel, and the environment.**

### ***Control***

**Methods to eliminate or reduce the impact of the hazard.**

### **CHEMICAL HAZARDS**

- ***Toxic***
- ***Combustion***
- ***Explosive***
- ***Chemical Reactive***
- ***Corrosive***

## NOTES

### *Toxic Hazards*

### *Combustion Hazards*

- *fires*
- *explosions*

#### **Combustion Hazards**

##### *Practical Considerations*

##### ***Most dangerous substances:***

- low ignition temperature
- low LEL
- wide flammable range

##### ***Additional hazards:***

- shockwave, heat, flying objects
- initiation of secondary fires
- release of toxic & corrosive compounds

## NOTES

### *Hazards Due to Chemical Reactivity*

#### Chemical Incompatibility

The combination of two or more reactive materials resulting in uncontrollable, undesirable conditions.

#### Some Results of Chemical Reactions

- *heat generation*
- *fire*
- *explosion*
- *formation of toxic vapors*
- *volatilization of toxic or flammable substances*
- *violent polymerization*

## **NOTES**

### **Oxidizers**

Materials that contain large amounts of chemically bound oxygen that is easily released, especially when heated, and that will stimulate the burning of combustible material.

### **EXAMPLES OF OXIDIZERS**

#### **HALOGENS**

*Chlorine*

*Fluorine*

#### **PEROXIDES**

*Hydrogen Peroxide*

*Benzoyl Peroxide*

#### **OZONE**

#### **HYPOCHLORITES**

### **Oxidation Hazards**

#### ***Practical Considerations***

- *Destruction of metals and organics.*
- *Ignition of combustible materials.*
- *Organic peroxides may be shock sensitive.*

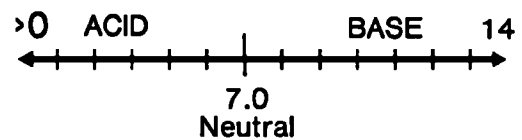
## NOTES

### *Corrosion Hazards*

#### Corrosion

The electrochemical degradation of metals or alloys due to reaction with their environment, which is accelerated by presence of acids or bases.

### **pH Scale**



## NOTES

### EXAMPLES OF CORROSIVES

#### ACIDS

Acetic Acid

Hydrochloric Acid

Sulfuric Acid

#### BASES (Caustics)

Sodium Hydroxide

Potassium Hydroxide

Ammonia

### **Corrosive Hazards**

#### *Practical Considerations*

- *What is the toxicity of the corrosive?*
- *What structural damage can occur?*
- *What other hazards can this lead to?*
- *Can the corrosive be monitored?*

### PHYSICAL PROPERTIES

- DENSITY
- VAPOR PRESSURE
- SOLUBILITY

# NOTES

## PHYSICAL HAZARDS

- Drum/Container Handling
  - labels or placards?*
  - sound or undamaged?*
  - rusted or corroded?*
  - bulging or leaking?*

## CONTAINER HANDLING PROCEDURES

- Assume all containers are hazardous
- Inspect all containers BEFORE moving them
- Brief all personnel on potential hazards
- Develop a spill prevention and containment plan

## SPILL CONTAINMENT & CONTROL

- Reduces the spread of contamination
- Minimizes cleanup efforts
- Reduces exposure to hazardous materials



## NOTES

### SPILL CONTAINMENT & CONTROL PLAN

- Define the hazards of materials on site
- Assess the potential for leaks
- Evaluate influencing physical factors
- Provide spill control equipment
- Implement a leak detection system
- Train staff

### SPILL PREVENTION GOALS

- *Prevent operational errors*  
Minimize through training and awareness.
- *Prevent equipment failures*  
Minimize by selecting proper equipment and performing proper maintenance.

### OTHER PHYSICAL HAZARDS

- Kinetic
- Thermal
- Electrical
- Acoustic
- Biological
- Radiological
- Heat Stress/Cold Exposure

## **NOTES**

### ***HEAT RELATED ILLNESSES & EMERGENCIES***

- Heat Rash
- Heat Cramps
- Heat Exhaustion
- Heat Stroke

### ***COLD EXPOSURE***

- *Frostbite*
- *Hypothermia*

### **CONFINED SPACE HAZARDS**

- Atmospheric
- Safety

## NOTES

### Confined Space

A space which by design has limited openings for entry and exit; unfavorable natural ventilation; *and* which is not intended for continuous employee occupancy.

### CONFINED SPACE HAZARDS

#### *Atmospheric Hazards:*

- Oxygen deficient
- Toxic
- Flammable
- Irritant (corrosive)

### CONFINED SPACE HAZARDS

#### *Safety Hazards:*

- Slip/trip/fall
- Mechanical/electrical
- Limited entry/exit
- Physiological stress
- Entrapment

## **NOTES**

### **Reference Materials and Resources**

## **NOTES**

### ***Air Monitoring Instruments Part I***

#### **FIELD AIR MONITORING INSTRUMENTS**

Collection of "Real Time" data to aid in decisions concerning:

- Hazards & Risks to Public & Personnel
- Personal Protective Equipment Selection
- Site Work Zones
- Effects on Environment
- Mitigative Actions

#### **DESIRED CHARACTERISTICS of Field Instruments**

- Portable and Rugged
- Easy to Operate
- Inherently Safe
- Reliable and Useful Results

## NOTES

### RELIABLE & USEFUL RESULTS

- Response Time
- Sensitivity
- Selectivity
- Accuracy
- Precision

### HAZARDOUS ATMOSPHERES

National Electrical Code

*Definition of a Hazardous Atmosphere:*

- Concentration between the Lower Explosive Limit and Upper Explosive Limit (LEL - UEL)
- Presence of an Ignition Source
- Exothermic Reaction

### INHERENT SAFETY APPROVAL

Electrical devices, such as portable air monitoring instruments, are to be constructed in such a fashion to eliminate the possibility of igniting a combustible atmosphere.

## **SAFETY STANDARDS**

### **Inherent Safety**

National Electrical Code (NEC) consensus standard, presented by National Fire Protection Association (NFPA) defining:

- Hazardous Locations
- Approval Criteria

## **HAZARDOUS LOCATIONS**

### **Inherent Safety**

#### **CLASS**

- I Combustible Gases & Vapors
- II Combustible Dusts
- III Combustible Fibers, Flyings

#### **GROUP**

- A,B,C,D Gases & Vapors found in Class I Atmosphere
- E,F,G Dusts found in Class II Atmosphere

## **HAZARDOUS LOCATIONS**

### **Inherent Safety**

#### **DIVISION**

- 1 Location in which hazardous concentrations exist continuously, intermittently, or periodically under NORMAL operating conditions
- 2 Location in which hazardous concentrations do NOT normally exist under normal operating conditions

## **NOTES**

# NOTES

## INSTRUMENT PROTECTION CRITERIA

- Class I, Division 1, Groups A,B,C, & D
  - "Intrinsically Safe"
  - "Explosion-Proof"
  - "Purged System"
- Class I, Division 2, Groups A,B,C, & D
  - "Non-Incendive"
- Class II, Division 1 & 2, Groups E,F, & G
  - "Dust-Ignition Proof"

## DEFINITIONS

### INTRINSICALLY SAFE

Designed so that parts are not exposed to explosive atmosphere or, if so, there is insufficient energy for ignition.

### EXPLOSION PROOF

Designed to contain an explosion and cool gases to prevent spread.

### PURGED SYSTEM

Inert gas filled system; positive pressure to prevent explosive gases or vapors from entering.

## OXYGEN INDICATORS

Oxygen in the Atmosphere

To Determine:

- Types of Respirator Protection
- Combustion Risk
- Use of Other Instruments
- Presence of Contaminants



## NOTES

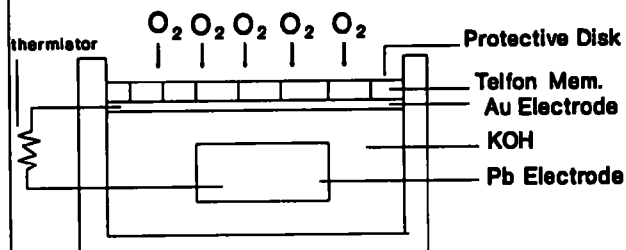
### OXYGEN INDICATORS

- Exterior Sensor
- Interior Sensor
  - manual pump
  - automatic pump
- Combination Units

### OXYGEN INDICATORS

#### Theory of Operation

- Oxygen diffusion into detector cell
- Chemical reaction establishes current proportional to oxygen concentration



### OXYGEN INDICATORS

#### Limitations/Precautions

- Atmospheric Pressure (Altitude)
- Interfering Gases
- Operating Temperature

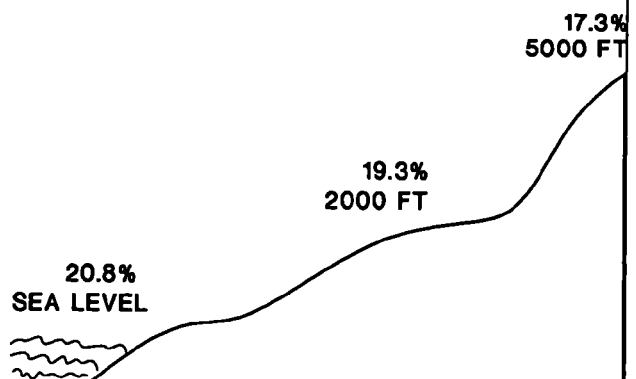
## NOTES

### OXYGEN INDICATORS

#### Interpretation of Data

- Instantaneous Response
- Specific, Quantitative Results
  - 0-25% Oxygen
  - 0-100% Oxygen
- Calibrate to Ambient Oxygen (20.8%)

### ALTITUDE/OXYGEN METER READING



### ALTITUDE/OXYGEN INDICATION

<u>Altitude</u>	<u>Oxygen Indication</u>
-1000 feet	21.6%
Sea Level	20.8
1000	20.1
2000	19.3
3000	18.6
4000	18.0
5000	17.3
6000	16.7
7000	16.1
8000	15.4
9000	14.9
10000	14.3

## COMBUSTIBLE GAS INDICATORS (CGIs)

To Determine:

- Risk of Fire/Explosion
- Indication of Contaminants

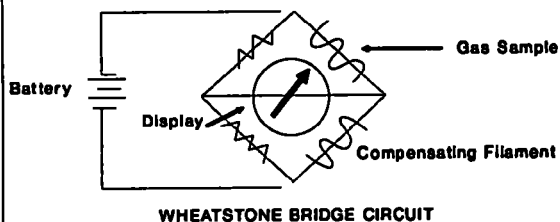
## NOTES

## COMBUSTIBLE GAS INDICATORS

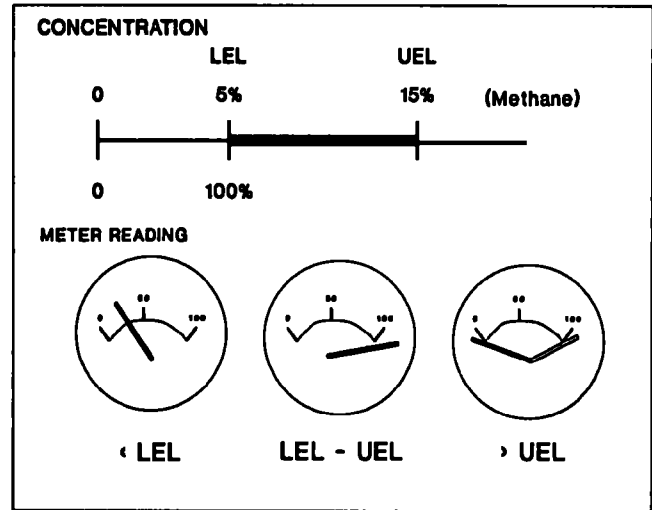
- Manual vs. Automatic Pumps
- "Super-Sensitive" Unit
- Combination Units (CGI-Oxygen)

## COMBUSTIBLE GAS INDICATOR Theory of Operation

In the presence of a combustible gas, a heated catalytic filament (or bead) burns the gas, increasing the filament's temperature. An electrical resistance is created causing an imbalance in a Wheatstone Bridge circuit.



# NOTES

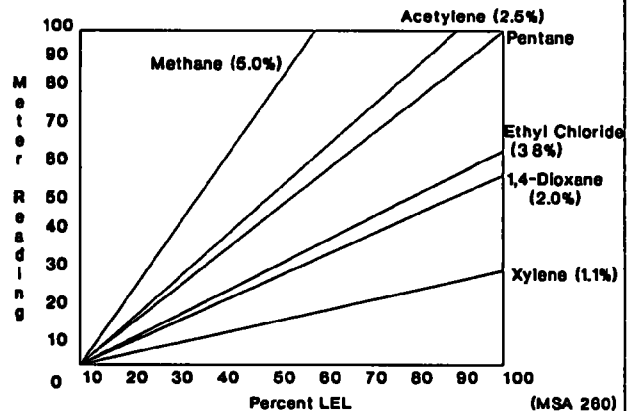


## COMBUSTIBLE GAS INDICATORS

### Limitations/Precautions

- Temperature
- Oxygen Requirements
- Interfering Gases
  - Lead*
  - Sulfur*
  - Silicone*
  - Hydrogen Chloride*
  - Hydrogen Fluoride*
- Relative Response

## COMBUSTIBLE GAS INDICATORS Relative Response Curve



## COMBUSTIBLE GAS INDICATORS

### Relative Response

<u>Chemical LEL</u>	<u>Concentration %LEL</u>	<u>Meter Response %LEL</u>
Methane (5.0%)	50	85
Acetylene (2.5%)	50	60
Pentane (1.5%)	50	63
Ethyl Chloride (3.8%)	50	37
1,4 Dioxane (2.0%)	50	37
Xylene (1.1%)	50	27

## NOTES

## TOXIC ATMOSPHERE MONITORS

To Determine:

- Health Risks to Workers/Public
- Personal Protective Equipment
- Work Zones/Safety Plans

## TOXIC ATMOSPHERE MONITORS

### Types

- Detector Tube System
  - Monitors for Specific Agents  
(i.e. CO, Hydrogen Sulfide)
  - Total Vapor Analyzers
  - Gas Chromatograph
- > (PID, FID)

# NOTES

## DETECTOR TUBE SYSTEMS

### Components

- Pump
  - piston*
  - bellows*
- Tubes
  - specific chemicals*
  - general chemicals*
  - concentration ranges*

## DETECTOR TUBE SYSTEM

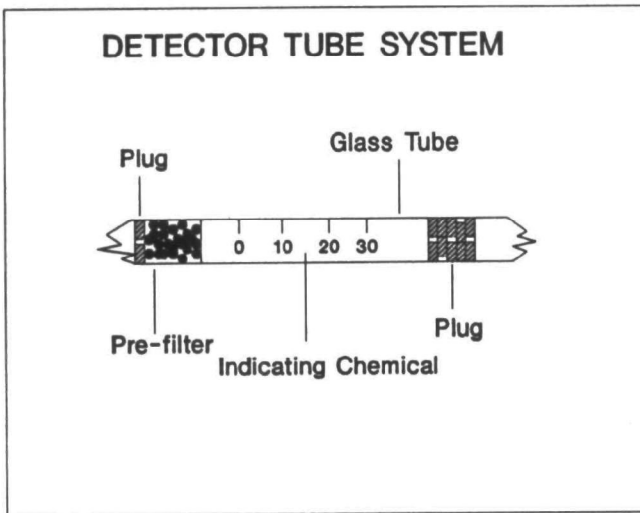
### Theory of Operation

- Glass Tube w/ Indicating Chemical
- Specific Volume of Air
- Color Change
- Stain Length = Concentration

## DETECTOR TUBE SYSTEMS

### Limitations/Precautions

- Accuracy
- Temperature/Humidity/Pressure
- Expiration Date
- Chemical Group/Specific
- Lot #
- Color Change/Endpoint
- Pump Strokes/Volume/Time
- Interferences
- Reusable

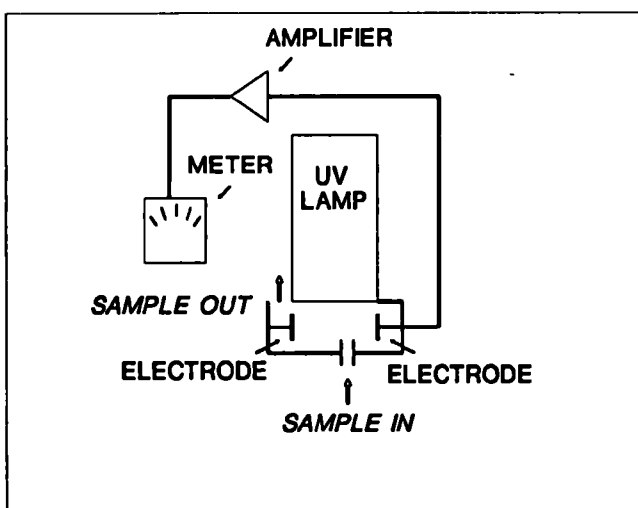
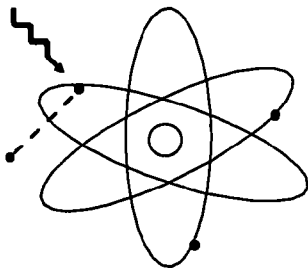


## NOTES

## NOTES

### *Air Monitoring Instruments Part II*

#### PHOTOIONIZATION





## NOTES

### PHOTOIONIZATION



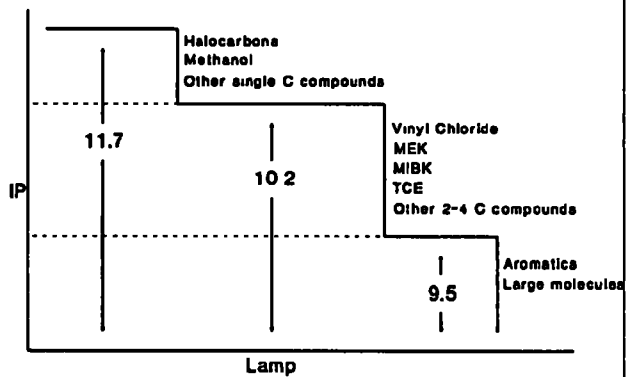
R = chemical absorbing UV

$h\nu$  = photon with energy  $\geq$   
Ionization Potential (IP)  
of chemical

### Ionization Potentials

<u>CHEMICAL</u>	<u>IP(eV)</u>
Carbon Monoxide	14.0
HCN	13.9
Methane	13.0
Water	12.6
HCl	12.7
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	7.5

### Examples of Lamp Energies and Detectable Chemicals



## NOTES

### SELECTIVE DETERMINATION OF VINYL CHLORIDE

<u>COMPOUND</u>	<u>IP</u>
Carbon dioxide	13.8
Propane	11.1
Vinyl chloride	10.0
Acetone	9.7

### PHOTOIONIZATION

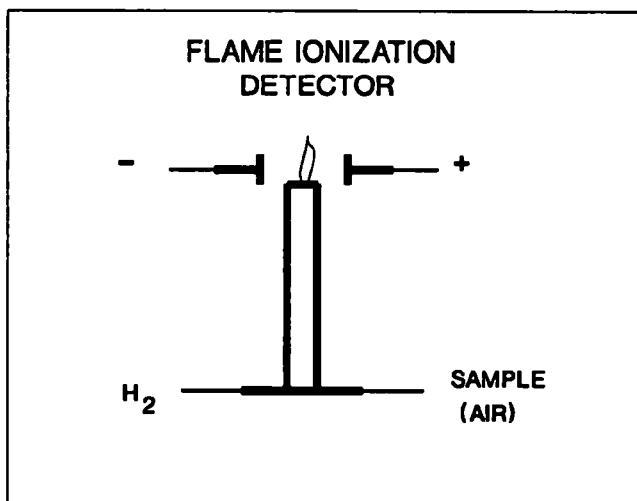
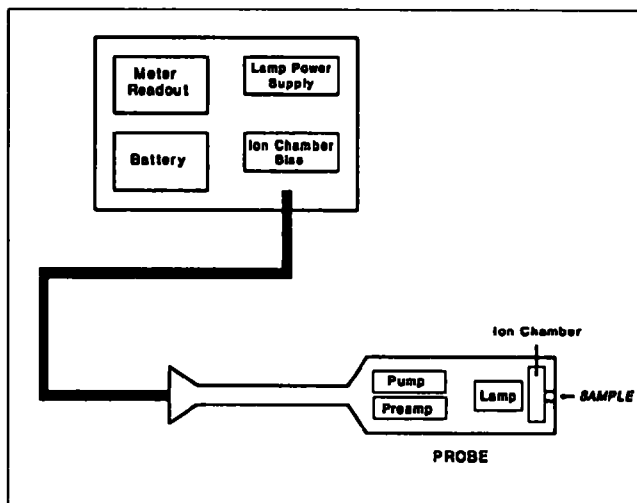
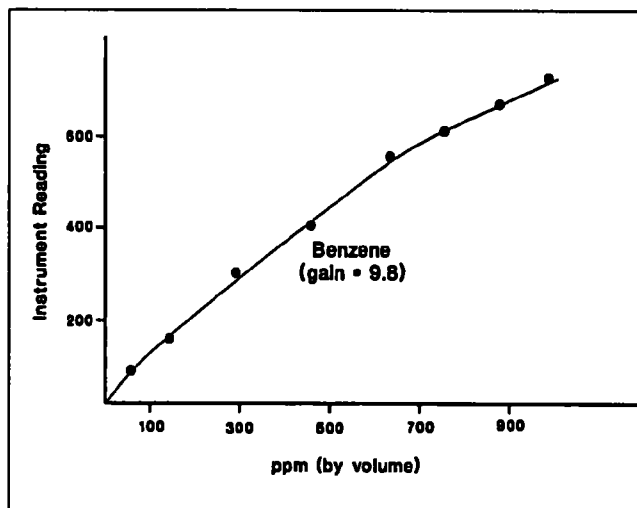
#### Considerations

- *Lamp Energy/Chemical IP*
- *Dust/Humidity*
- *High Methane*
- *Electromagnetic Radiation*
- *Lamp Aging*
- *Relative Response*
- *High Concentrations*

### RELATIVE RESPONSES FOR HNU PI-101 WITH 10.2 eV PROBE

<u>CHEMICAL</u>	<u>RR</u>	<u>IP</u>
m-Xylene	1.12	8.56
Benzene	1.00	9.25
Phenol	0.78	8.69
Isobutylene	0.56	9.25
Acetone	0.63	9.69
Hexane	0.22	10.18
Ammonia	0.03	10.15

## NOTES



## **FLAME IONIZATION**

### **Considerations**

- *Detects only organics*
- *Sensitive to methane*
- *Relative Response*
- *Hydrogen gas needed*
- *Electromagnetic radiation*

## **NOTES**

## Section 2

## NOTES

### *Toxicology and Exposure Guidelines*

*Which chemical  
poses the greatest risk?*

- Chlorine
- Ammonia
- Toluene
- Benzene
- Methyl Alcohol
- Hydrogen Cyanide
- Lead
- Mercury
- Asbestos
- Polychlorinated Biphenyls

### **RISK ASSESSMENT FOR CHEMICALS**

**WHAT IS THE TOXICITY OF THE COMPOUND?**

**WHAT IS THE PROBABILITY OF EXPOSURE?**

# **NOTES**

*What is the toxicity of the compound?*

- Dose-Response Relationship
- Adverse Effects

## **TOXICITY**

The ability of a substance to produce injury once it reaches a susceptible site in or on the body.

## **TOXICOLOGY**

**CLASSIC DEFINITION:**

**"Science of Poisons"**

**MODERN CONCEPT:**

**"Limits of Safety"**

## NOTES

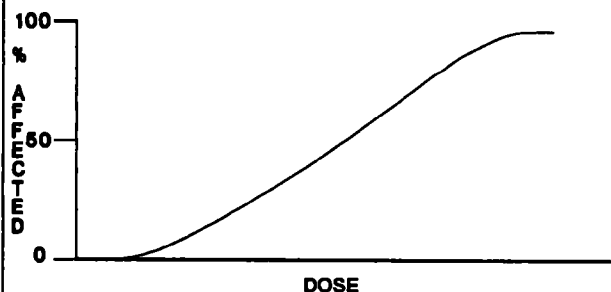
"All things are poisons, for there is nothing without poisonous qualities. It is only the dose which makes a thing poison."

Paracelsus  
(1493 - 1541)

### TYPES OF TOXICITY INFORMATION

- Epidemiologic Data
- Animal Bioassays
- Short-Term Studies
- Comparisons to Molecular Structure

### DOSE-RESPONSE CURVE





# NOTES

## EXAMPLES OF DOSE-RESPONSE INDICES

ENDPOINT - L \_ : Lethality  
T \_ : Toxicity  
E \_ : Effectiveness

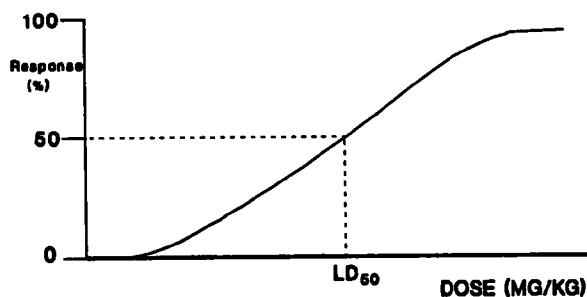
ROUTE - \_ D : Dose based on all routes  
except inhalation  
\_ C : Concentration based  
upon inhalation only

RESPONSE - Percentage of experimental population  
Lo - Lowest dose at which effect  
was observed

## LETHAL DOSE FIFTY (LD<sub>50</sub>)

The dose of a substance which is  
expected to cause the death of  
50% of a defined experimental  
animal population.

## Relationship of LD<sub>50</sub> to Dose-Response

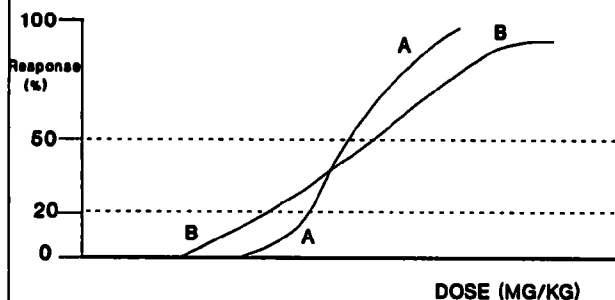


### LIMITATIONS OF DOSE-RESPONSE DATA

- SPECIES VARIATION
- BASED ON SINGLE DOSE
- STATISTICAL VALUE

## NOTES

### Dose-Response Curves for Two Substances



### ADVERSE EFFECTS

- LOCAL EFFECTS
- SYSTEMIC EFFECTS
- ASPHYXIATION
  - *simple*
  - *chemical*
- SENSITIZATION
- TERATOGENIC
- MUTAGENIC
- CARCINOGENIC

## **NOTES**

*What is the probability of exposure?*

- Route of exposure
- Duration and frequency of exposure
- Personal characteristics
- Chemical interactions

### **ROUTES OF EXPOSURE**

- INHALATION
- ABSORPTION
  - Skin
  - Eyes
- INJECTION
- INGESTION

### **PERSONAL CHARACTERISTICS**

- gender
- genetic factors
- health status
- age

## NOTES

### *Types of Chemical Interactions*

#### EXAMPLES

**ADDITION**                       $(2 + 2 = 4)$

**SYNERGISM**                       $(2 + 2 = 6)$

**POTENTIATION**                       $(0 + 2 = 4)$

**ANTAGONISM**                       $(2 + 2 = 2)$

### EXPOSURE GUIDELINES

#### OSHA

Permissible Exposure Limits (PEL)  
Enforced standards

#### NIOSH

Recommended Exposure Limits (REL)  
Research agency, recommendations for OSHA

#### ACGIH

Threshold Limit Values (TLV)  
Recommended workplace exposure levels

### **EXPOSURE LIMITS**

*(29 CFR PART 1910.120)*

#### ■ Permissible Exposure Limits

29 CFR Part 1910.1000, Subparts G & Z  
(OSHA)

#### ■ "Published Exposure Levels"

"NIOSH Recommendations for  
Occupational Health Standards," 1986

ACGIH's TLVs and BEIs for 1987-1988

## NOTES

### **EXPOSURE LIMITS** *are used to determine:*

- Site Characterization
- Medical Surveillance
- Exposure Controls
  - engineered controls
  - work practices
  - PPE selection

29 CFR 1910.120

### **TIME WEIGHTED AVERAGE (TWA)**

- Averages the concentrations of exposure
- Based on duration of exposure

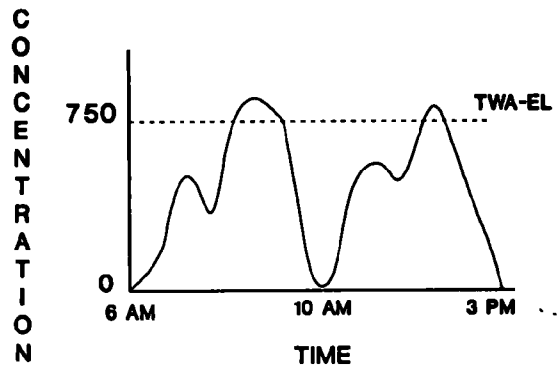
EXAMPLE: ACETONE TLV-TWA 750 ppm (ACGIH)

1000 ppm for 3 hours  
500 ppm for 2 hours  
200 ppm for 3 hours

For an 8 hour TWA:

- $$\frac{(3 \text{ hrs})(1000) + (2 \text{ hrs})(500) + (3 \text{ hrs})(200)}{8}$$
- 575 ppm

### **TIME WEIGHTED AVERAGE (TWA)**



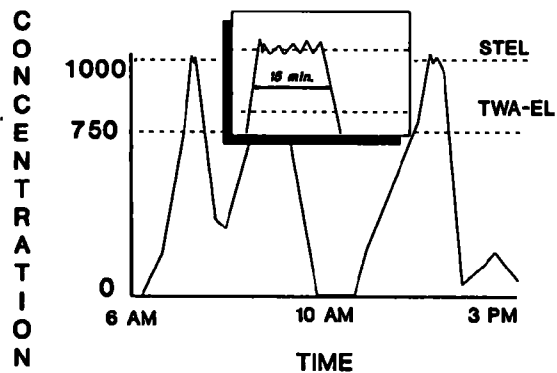
## NOTES

### SHORT TERM EXPOSURE LIMIT (STEL)

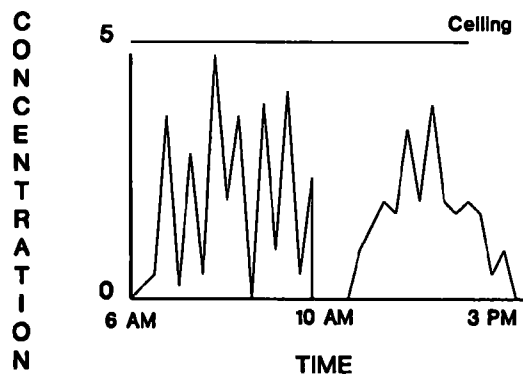
The concentration to which workers can be exposed continuously for a short period of time without suffering from:

- Irritation
- Chronic or Irreversible tissue damage
- Narcosis

### SHORT TERM EXPOSURE LIMIT (STEL)



### CEILING (C)



## **NOTES**

### **THRESHOLD LIMIT VALUES are 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
- as proof or disproof of an existing disease or physical condition
- for adoption by countries whose working conditions differ from those in the U.S.

ACGIH TLVs and BEIs (current version)

## NOTES

### *Respiratory Protection: Air-Purifying Respirators*

#### **REQUIREMENTS FOR A MINIMAL ACCEPTABLE PROGRAM**

OSHA 29 CFR 1910.134(B)

1. WRITTEN STANDARD OPERATING PROCEDURES
2. SELECTION BASED ON HAZARD
3. TRAINING
4. CLEAN AND DISINFECT
5. STORAGE
6. INSPECTION
7. MONITORING
8. PROGRAM EVALUATION
9. PHYSICALLY FIT
10. APPROVED OR ACCEPTED RESPIRATORS

#### **APPROVED RESPIRATORS**

MSHA: Establish Testing Criteria

NIOSH: Conduct Approval Testing



## NOTES

### PHYSIOLOGICAL AND PSYCHOLOGICAL LIMITATIONS FOR RESPIRATOR WEARERS

Respiratory Impairment	Cardiovascular Impairment
Anemia	Diabetes
Epilepsy	Claustrophobia
Punctured Eardrum	Comfort
Facial Hair	Vision

Adapted from ANSI Z88.2-1980, APPENDIX A4

### OXYGEN REQUIREMENTS

• ACGIH TLV'S	18%
• ANSI STANDARDS	19.5%
• OSHA REGULATIONS	16 - 19.5%
• USEPA GUIDES	19.5%

• Z88.2 (1980)

### IMMEDIATELY DANGEROUS TO LIFE OR HEALTH (IDLH)

A concentration that represents 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.

Reference: NIOSH Pocket Guide to Chemical Hazards

## NOTES

### AIRBORNE CONTAMINANTS

- Gases
- Vapors
- Aerosols
  - dust*
  - fumes*
  - mist*

### NIOSH APPROVED PARTICULATE FILTERS

- DUST
- MIST
- FUME
- HEPA
- RADON DAUGHTERS
- ASBESTOS
- SINGLE-USE
- ABRASIVE BLASTING

### PARTICULATE CLASSIFICATION

#### Dust & Mist

80 - 90% efficiency  $0.6\mu$

#### Fume

90 - 99% efficiency  $0.6\mu$

#### HEPA

99.97% efficiency  $0.3\mu$   
Exposure limit <  $0.05\text{ mg/m}^3$

## **NOTES**

### ***Vapor & Gas Removing Respirators***

- Organic vapors
- Acid gases
- Ammonia
- Combinations (gases, vapors & particulates)
- Specific conditions/approvals required
  - carbon monoxide
  - hydrogen sulfide
  - hydrogen cyanide
  - vinyl chloride
  - formaldehyde

### **WARNING PROPERTIES**

Adequate warning properties can be assumed when the substance's odor, taste, or irritation effects are detectable and persistent at concentrations "at or below" the Permissible Exposure Limit.

SOURCE: NIOSH/OSHA RESPIRATOR DECISION LOGIC

<b><u>SOLVENTS</u></b>	<b><u>1% Breakthrough Time</u></b> <b><u>(Minutes)</u></b>
------------------------	---

• BENZENE	73
• CHLOROFORM	33
• ETHANOL	28
• METHANOL	0.2
• METHYL CHLORIDE	0.05
• VINYL CHLORIDE	3.8
• CARBON TETRACHLORIDE	77

## WARNING PROPERTIES

CHEMICAL	WARNING CONCENTRATION	EL
ACETONE	0.1 - 699	750
BUTYLAMINE	0.1 - 5	C-5
CARBON MONOXIDE	ODORLESS	35
CARBON TETRACHLORIDE	2 - 700	C-2
HYDROGEN SULFIDE	0.00001 - 14 (fatigue)	C-10
SULFUR DIOXIDE	0.3 - 5 (taste)	2
BUTYL MERCAPTAN	0.0008-0.038	C-0.5

## PROTECTION FACTORS

### RESPIRATOR TYPE      NIOSH

#### AIR-PURIFYING

QUARTER MASK	5
HALF MASK	10
FULL MASK	50

#### SUPPLIED-AIR

##### *Demand*

HALF MASK	10
FULL MASK	50

##### *Pressure-Demand*

FULL MASK SCBA	10,000
----------------	--------

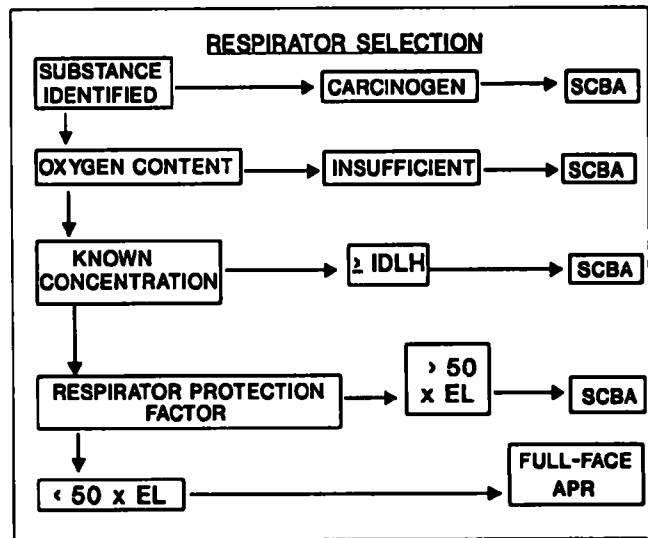
$$MUC = PF \times EL$$

$$? = 10 \times 10 \text{ ppm}$$

$$500 = ? \times 5 \text{ ppm}$$

## NOTES

## NOTES



## RESPIRATOR SELECTION

- Nature of Hazard
- Characteristics of Operation & Worker Activity
- Location Of Hazardous Area
- Duration Of Respirator Use
- Respirator Capabilities And Limitations

ANSI Z88.2-1980

## NOTES

### *Respiratory Protection: Supplied-Air Respirators*

#### SUPPLIED-AIR RESPIRATORS

##### **Benefits:**

- *Provide breathing air*
- *No filter/sorbent limitations*
- *Better protection factors*

#### SUPPLIED AIR RESPIRATORS

##### **Modes of Operation**

- **NEGATIVE PRESSURE**
  - pressure inside facepiece can become negative
  - leakage in
  - "demand"
- **POSITIVE PRESSURE**
  - pressure inside facepiece stays positive
  - leakage out
  - "pressure-demand"

## NOTES

### COMPARISON OF RESPIRATOR PROTECTION FACTORS

<u>TYPE OF RESPIRATOR</u>	<u>ASSIGNED PROTECTION FACTOR (APF)</u>
---------------------------	---

#### *Negative Pressure*

Full facepiece APR	50
Full facepiece SAR	50

#### *Positive Pressure*

Full facepiece air-line (without SCBA)	2000
Full facepiece SCBA	10000

### SUPPLIED-AIR RESPIRATORS

#### Types

- Hose Mask
- Airline
- Self-Contained Breathing Apparatus (SCBA)
- Combination Airline/SCBA
- Escape SCBA

### TYPES OF SCBAs

- CLOSED CIRCUIT
- OPEN CIRCUIT

**BREATHING AIR SPECIFICATIONS  
(Compressed Gas Association)**

<b><u>Characteristics</u></b>	<b><u>GRADE D</u></b>	<b><u>GRADE E</u></b>
<b>% Oxygen</b>	atm/19.5-23.5	atm/19.5-23.5
<b>Water</b>	varies	varies
<b>Hydrocarbons</b>	5 mg/m3	5 mg/m3
<b>Carbon Monoxide</b>	20 ppm	10 ppm
<b>Odor</b>	none	none
<b>Carbon Dioxide</b>	1000 ppm	500 ppm

**NOTES**



***Levels of Protection  
and  
Chemical Protective Clothing***

**SELECTING LEVELS OF PROTECTION**

- Known vs. Unknown
- Chemical hazard recognition
- Actual concentrations vs. exposure guidelines
- Work function
- Work location
- Weather conditions

**LEVEL D**

Should not be worn on any site with respiratory or skin hazards. Level D is primarily a work uniform providing minimal protection.

**NOTES**

## NOTES

*Level D protection is used when:*

- Atmosphere contains no known hazard
- Work function precludes the potential for unexpected exposure to hazardous levels of any substances

### Level D Equipment

- Coveralls
- Gloves •
- Safety Boots/Shoes  
(leather or chemical resistant)
- Disposable Boot Covers •
- Safety Glasses or Chemical  
Splash Goggles •
- Hard Hat (face shield•)
- Escape Mask •

• OPTIONAL

### LEVEL C

Should be selected when the types of airborne contaminants are known, the concentrations are measured, and the criteria for using air-purifying respirators are met.

## NOTES

**Level C protection is used when:**

- Criteria for the use of APRs are met
- Air contaminants have been identified and concentrations measured
- Direct contact does not pose a severe skin hazard

### **Level C Equipment**

- Air-Purifying Respirator (full-face, canister)
- Hooded Chemical Resistant Clothing
- Inner Clothing
- Chemical Resistant Gloves (inner and outer)
- Chemical Resistant Safety Boots
- Disposable Boot Covers •
- Hard Hat (face shield-)
- Escape Mask •
- 2-Way Radio (inherently safe)

• OPTIONAL

### **LEVEL B**

Should be selected when the highest level of respiratory protection is needed and some degree of skin protection is required.

Level B is the minimum recommendation for initial site entry.

## NOTES

### *Level B protection is used when:*

- Air contaminants are unknown
- Air contaminants have been identified and the criteria for using APRs are not met
- IDLH air concentrations exist
- The atmosphere contains less than 19.5% oxygen
- Direct contact does not pose a severe skin hazard

### **Level B Equipment**

- Supplied-Air Respirator  
Pressure-Demand
- Hooded Chemical Resistant Clothing
- Inner Clothing
- Chemical Resistant Gloves  
(inner and outer)
- Chemical Resistant Safety Boots
- Disposable Boot Covers •
- Hard Hat (face shield•)
- 2-Way Radio (inherently safe)

• OPTIONAL

### **LEVEL A**

Should be worn when the highest level of respiratory, skin, and eye protection is required.

## NOTES

### *Level A protection is used when:*

- Conditions are unknown
- The hazardous substance has been identified and it requires the highest level of protection for skin, eyes, and respiratory system
- Operations are being conducted in confined, poorly ventilated areas
- Work function involves a high potential for splash, immersion, or exposure to unexpected skin hazards

### **Level A Equipment**

- Supplied-Air Respirator  
Pressure-Demand
- Fully Encapsulating  
Chemical Resistant Suit
- Inner Clothing
- Chemical Resistant Gloves  
(inner and outer)
- Chemical Resistant Safety Boots
- Outer Clothing (disposable protective  
suit, gloves, and boot covers) •
- Hard Hat • (under suit)
- Cooling Unit •
- 2-Way Radio (Inherently safe)  
• OPTIONAL

### **Levels of Protection**

	<i>Chemical Protective Clothing</i>	<i>Respiratory Protection</i>
Level A	<i>FES</i>	<i>SAR</i>
Level B	<i>Splash Suit</i>	
Level C		<i>APR</i>
Level D	<i>None</i>	<i>None</i>

## **NOTES**

### **PERFORMANCE QUALITIES**

- Chemical Resistance
- Durability
- Flexibility
- Temperature Resistance
- Aging Resistance
- Cleanability
- Design (color)
- Comfort (size)

### **CHEMICAL RESISTANCE**

- Penetration
- Degradation
- Permeation

### **PENETRATION (a physical process)**

The flow of a chemical through closures, porous materials, seams, and pinholes or other imperfections in a protective clothing material on a nonmolecular level.

## NOTES

### DEGRADATION (a chemical process)

A deleterious change in one or more physical properties of a protective clothing material due to contact with a chemical.

ASTM F739

### PERMEATION (a chemical process)

The process by which a chemical moves through a protective clothing material on a molecular level.

ASTM F739

### PERMEATION involves:

1. Sorption of molecules of the chemical into the contacted (outside) surface of a material,
2. Diffusion of the sorbed molecules in the material; and
3. Desorption of the molecules from the opposite (inside) surface of the material into the collecting medium.

ASTM F739

## NOTES

### MEASURED PARAMETERS

- BREAKTHROUGH TIME
- PERMEATION RATE (STEADY-STATE)

### PERMEATION/DEGRADATION RESISTANCE GUIDE

	NITRILE NBR			NEOPRENE			PVC		
	DR	PBT	PR	DR	PBT	PR	DR	PBT	PR
Acetone	NR	-	-	G	6 min	F	NR	-	-
Ammonium Hydroxide (50%)	E	ND	-	E	6 hr	-	E	4 hr	-
Hydrofluoric Acid (48%)	E	2 hr.	-	E	1 hr	-	G	40 min.	-
Toluene	F	10 min	F	NR	-	-	NR	-	-
1,1,1-Trichloroethane	F	16 hr	P	NR	-	-	NR	-	-

DR - Degradation Rating

PBT - Permeation Breakthrough Time

PR - Permeation Rate

ND - None Detected during 6 hr test

NR - Not Recommended

### BLEND and LAYERS

NEOPRENE and LATEX RUBBER (Gloves)

VITON<sup>®</sup>/NEOPRENE (FES - MSA Vautex, Draeger)

VITON<sup>®</sup>/BUTYL (FES - Trelleborg)

PVC/NITRILE (Boots)

PVC/PARACRIL (Splash Suit)



**PROTECTIVE CLOTHING  
REFERENCES**

- Manufacturers' data
- Published studies
- *Guidelines for the Selection of Chemical Protective Clothing* (Arthur D. Little, Inc.)
- *Personal Protective Equipment for Hazardous Material Incidents: A Selection Guide* (NIOSH)
- *Quick Selection Guide to Chemical Protective Clothing* (K. Forsberg/S.Z. Mansdorf)
- Computer Systems
- Field Test Kit

**NOTES**

***PERSONAL PROTECTIVE EQUIPMENT***

**OSHA REGULATION**

**SOURCE**

29 CFR 1910.132  
GENERAL REQUIREMENTS

41 CFR 50-204.7

29 CFR 1910.133  
EYE AND FACE PROTECTION

ANSI Z87.1-1988  
(REV. 1989)

29 CFR 1910.134  
RESPIRATORY PROTECTION

ANSI Z88.2-1969  
(REV. 1980)

29 CFR 1910.135  
HEAD PROTECTION

ANSI Z89.1-1969  
(REV. 1986)

29 CFR 1910.136  
FOOT PROTECTION

ANSI Z41.1-1967  
(REV. 1983)

### Section 3

## **NOTES**

### ***Site Entry and Reconnaissance***

#### **SITE SAFETY PLAN REQUIREMENTS As a Minimum, the Plan MUST-**

- Name Key Personnel, Alternates, Health and Safety Personnel
- Task/Operation Safety & Health Risk Analysis
- Employee Training
- Personal Protective Equipment
- Air Monitoring Program
- Sampling Techniques
- Personnel Medical Monitoring

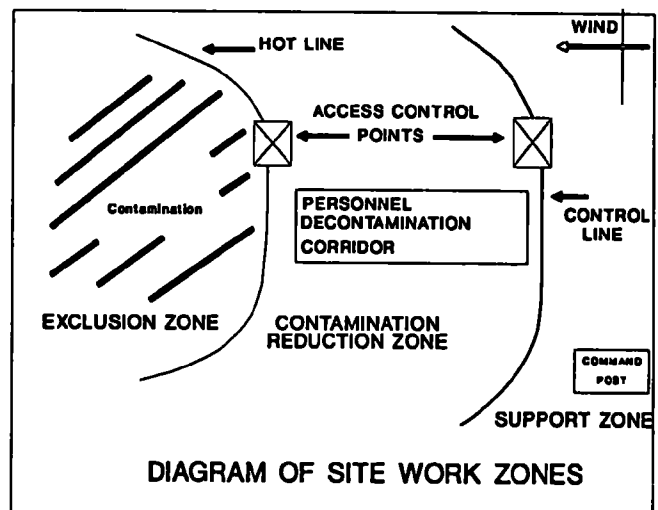
#### **SITE SAFETY PLAN REQUIREMENTS (Con't)**

- Site Control Measures
- Decontamination Procedures
- Emergency Planning/Medical Facilities
- Confined Space Procedures
- Medical Surveillance Program
- Weather-Related Problems
- Buddy System
- Communications (Visual/Verbal)
- Spill Containment

## NOTES

### THREE WORK ZONES

- Support Zone (Cold)
  - Command Post
  - No Contamination
  - Normal Work Clothes
- Contamination Reduction Zone (Warm)
  - Decon Line
  - Buffer
  - PPE Required
- Exclusion Zone (Hot)
  - Hot Line
  - Contamination
  - PPE Required



### SITE CONTROL

- Security/Physical Barriers
- Minimize Personnel/Equipment
- Work Zones
- Access Control Points
- Control Airborne Dispersion
- Decontamination Procedures

### **OFFSITE CHARACTERIZATION**

#### **Interviews/Records Research**

- Habitation
- Site Location and Size
- Response Activities/Emergency
- Duration of Employee Activity
- Site Topography
- Geologic and Hydrologic Data
- Accessibility by Air/Road
- Hazardous Substances Involved
- Pathways of Dispersion
- Previous Surveying/Sampling

### **PERIMETER RECONNAISSANCE**

- Site Maps
- Historical/Current Photographs
- Container/Vehicle Markings
- Condition of Containers/Vehicles
- Biologic Indicators
- Unusual Conditions
- Unusual Odors
- Air Monitoring at Site Perimeter
- Off Site Samples

### **On-Site Survey PRIMARY ENTRY OBJECTIVE**

- Monitor air for IDLH atmospheres
  - combustibles or explosives
  - oxygen deficiency
  - radiation
  - toxic substances

## **NOTES**

## NOTES



### EPA ACTION GUIDELINE

#### Combustible Gas Indicators

##### METER READING

##### ACTION

< 10% LEL

Continue investigation with caution.

10-25%

Continue on-site monitoring with extreme caution as higher levels are encountered.

> 25%

Explosion hazard! Withdraw from area immediately.



### EPA ACTION GUIDELINE

#### Oxygen Indicators

##### METER READING

##### ACTION

< 19.5%

Monitor wearing SCBA. Note: CGI readings may not be valid.

19.5-25%

Continue investigation with caution. SCBA not needed based only on oxygen content.

> 25%

Discontinue investigation; fire hazard potential.



### EPA ACTION GUIDELINE

#### Radiation Survey

##### METER READING

##### ACTION

< 1 mR/hr

If levels are above background continue investigation with caution. Perform thorough monitoring. Consult health physicist.

≥ 1 mR/hr

Potential radiation hazard. Evacuate site. Continue monitoring only upon advice of a health physicist.



## **EPA ACTION GUIDELINE**

### **Total Gas/Vapor Meters**

#### **METER READINGS    ACTION**

##### ***Unknowns***

<b><i>Background</i></b>	<b>Level D</b>
<b><i>0-5</i></b>	<b>Level C</b>
<b><i>5-500</i></b>	<b>Level B</b>
<b><i>500 -1000</i></b>	<b>Level A</b>
<b><i>&gt;1000</i></b>	<b>Consider explosive</b>

<b><i>Knowns</i></b>	<b>Compare to Exposure Guide IDLH/PEL/REL/TLV</b>
----------------------	---

## **NOTES**

### **On-Site Survey PRIMARY ENTRY OBJECTIVE**

- Visually observe for signs of IDLH conditions
  - confined spaces
  - visible vapor clouds
  - biological indicators

### **On-Site Survey ENTRY OBJECTIVE**

- Note types of containers
  - paper or wood packages
  - metal or plastic barrels/drums
  - underground tanks
  - above ground tanks
  - compressed gas cylinders
  - pits, ponds or lagoons

## **NOTES**

### **On-Site Survey ENTRY OBJECTIVE**

- Note condition of containers and storage systems
  - sound (undamaged)
  - rusted or corroded
  - leaking
  - bulging
  - types & quantities of material
  - labels

### **On-Site Survey ENTRY OBJECTIVE**

- Note physical condition of materials
  - solid, liquid, or gas
  - color & turbidity
  - behavior (corroding, foaming, or vaporizing)
  - conditions conducive to splash or contact

### **On-Site Survey ENTRY OBJECTIVE**

- Note indicators of potential exposure
  - biological indicators
  - dust or spray in the air
  - pools of liquid
  - foams or oils on liquid surfaces
  - possible landfilled areas



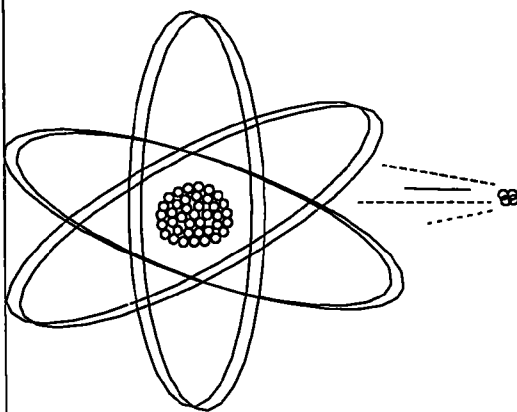
## NOTES

### *Radiation Survey Instruments*

#### **RADIOACTIVITY**

*The tendency of unstable atoms to undergo radioactive decay.*

*Radioactive atoms are called radionuclides.*



**Radioactive Decay**

# NOTES

## **Radiation** **Characteristics of the Three Major Types**

Source	Symbol	Form	Relative Mass (Charge)	# of Ionizations /cm in Air	Path Length in Air	Hazard Location of Source
ALPHA	$\alpha$	Particle	4 (+2)	100,000's	< 1 inch	Internal
BETA	$\beta$	Particle	0.00055 (-1/+1)	100's	1 meter	Internal/ External
GAMMA	$\gamma$	Electro-Magnetic Energy	0 (0)	1	Several meters to kilometers	Internal/ External

## **Definitions**

**Roentgen** - The unit of measure for X or gamma radiation in air.

**Rad** - The unit of measure for radiation energy transferred to an absorbing tissue.

**Quality Factor** - The factor by which absorbed doses are multiplied to obtain a quantity that expresses the risk associated with the dose.

**Rem** - The unit of measure which represents the risk associated with the radiation exposure.

	Rad	X	QF	=	Rem
Gamma	1 Rad	X	1	=	1 Rem
Beta	1 Rad	X	(1 to 2.6)	=	1 to 2.6 Rem
Alpha	1 Rad	X	20	=	20 Rem

## NOTES

### Subunits

1000 mRem    ▪    1 Rem

1000  $\mu$  Rem    ▪    1 mRem

### Acute Exposure Risk

700 Rem    ▪    LD<sub>100</sub>

600 Rem    ▪    LD<sub>99</sub>

450 Rem    ▪    LD<sub>50</sub>

200 Rem    ▪    LD<sub>LO</sub>

100 Rem    ▪    TD<sub>LO</sub>

25 Rem    ▪    ED<sub>LO</sub>

### Chronic Exposure Risk

A normal U.S. citizen has a 25% risk of cancer. 1 Rem increases risk to 25.03%  
100 Rem increases risk to 28%.

## NOTES

### Background Radiation

- is unavoidable
- comes from cosmic sources and earth materials
- averages .01 - .02 mR/hr gamma in the USA

### *US EPA Action Level:*

1 mR/hr gamma above background



Maintain exposure ALARA

(As Low As Reasonably Achievable)

## **NOTES**

### **Exposure Reduction Mechanisms**

**Time**

**Distance**

**Shielding**

### **Purpose of Radiation Monitoring**

- **Determine risk of exposure**
- **Determine types of radiation**

### **Interpretation of Instrument Data**

- **mR/hr (beta/gamma) -  
used to make exposure estimates**
- **cpm (alpha or beta) -  
used to determine activity of the source**

## **NOTES**

### **Limitations and Considerations**

- Annual calibration (minimum)
- Instruments are calibrated for one type of radiation

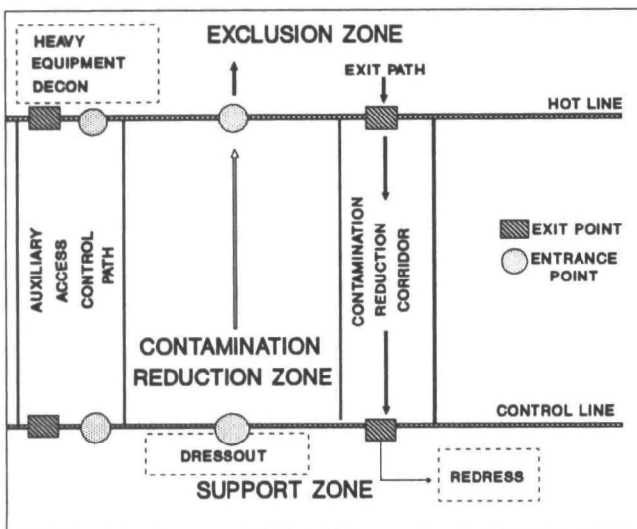
## NOTES

### *Decontamination*

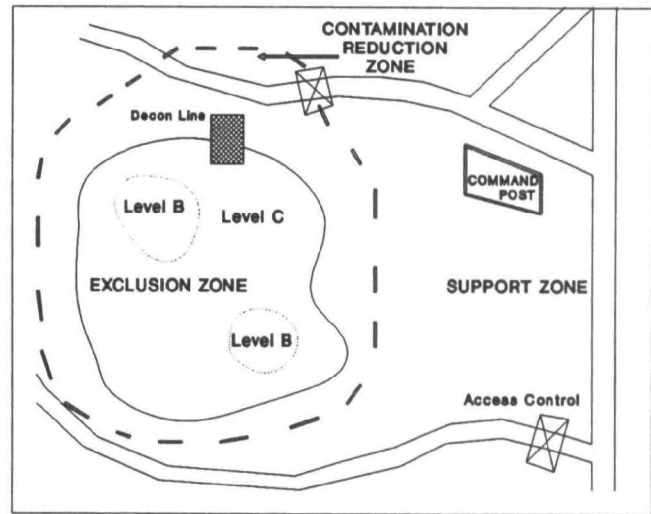
#### DECONTAMINATION

The process of removing potentially harmful contaminants from exposed individuals and equipment in order to:

- reduce the spread of contamination from the work area, and
- prevent inadvertent and unnecessary contact with contaminated materials



## NOTES



### FACTORS THAT DETERMINE EXTENT OF DECONTAMINATION

- Type of Contaminants
- Amount of Contaminants
- Level of Protection
- Work Function
- Location of Contaminants
- Reason for Leaving Site

### DECONTAMINATION PLAN SHOULD PROVIDE FOR:

- proper level of decontamination
- suitable location
- decontamination worker protection
- appropriate decon methods
- program evaluation
- disposal of decontamination materials
- emergency decontamination procedures



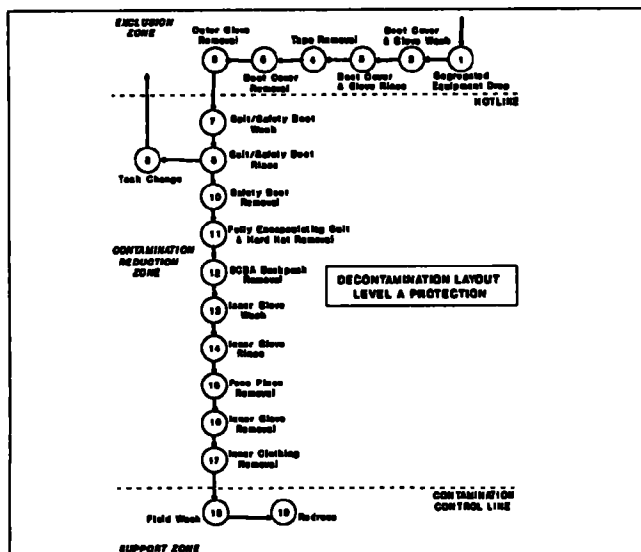
## NOTES

### DECONTAMINATION PROCEDURES

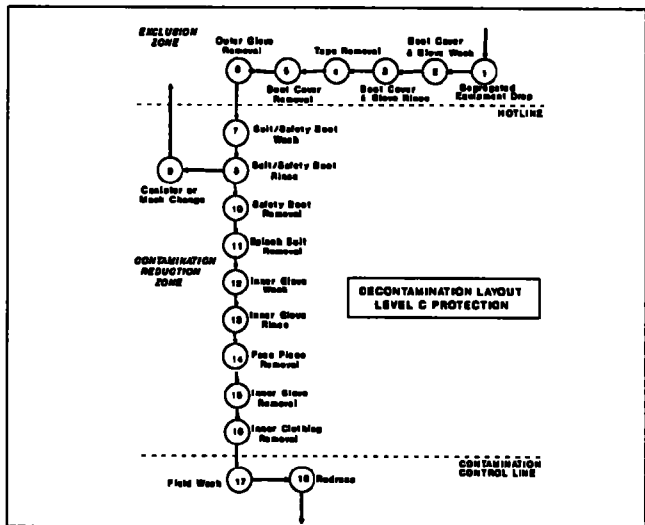
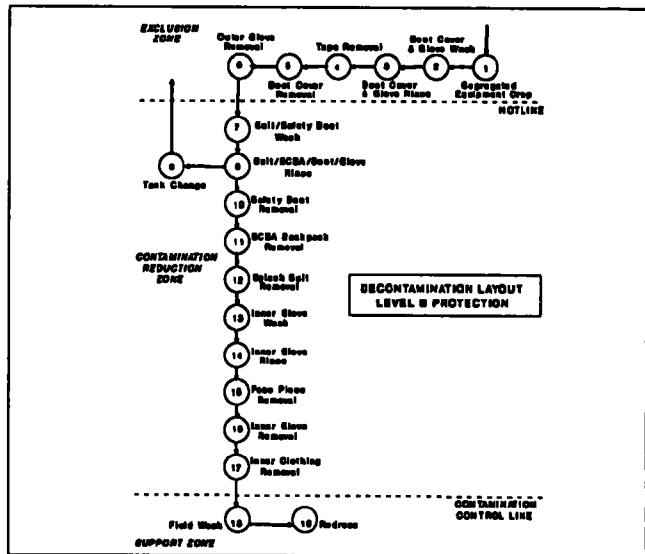
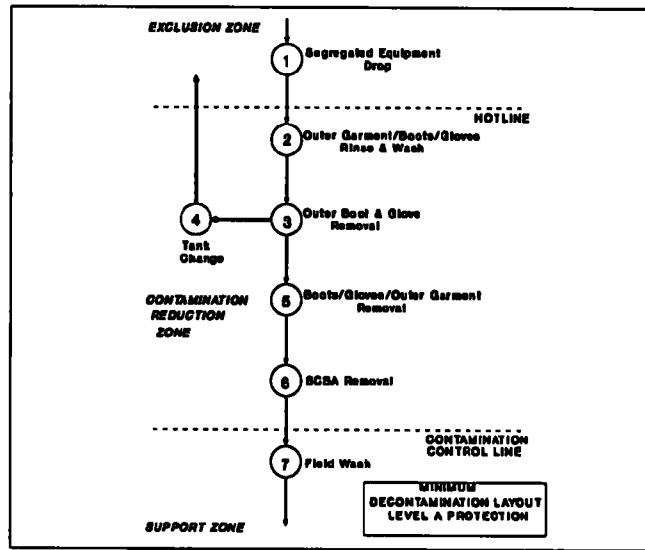
- assume personnel grossly contaminated
- determine level of protection and specific equipment to be worn
- remove protective clothing starting with the most heavily contaminated, ending with the least contaminated
- wash and rinse each piece of protective clothing at least once
- separate each operation by a minimum of 3 ft.
- adapt original decon plan to actual conditions

### DECONTAMINATION WORKERS DETERMINE LEVEL OF PROTECTION BY:

- expected or visible contamination on entry team
- type of contaminant and associated respiratory and skin hazards
- contaminant concentrations in the contamination reduction corridor (CRC)
- results of swipe tests



# NOTES





## **NOTES**

### ***Response Organization***

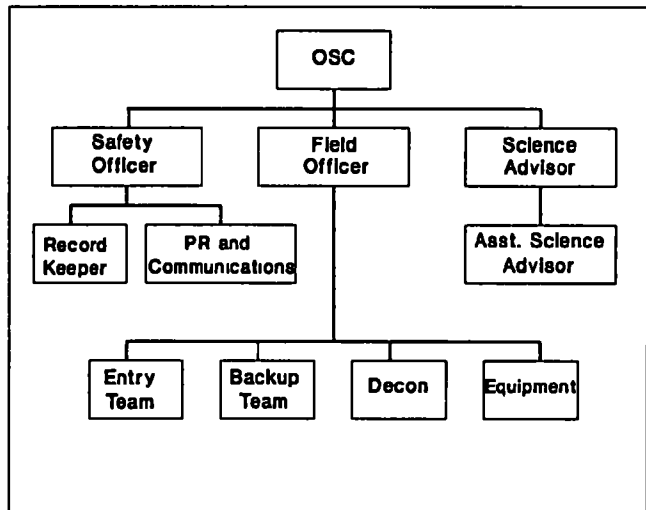
#### **RESPONSE IMPLEMENTATION**

- Organize
- Evaluate situation
- Develop plan of action
  - Make preliminary off-site survey
  - Make initial on-site reconnaissance
- Modify original plan of action
- Complete planned cleanup and restoration

#### **KEY REQUIREMENTS**

- Establish a chain-of-command
- Assign job functions/duties
- Develop personnel requirements
- Establish internal communications

## NOTES



### PERSONNEL

- Project leader/on-scene coordinator/ incident manager •
- Scientific advisor
- Safety officer •
- Field leader
- Public information officer
- Security officer
- Recordkeeper
- Operations officer
- Team leaders
- Financial officer
- Logistics officer
- Medical officer

• Specified by 1910 120

### ON-SITE PERSONNEL

#### PROJECT TEAM LEADER

- Directs response operations.
- Prepares & organizes work plan, site safety plan, and field team.
- Ensures that the work plan is completed and on schedule.

## NOTES

### ON-SITE PERSONNEL

#### SAFETY & HEALTH OFFICER

- Recommends stopping work when conditions warrant.
- Selects personal protective equipment & takes care of storage/maintenance.
- Confirms team member's suitability for work based on physician's recommendation.
- Coordinates emergency medical care.
- Monitors on-site hazards & conditions.

### ON-SITE PERSONNEL

#### FIELD TEAM LEADER

- Responsible for field team operations.
- Executes work plan & schedule.
- Enforces site control & safety.
- Documents field activities & sample collection.

### ON-SITE PERSONNEL

#### SCIENTIFIC ADVISOR

- Advises on field monitoring, sample collection & analysis, scientific studies, data interpretation and remedial plans.

## **NOTES**

### **ON-SITE PERSONNEL**

#### **PUBLIC INFORMATION OFFICER**

- Releases information to the news media & public concerning site activities.

### **ON-SITE PERSONNEL**

#### **LOGISTICS/EQUIPMENT OFFICER**

- Plans & mobilizes facilities, materials and personnel required for response.

### **ON-SITE PERSONNEL**

#### **RECORD KEEPER**

- Maintains official records of site activities.

## ON-SITE PERSONNEL

### DECONTAMINATION OFFICER

- Sets up decon lines.
- Controls decon of all equipment, personnel, and samples.
- Ensures that all required equipment is available.

## ON-SITE PERSONNEL

### ENTRY TEAM/WORK PARTY

- Safely completes the on-site tasks.
- Complies with site safety plan.
- Notifies safety officer of unsafe conditions.

## ON-SITE PERSONNEL

### SECURITY OFFICER

- Manages site security.

## NOTES



## **NOTES**

### **AS-NEEDED PERSONNEL**

- FIREFIGHTERS
- BOMB SQUAD/EXPLOSION EXPERTS
- ENVIRONMENTAL SCIENTISTS
- HAZARDOUS CHEMICAL EXPERTS
- HEALTH PHYSICISTS
- INDUSTRIAL HYGIENISTS
- TOXICOLOGISTS

### **EFFECTIVE ORGANIZATION**

- Designate leader
- Determine objectives
- Establish authority
- Develop policy and procedures
  - Assign duties
  - Plan and direct operations
  - Establish internal communications
  - Manage resources
  - Establish external communications



## HAZARD RECOGNITION

A hazardous material incident is a situation in which a hazardous material has escaped or may escape into the environment. Hundreds of thousands of different chemicals are produced stored, transported, and used annually. Because of the hazardous nature of many of them, safeguards are established to prevent them from causing harm. If these safeguards are accidentally or purposefully disregarded, the material is no longer under effective control. Then a situation is established that can have dangerous effects. Hazardous material incidents vary considerably. Considerations are chemicals and quantities involved, types of hazard, response efforts required, number of responders needed, and effects produced. They may require immediate control measures (emergency) or long term cleanup activities (remedial action) to restore acceptable conditions.

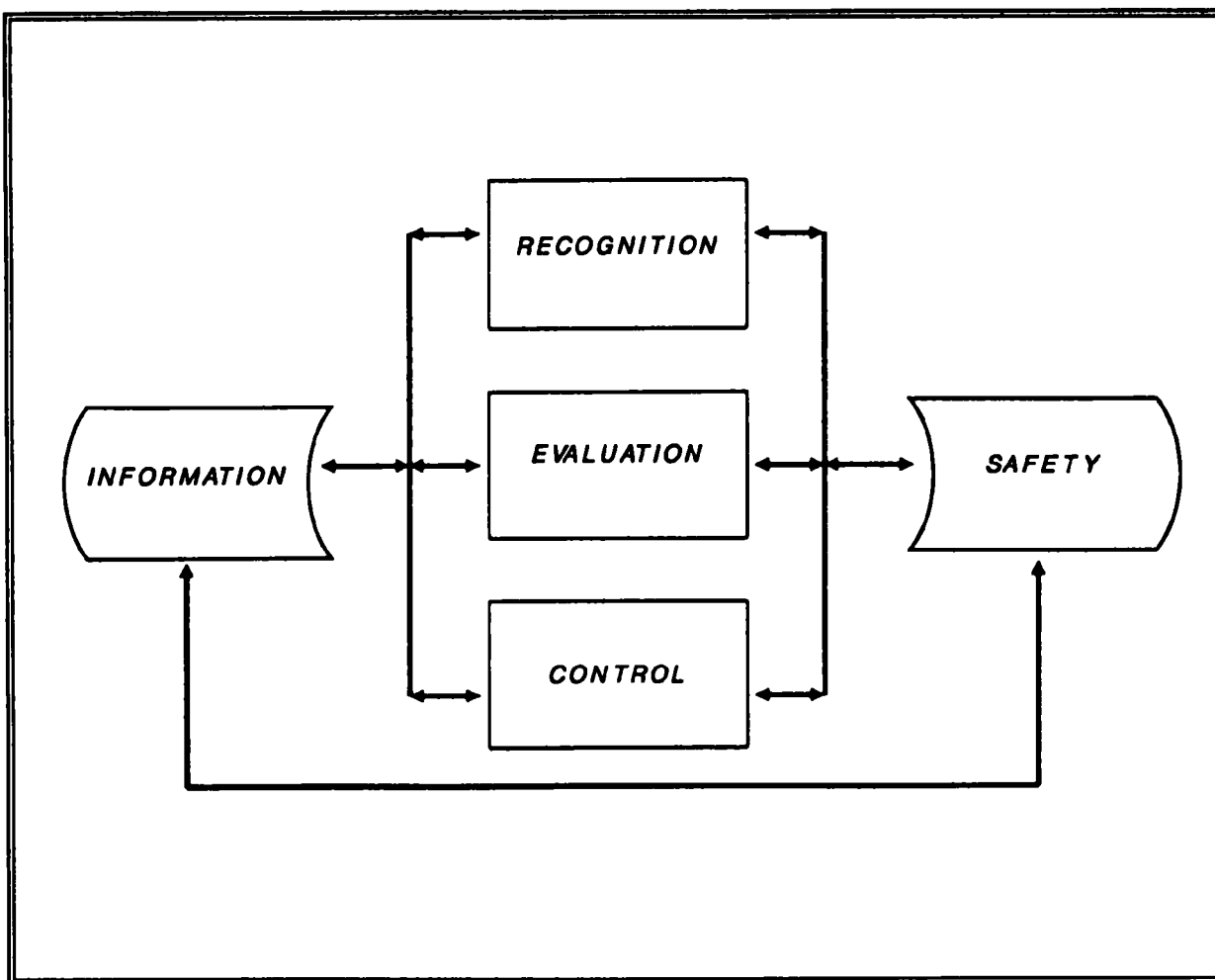
Activities that are required when responding to incidents can be divided into five broad, interacting elements.

- **Recognition:** identification of the substance involved and the characteristics which determine its degree of hazard.
- **Evaluation:** impact or risk the substance poses to the workers, public health and the environment.
- **Control:** methods to eliminate or reduce the impact of the incident.
- **Information:** knowledge gained about the conditions or circumstances particular to an incident. Information is often called intelligence. In a response you gather intelligence and disseminate it.
- **Safety:** protection of responders from harm.

These elements make up a system—an orderly arrangement of components that interact to accomplish a task (Figure 1). In response work, the task is to prevent or reduce the impact of the incident on people, property, and the environment, and to restore conditions to as near normal as possible. To achieve this goal response personnel undertake a variety of activities; for example, firefighting, sampling, developing safety plans, erecting fences, installing a physical treatment system, recordkeeping, evaluation, etc. These activities are all related; what occurs in one affects or is affected by the others.

Five elements classify all response activities. Recognition, evaluation, and control describe performance-oriented elements. There is an outcome - a sample needs collected, a treatment system installed, a chemical identified or a risk determined. Information and safety are supportive elements. They are the results that come from recognizing, evaluating, and controlling.

Understanding the system provides some insight into how response activities relate to each other. It helps explain, in broad terms, the processes involved in responding to a hazardous material incident.



**FIGURE 1**  
**THE INCIDENT RESPONSE SYSTEM**

### **Recognition**

Recognizing the type and degree of the hazard present is usually one of the first steps in responding to an incident. The substance involved must be identified. Then the physical and chemical properties which may make it hazardous - capable of causing harm - are determined. These inherent properties are used, on a preliminary basis, to predict the behavior and anticipated problems associated with a material.

Recognition may be easy. For example, the placard on a railroad tank car carrying a hazardous material is used to quickly identify its content. At a hazardous waste site, which may contain hundreds of different chemicals, complete identification is more difficult. The element of recognition, therefore, involves use of all available information (e.g., sampling results, historical

data, visual observation, instruments, package labels, shipping manifests, existing documentation, witnesses, and other sources) to identify the substances.

An incident involves more than the mere presence of a hazardous material. It is a situation in which the normal safeguards associated with the materials are compromised, thus creating the chance of undesirable effects. For instance, gasoline can do harm because its vapors can ignite and explode. However, the usual safety techniques for handling gasoline prevent this from happening. Problems caused by the release of gasoline into the environment can be anticipated based on its chemical and physical properties. The harm that gasoline will do if released at a site, however, depends on site-specific conditions.

Thousands of substances exhibit one or more characteristics of flammability, radioactivity, corrosiveness, toxicity, or other properties which classify them as hazardous. For any particular hazardous category, the degree of hazard varies depending on the substance. The degree of hazard is a relative measure of how hazardous a substance is. For instance, the Immediately Dangerous to Life or Health (IDLH) concentration of butyl acetate in air is 10,000 parts per million (ppm); the IDLH for sulfur dioxide is 100 ppm. Sulfur dioxide, therefore, is much more acutely toxic (has a higher degree of hazard) when inhaled at IDLH concentrations than butyl acetate. Vapors from butyl acetate, however, have a higher degree of explosive hazard than tetrachloroethane vapors, which are not explosive.

Once the substance(s) has been identified, its hazardous properties and its degree of hazard is determined using reference material. Although appropriate references give information about the substance's physical/ chemical properties and may give indications of its environmental behavior, additional data is required. Most frequently, monitoring and sampling data is used to: (1) identify substances, (2) determine concentrations, (3) confirm dispersion patterns, and (4) verify the presence of material.

## **Evaluation**

Recognition provides basic data about the substance. Evaluation is defined as determining its effects, or potential impact, on public health, property, and the environment. A hazardous substance is a threat due to its physical and chemical characteristics. Its actual impact however, depends on the location of the release, on weather, and other site-specific conditions. Two measures of impact are: (1) the adverse effects that have occurred, and (2) the potential impact of the substance if released. Risk is the chance of harm being done, a measure of the potential impact or effect. The presence of a hazardous substance is a risk, but if the material is under control, the risk is low; if uncontrolled, the risk increases. For harm to be done, a critical receptor must be exposed to the uncontrolled material, as when people live in the area, property will be impacted, or a sensitive ecological habitat will be affected. Chlorine gas, for instance, is highly toxic and represents a risk. If chlorine gas is released in a densely populated area, the risk to people is very great, while the human risk associated with a release of chlorine gas in an unpopulated area is very low. If the substance was carbon dioxide rather than chlorine, the human risk in both situations would be substantially less, since carbon dioxide is much less toxic than chlorine.

Evaluating risk in these two examples is relatively simple. Much more complex are those episodes where many compounds are involved and a higher degree of uncertainty exists regarding their behavior in the environment and their contact with and effects on receptors. For instance: what is the risk if a few thousand people drink from a water supply obtained from an aquifer underlying soil containing a few parts per billion of styrene?

The completeness of information must also be assessed. Is additional sampling and monitoring of air, water, and soil necessary to provide more comprehensive information on what the material is, where it is, how it moves through the environment, what it will contact, and what is the associated risk? To evaluate completely the effects of a hazardous materials incident, all substances must be identified, their dispersion pathways established, and for toxic chemicals, concentrations determined. Risk is then assessed based on exposure (or potential exposure) to the public or other critical receptors.

Identifying the materials involved in an incident and evaluating the impact the incident may have, is frequently termed site characterization. Site characterization may be easy and rapid, or as in the case of an abandoned waste site, a process that may take a long time to completely accomplish.

### **Control**

Control is a method (or methods) which prevents or reduces the impact of the incident. Preliminary control actions are instituted as rapidly as possible in emergency situations. As additional information is developed through recognition and evaluation, initial control actions are modified or others instituted. Releases that do not require immediate action allow more time for planning and instituting remedial measures. Control measures include physical, chemical, and biological treatment and cleanup techniques for restoring the area to prerelease conditions. It also includes public health countermeasures, for example, evacuation or the shutdown of a drinking water supply, to prevent contact of people with the substance.

### **Information**

An integral part of response is information. All response activities evolve having information that is readily available or subsequently obtained. Information is a support element to recognition, evaluation, and control. It is an input to the three performance elements and provides data for decision-making. It is also an outcome of these elements. A sample is collected and analyzed. The results provide an input to determine treatment options, an outcome. Information comes from three sources:

- **Intelligence:** Information obtained from existing records or documentation, placards, labels, signs, special configuration of containers, visual observations, technical reports, and others.
- **Direct-reading instruments:** Information relatively quickly obtained from instruments.
- **Sampling:** Information obtained from collecting representative portions of appropriate media or material and subsequent laboratory analysis.

Information acquisition, analyses, and decision-making are iterative processes that define the extent of the problem and the array of possible response actions. For incident response to be effective, an information base must be established which is accurate, valid, and timely. Throughout the lifetime of the incident, a continuous stream of information is collected, processed, and applied. Sound

decisions are based on (1) receipt and evaluation of good information and (2) development of a good knowledge base concerning the situation.

## **Safety**

All hazardous material responses pose varying dangers to responders. An important consideration in all response activities is to protect the health and safety of the responders. To do this requires that the chemical and physical hazards associated with each operation be assessed and methods implemented to prevent or reduce harm to responders. Safety considerations are an input to every activity that and are an outcome of each response activity. For example, an outcome of identifying a specific chemical may be changes in safety requirements. Each response organization must have an effective health and safety program including medical surveillance and health monitoring, appropriate safety equipment, standardized safety procedures, and an active training program.

## **Relationship of Elements**

Recognition, evaluation, control, information, and safety describe the five elements of response. Each includes a variety of activities or operations. Elements are not necessarily sequential steps for responding. In some situations, control measures can start before the substances are completely identified. In others, a more thorough evaluation of the material's dispersion needs completed before effective control actions can be determined. Likewise, safety measures for workers may be instituted before the materials are identified or all the hazardous conditions fully known.

Each element and activity are interrelated. A dike (control), to contain the runoff water from fighting a fire at a warehouse suspected of containing pesticides, is built. Once determined that the runoff contains no hazardous chemicals (recognition), or that concentrations in the runoff are below acceptable values (evaluation), no treatment is necessary and the dike is removed. This knowledge (information) also changes the safety requirements for responders (safety).

A constant flow of information is needed to characterize the incident and to make decisions. For example, an option to use carbon absorption for water treatment may require additional sample collection and analysis to identify completely the substances involved. In turn, this would require reevaluating the effectiveness of carbon absorption for the identified chemicals.

Additional information regarding where and how the substance is migrating may change the requirements for sampling.

The response system is a concept explaining, in general terms, the processes involved in incident response. All responses require the performance elements of recognizing, evaluating, and controlling. To support these, information is needed and responder safety must be considered.

## **CHEMICAL HAZARDS**

Chemical hazards may be classified according to one of many groups. These groups may include toxic, fire and explosive, corrosive, and chemical reactive. A material may elicit more than one chemical hazard. For example, toxic vapors can be released during chemical fires. The hazard may be a result of the physical/chemical properties of the material or of its chemical reactivity with other materials or the environment to which it is exposed.

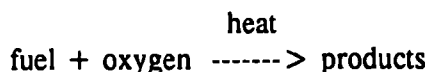
### **Toxic Hazards**

Toxic materials cause local or systemic detrimental effects in an organism. Exposure to such materials does not always result in death, although that is often the most immediate concern. Types of toxic hazards are categorized by the physiological effect they have on the organism. A material may induce more than one physiological response that may include: asphyxiation, irritation allergic sensitization, systemic poisoning, mutagenesis, teratogenesis and carcinogenesis.

The likelihood that any of these effects will be experienced by an organism depends on: (1) the inherent toxicity of the material itself (as measured by its lethal dose); (2) the magnitude of the exposure (acute or chronic) and; (3) the route of exposure (ingestion, inhalation, skin absorption).

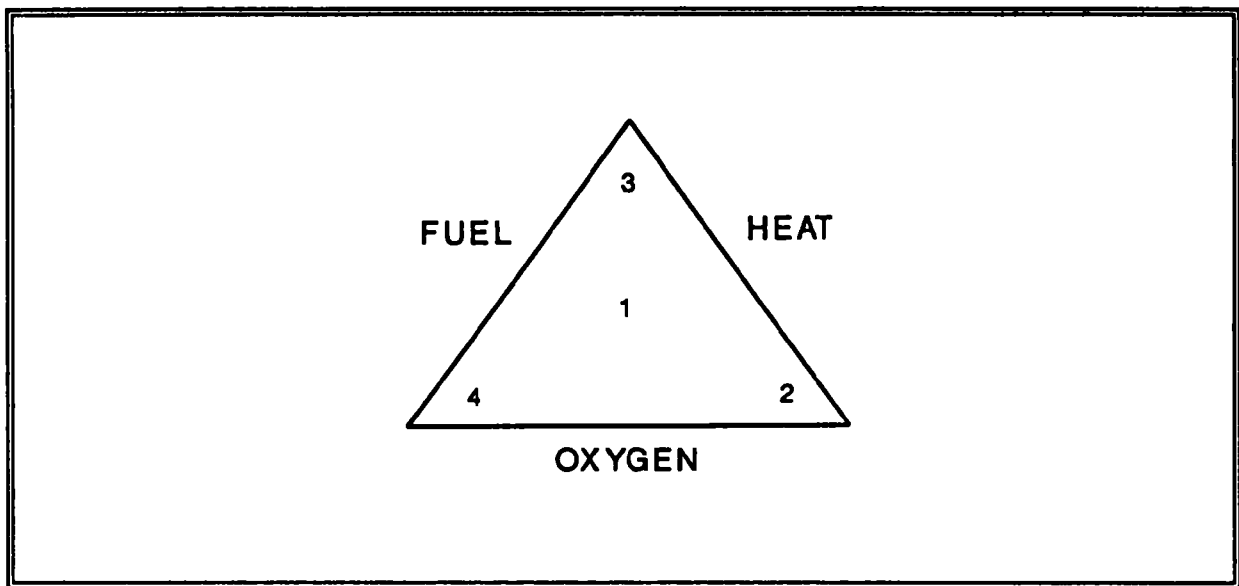
### **Fire and Explosion Hazards**

**Combustibility** is the ability of a material to act as a fuel. Materials that can be readily ignited and sustain a fire are considered combustible. Those that do not are called noncombustible. Three components are required for combustion to occur: fuel, oxygen, and heat. The concentration of fuel and oxygen must be high enough to allow ignition and to maintain the burning process. Combustion is a chemical reaction that requires heat to proceed:



Heat is either supplied by the ignition source and maintained by the combustion, or is supplied from an external source. The relationship of these three components is illustrated by the fire triangle (**Figure 2**). Most fires can be extinguished by removing one of the three components. For example, water applied to a fire removes the heat, thereby extinguishing the fire. When a material by itself generates enough heat to self-ignite and combust, spontaneous combustion occurs, either as a fire or explosion.





**FIGURE 2  
FIRE TRIANGLE**

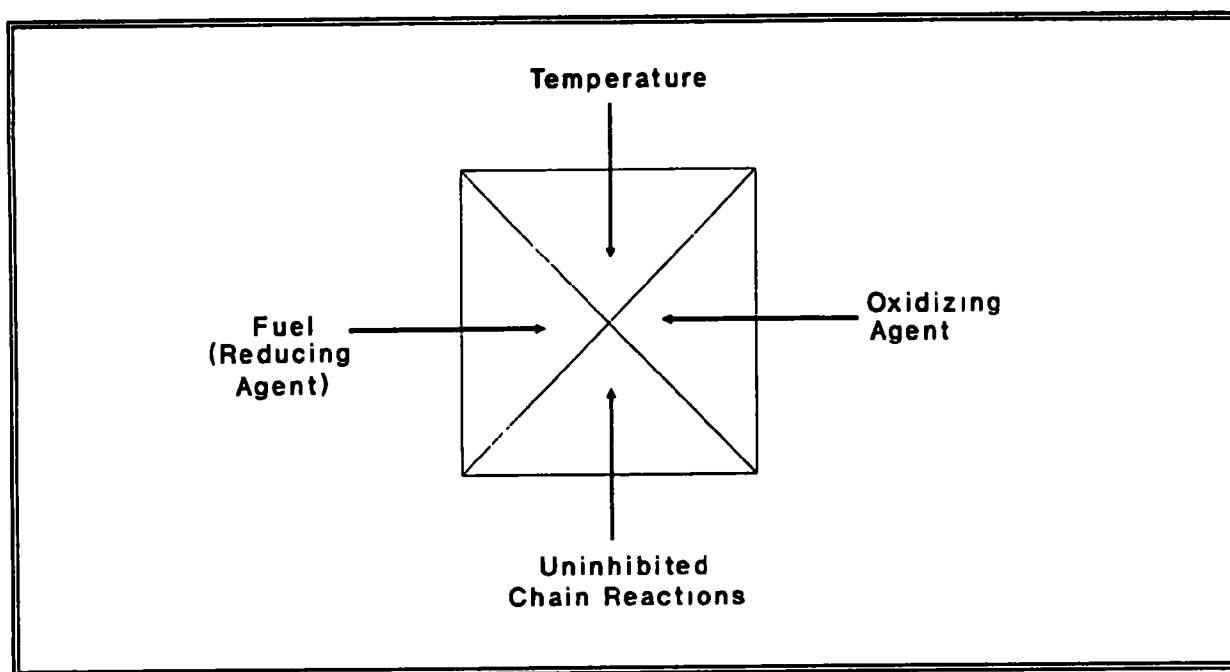
While oxygen is the usual oxidizing agent during the combustion process, there are chemicals that can burn without oxygen being present. For example, calcium and aluminum will burn in nitrogen. Therefore, the first side of the fire tetrahedron (Figure 3) is an oxidizing agent that permits the fuel to burn.

The fuel is the material that oxidized. Since the fuel becomes chemically charged by the oxidizing process, it is a reducing agent. This makes the second side of the tetrahedron. Fuels can be anything from elements (carbon, hydrogen, magnesium) to compounds (cellulose, wood, paper, gasoline, petroleum compounds).

Some mixtures of reducing agent and oxidizing agent remain stable under certain conditions. However, when there is some activation energy, a chain reaction is started, which causes combustion. The factor that can trigger this chemical reaction can be as simple as exposing the combination to light. Once the chain reaction begins, extinguishment must take place by interrupting the chain reaction.

Scientists have known for many years that certain chemicals act as excellent extinguishing agents. However, they were at a loss to explain how these chemicals actually accomplished extinguishment, given the triangle of the fire model. With the development of the tetrahedron model and the inclusion of the uninhibited chain reaction, a scientifically sound theory could be postulated. With this as the basis, the extinguishing capabilities of the halons and certain dry chemicals were possible.

The final side of the tetrahedron is temperature. The fact that temperature is used instead of heat is deliberate. Temperature is the quantity of the disordered energy, which is what initiates combustion. It is possible to have a high heat as indicated by a large reading of Btu and still not have combustion. The temperature is therefore the key ingredient and the one that influences the action of the tetrahedron.



**FIGURE 3**  
**FIRE TETRAHEDRON**

**Flammability** is the ability of a material (liquid or gas) to generate enough concentration of combustible vapors under normal conditions to be ignited and produce a flame. It is necessary to have a proper fuel-to-air ratio (expressed as the percentage of fuel in air) to allow combustion. There is a range of fuel concentrations in air for each material that is optimal for the ignition and the sustenance of combustion. This is the Flammable Range. The lowest concentration of fuel in this range is the Lower Flammable Limit (LFL). Concentrations less than the LFL are not flammable because there is too little fuel—that is, the mixture is too "lean." The highest ratio that is flammable is the Upper Flammable Limit (UFL).

Concentrations greater than the UFL are not flammable because there is too much fuel displacing the oxygen (resulting in too little oxygen). This mixture is too "rich." Fuel concentrations between the LFL and UFL are optimal for starting and sustaining fire. Example: the LFL for benzene is 1.3% (13,000 ppm), the UFL is 7.1% (71,000 ppm), thus the flammable range is 1.3% to 7.1%.

A flammable material is considered highly combustible if it can burn at ambient temperatures (Table 1). But a combustible material is not necessarily flammable, because it may not be easily ignited or the ignition maintained. For example some pyrophoric materials will ignite at room temperature in the presence of a gas or vapor or when a slight friction or shock is applied.

It is important to note that the U. S. Department of Transportation (DOT), the Occupational Safety and Health Administration (OSHA), the National Institute for Occupational Safety and Health (NIOSH), and the National Fire Protection Association (NFPA) have established strict definitions for flammability based on the flash point of a material.

TABLE 1 FLAMMABLE COMPOUNDS AND ELEMENTS	
Flammable Liquids	Flammable Solids
Aldehydes Ketones Amines Ethers Aliphatic hydrocarbons Aromatic hydrocarbons Alcohols Nitroaliphatics	Phosphorus Magnesium dust Zirconium dust Titanium dust Aluminum dust Zinc dust
<u>Water-Reactive Flammable Solids</u>  Potassium Sodium Lithium	<u>Pyrophoric Liquids</u>  Organometallic compounds Dimethyl zinc Tributyl aluminum

An **explosive** is a substance that undergoes a very rapid chemical transformation producing large amounts of gases and heat. The gases produced, for example, nitrogen, oxygen, carbon monoxide, carbon dioxide, and steam, due to the heat produced, rapidly expand at velocities exceeding the speed of sound. This creates both a shockwave (high pressure wave front) and noise.

Explosive gases/vapors exhibit an explosive range, which is the same as the flammable range. The upper explosive limit (UEL) and lower explosive limit (LEL) are the UFL and LFL but in confined areas. Most reference books list either explosive limits or flammable limits which are identical.

A **gas or vapor explosion** is a very rapid, violent release of energy. If combustion is extremely rapid large amounts of kinetic energy, heat, and gaseous products are released. The major factor contributing to the explosion is the confinement of a flammable material.

When vapors or gases cannot freely dissipate, they enter the combustion reaction more rapidly. Confinement also increases the energy associated with these molecules, which enhances the explosive process. Poorly ventilated buildings, sewers, drums, and bulk liquid containers are examples of places where potentially explosive atmospheres may exist.

There are several types of explosive hazards:

- **High or detonating:** Chemical transformation occurs very rapidly with detonation rates as high as 4 miles per second. The rapidly expanding gas produces a shock wave which may be followed by combustion.

- **Primary high explosive:** detonating wave produced in an extremely short period of time. May be detonated by shock, heat, or friction. Examples are lead azide, mercury fulminate, and lead styphnate.
- **Secondary high explosive:** generally needs a booster to cause them to detonate. Relatively insensitive to shock, heat, or friction. Examples are tetryl, cyclonite, dynamite, and TNT.
- **Low or deflagrating:** Rate of deflagration up to 1000 feet per second. Generally combustion followed by a shock wave. Examples are smokeless powder, black powder, and solid rocket fuel.

High or low does not indicate the explosion hazard (or power) but only the rate of chemical transformation. Explosions can occur as a result of reactions between many chemicals not ordinarily considered as explosives. Ammonium nitrate, a fertilizer, can explode under the right conditions. Alkali metals and water explode; as will water and peroxide salts. Picric acid and certain ether compounds become highly explosive with age. Gases, vapors, and finely divided particulates, when confined, can also explode if an ignition source is present.

In summary, fires and explosions require fuel, air (oxygen), and an ignition source (heat). At a hazardous materials incident, the first two are not easily controlled. Consequently, while working on-site where a fire hazard may be present, the concentration of combustible gases in air must be monitored, and any potential ignition source must be kept out of the area.

The most dangerous flammable substances:

- are easily ignited (e.g., pyrophorics).
- require little oxygen to support combustion.
- have low LFL/LEL and a wide flammable/explosive range.

Hazards related to fires and explosions cause:

- physical destruction due to shock waves, heat, and flying objects.
- initiation of secondary fires or creation of flammable conditions.
- release of toxic and corrosive compounds into the surrounding environment.

### **Corrosive Hazards**

**Corrosion** is a process of material degradation. Upon contact, a corrosive material may destroy body tissues, metals, plastics, and other materials. Technically, corrosivity is the ability of material to increase the hydrogen ion or hydronium ion concentration of another material; it may have the potential to transfer electron pairs to or from itself or another substance. A corrosive agent is a reactive compound or element that produces a destructive chemical change in the material upon which it is acting. Common corrosives are the halogens, acids, and bases (Table 2). Skin irritation and burns are typical results when the body contacts an acidic or basic material.

The corrosiveness of acids and bases can be compared on the basis of their ability to dissociate (form ions) in solution. Those that form the greatest number of hydrogen ions ( $H^+$ ) are the strongest acids, while those that form the most hydroxide ions ( $OH^-$ ) are the strongest bases. The  $H^+$  ion concentration in solution is called pH. Strong acids have a low pH (many  $H^+$  in solution) while strong bases have a high pH (few  $H^+$  in solution; many  $OH^-$  in solution). The pH scale ranges from 0 to 14 as follows:

< *Increasing acidity*                      *Neutral*                      *Increasing basicity* >  
 0   1   2   3   4   5   6   7   8   9   10   11   12   13   14

Measurements of pH are valuable because they can be quickly done on-site, providing immediate information on the corrosive hazard.

TABLE 2 CORROSIVES	
<b><u>HALOGENS</u></b>  Bromine Chlorine Fluorine Iodine  <b><u>BASES (CAUSTICS)</u></b>  Potassium hydroxide Sodium hydroxide	<b><u>ACIDS</u></b>  Acetic acid Hydrochloric acid Hydrofluoric acid Nitric acid Sulfuric acid

When dealing with corrosive materials in the field, it is imperative to determine:

- How toxic is the corrosive material? Is it an irritant or does it cause severe burns?
- What kind of structural damage does it do, and what other hazards occur? For example, will it destroy containers holding other hazardous materials, releasing them into the environment?

### **Chemical Reactivity**

A **reactive material** is one that undergoes a chemical reaction under certain specified conditions. Generally, the term "reactive hazard" is used to refer to a substance that undergoes a violent or abnormal reaction in the presence of either water or normal ambient atmospheric conditions. Among this type of hazard are the pyrophoric liquids which will ignite in air at or below normal room temperature in the absence of added heat, shock, or friction, and the water-reactive flammable solids which will spontaneously combust upon contact with water (Table 1).

A **chemical reaction** is the interaction of two or more substances, resulting in chemical changes. Exothermic chemical reactions, which give off heat, can be the most dangerous. A separate source of heat is required to maintain endothermic chemical reactions. Removing the heat source stops the reaction.

Chemical reactions usually occur in one of the following ways:

- Combination       $A + B \rightarrow AB$
- Decomposition       $AB \rightarrow A + B$
- Single replacement       $A + BC \rightarrow B + AC$
- Double replacement       $AB + CD \rightarrow AD + CB$

The rate at which a chemical reaction occurs depends on the following factors:

- Surface area of reactants available at the reaction site (for example, a large chunk of coal is combustible, but coal dust is explosive)
- Physical state of reactant - solid, liquid, or gas
- Concentration of reactants
- Temperature
- Pressure
- Presence of a catalyst.

If two or more hazardous materials remain in contact indefinitely without reaction, they are **compatible**. Incompatibility, however, does not necessarily indicate a hazard. For example, acids and bases (both corrosive) react to form salts and water, which may not be corrosive.

Many operations on waste or accident sites involve mixing or unavoidable contact between different hazardous materials. It is important to know ahead of time if such materials are compatible. If they are not, then any number of chemical reactions could occur. The results could range from the formation of an innocuous gas to a violent explosion. Table 3 illustrates what happens when some incompatible materials are combined.

The identity of unknown reactants must be determined by chemical analysis to establish compatibility. On the basis of their properties, a chemist then should be able to anticipate any chemical reactions resulting from mixing the reactants. Judging the compatibility of more than two reactants is very difficult; analysis should be performed on a one-to-one basis.

Response personnel who must determine compatibilities should refer to *A Method for Determining the Compatibility of Hazardous Wastes* (EPA 600/2-80-076), published by EPA's Office of Research and Development. Final decisions about compatibilities should only be made by an experienced chemist.

Sometimes the identity of a waste is impossible to ascertain due to money and time constraints. In this event, simple tests must be performed to determine the nature of the material or mixture. Tests such as pH, oxidation-reduction potential, and flash point are useful. In addition, very small amounts of the reactants may be carefully combined to determine compatibility.

If materials are compatible they may be stored together in bulk tanks or transferred to tank trucks for ultimate disposal. It is necessary, then, to establish the compatibility of the materials through analyses prior to bulking them. Compatibility information is also very important in evaluating an accident involving several different hazardous materials. The ultimate handling and treatment of the materials may be partially based on such information.

<b>TABLE 3</b> <b>HAZARDS DUE TO CHEMICAL REACTIONS (INCOMPATIBILITIES)</b>	
Heat Generation	Acid and Water
Fire	Hydrogen Sulfide and Calcium Hypochlorite
Explosion	Picric Acid and Sodium Hydroxide
Toxic Gas or Vapor Production	Sulfuric Acid and Plastic
Flammable Gas or Vapor Production	Acid and Metal
Formation of a Substance with Greater Toxicity than the Reactants	Chlorine and Ammonia
Formation of Shock or Friction Sensitive Compounds	Peroxides and Organics <u>OR</u> Liquid Oxygen and Petroleum Products
Pressurization of Closed Vessels	Fire Extinguisher
Solubilization of Toxic Substances	Hydrochloric Acid and Chromium
Dispersal of Toxic Dusts and Mists	Sodium or Potassium Cyanide and Water or Acid Vapor
Violent Polymerization	Ammonia and Acrylonitrile

### **Properties of Chemical Hazards**

Chemical compounds possess inherent properties which determine the type and degree of the hazard they represent. Evaluating risks of an incident depends on understanding these properties and their relationship to the environment.

The ability of a solid, liquid, gas or vapor to dissolve in a solvent is **solubility**. An insoluble substance can be physically mixed or blended in a solvent for a short time but is unchanged when it finally separates. The solubility of a substance is independent of its density or specific gravity. The solubility of a material is important when determining its reactivity, dispersion, mitigation, and treatment. Solubility can be given in parts per million (ppm) or milligrams per liter (mg/L)

The **density** of a substance is its mass per unit volume, commonly expressed in grams per cubic centimeter (g/cc). The density of water is 1 g/cc since 1 cc has a mass of 1 g.

**Specific gravity (SpG)** is the ratio of the density of a substance (at a given temperature) to the density of water at the temperature of its maximum density (4°C). Numerically, SpG is equal to the density in g/cc, but is expressed as a pure number without units. If the SpG of a substance is greater than 1 (the SpG of water), it will sink in water. The substance will float on water if its SpG is less than 1. This is important when considering mitigation and treatment methods.

The **density of a gas or vapor** can be compared to the density of the ambient atmosphere. If the density of a vapor or gas is greater than that of the ambient air, then it will tend to settle to the lowest point. If vapor density is close to air density or lower, the vapor will tend to disperse in the atmosphere. Vapor density is given in relative terms similar to specific gravity. In settling, dense vapor creates two hazards. First, if the vapor displaces enough air to reduce the atmospheric concentration of oxygen below 16%, asphyxia may result. Second, if the vapor is toxic, then inhalation problems predominate even if the atmosphere is not oxygen deficient. If a substance is explosive and very dense, the explosive hazard may be close to the ground rather than at the breathing zone (normal sampling heights).

The pressure exerted by a vapor against the sides of a closed container is called **vapor pressure**. It is temperature dependent. As temperature increases, so does the vapor pressure. Thus, more liquid evaporates or vaporizes. The lower the boiling point of the liquid, the greater the vapor pressure it will exert at a given temperature. Values for vapor pressure are most often given as millimeters of mercury (mm Hg) at a specific temperature.

The **boiling point** is the temperature at which a liquid changes to vapor - that is, it is the temperature where the pressure of the liquid equals atmospheric pressure. The opposite change in phases is the condensation point. Handbooks usually list temperatures as degrees Celsius (°C) or Fahrenheit (°F). A major consideration with toxic substances is how they enter the body. With high-boiling-point liquids, the most common entry is by body contact. With low-boiling-point liquids, the inhalation route is the most common and serious.

The temperature at which a solid changes phase to a liquid is the **melting point**. This temperature is also the freezing point, since a liquid can change phase to a solid. The proper terminology depends on the direction of the phase change. If a substance has been transported at a temperature that maintains a solid phase, then a change in temperature may cause the solid to melt. The particular substance may exhibit totally different properties depending on phase. One phase could be inert while the other highly reactive. Thus, it is imperative to recognize the possibility of a substance changing phase due to changes in the ambient temperature.

The minimum temperature at which a substance produces enough flammable vapors to ignite is its **flash point**. If the vapor does ignite, combustion can continue as long as the temperature remains at or above the flash point. The relative flammability of a substance is based on its flash point. An accepted relation between the two is:

Highly flammable:	Flash point less than 100°F
Moderately flammable:	Flash point greater than 100°F but less than 200°F
Relatively inflammable:	Flash point greater than 200°F



## **SAFETY HAZARDS**

Safety is the condition of being secure from undergoing or causing hurt, injury, or loss. In this definition, safety requires a twofold posture - offensive and defensive. The offensive posture provides protection for actions one can control. The defensive posture is the awareness of factors or situations others may create. Care must be taken that actions to protect or reduce accident potentials for one person do not set up conditions ("booby traps") for subsequent accidents by others.

### **Kinetic/Mechanical**

Generally referred to as "slip-trip-fall" type injuries, the kinetic/mechanical category includes "struck-by" injuries along with the "striking" injuries.

Workers must walk cautiously at a site to avoid tripping. Abandoned wastes usually are not kept neat and tidy. Train or other vehicle wrecks can produce debris that can increase the possibility of tripping. Problems at a hazardous waste site and an accident scene can be compounded by uneven terrain and mud, caused by rain or leaking chemicals.

Walking on drums is dangerous. Not only can they tip over, but they can be so corroded that they cannot support a person's weight. If it is necessary to walk over drums, place a piece of plywood over several drums and stand on this. This distributes the walker's weight over several drums. In some cases, a drum grappler can be used to move drums to a more accessible location.

Extra precautions must be taken if guardrails or railing are absent. The precautions generally include the use of a safety belt with lifeline.

### **Electrical**

Electrical hazards can exist at accident sites because of downed power lines or improper use of electrical equipment. The presence of underground electric lines must be checked before any digging or excavating. When using cranes or material handlers, care must be taken that the machinery does not come in contact with any energized lines. There should be a 10-foot clearance between a crane and electric power lines unless the lines have been deenergized or an insulating barrier has been erected. Shock is the primary hazard from electrical tools. Electrical shock may cause death or burns or falls that lead to injury.

Ways for protecting personnel from shock are:

- **Grounding equipment.** Grounding drains current, due to a short circuit, to earth. The ground wire is the third wire on three prong plugs. Equipment can also be grounded by a separate wire attached to the metal parts of equipment.
- **Using double-insulated tools.** These tools do not need to be grounded because they are: encased by a nonconductive material which is shatterproof, or have a layer of insulating material isolating the electrical components from a metal housing (used for

more rugged design). This insulation is in addition to that found in regular tools. Double-insulated tools are identified by writing on the tool or by the symbol of a square within a square ([□]).

- **Having overcurrent devices such as:** (1) fuses, which interrupt current by melting a fusible metal strip, or (2) circuit breakers, which operate by temperature change or magnetic difference.

Overcurrent devices open the circuit automatically if the current is high from accidental ground, short circuit or overload. They should be selected based on type of equipment and capacity. A ground fault circuit interrupter (GFCI) device can be used to protect personnel and equipment. This device breaks a circuit when it detects low levels of current leaking to ground. It is fast-acting to keep the size of the current and its duration so low that it cannot produce serious injury. This device only operates on line-to-ground fault currents and not on line-to-line contact. It is commonly used on construction sites and in hospitals. Additionally, tools and flexible cords should be inspected for damage that could lead to shock. For more detailed information check the National Electrical Code (National Fire Protection Association Section 70).

### **Acoustic**

Excessive acoustic energy can destroy the ability to hear and may also put stress on other parts of the body, including the heart. There is no cure for most effects of noise, therefore prevention is the only way to avoid health damage. The damage depends mainly on the intensity and length of exposure. The frequency or pitch can also have some effect and high-pitched sounds are more damaging than low-pitched ones.

Noise may tire out the inner ear, causing hearing loss. After a period of time off, hearing may be restored. Under some circumstances the damage may become permanent because cells in the inner ear have been destroyed and can never be replaced or repaired. Permanent damage can be caused by long-term exposure to loud noise, or in some cases, by brief exposure to very loud noises (explosions, shock waves).

Although research on the effects of noise on other parts of the body is not complete, it appears that excessive noise can quicken the pulse rate, increase blood pressure, and narrow blood vessels. Over a long period of time, these may place an added burden on the heart.

Excessive noise may also put stress on other parts of the body by causing the abnormal secretion of hormones and tensing of muscles. Workers exposed to noise sometimes complain of nervousness, sleeplessness, and fatigue. Excessive noise exposure also can reduce job performance and may cause high rates of absenteeism.

OSHA regulation 29 CFR 1910.95 limits a worker's noise exposure to 90 decibels -A weighted (dBA) for an 8-hour exposure. Time limits are shorter for higher noise levels. Decibel is the unit used in sound level measurements. Instruments generally are designed to use an A-weighted scale so that the instrument responds to the different sound frequencies in the same way as the human ear.

When daily noise exposure is composed of two or more periods of different noise levels, their combined effect should be considered, rather than the individual effect of each. If the sum—a time-weighted average (TWA)—of the following fractions  $C_1/T_1 + C_2/T_2 \dots C_n/T_n$  exceeds 1, then the mixed exposure should be considered to exceed the limit value.  $C_n$  indicates the total time of exposure at a specific noise level, and  $T_n$  indicates the total time of exposure permitted at that level.

Recent rule-making by OSHA requires a continued, effective hearing conservation program whenever worker noise exposures equal or exceed an 8-hour time-weighted average sound level (TWA) of 85 decibels measured on the A scale (dBA) or, equivalently, a dose of 50 percent.

The main elements of the hearing conservation program are:

- Monitoring of workers' exposures.
- An audiometric testing program for those exposed above a 85 dBA TWA. This requires a "baseline" audiogram for comparison and annual retesting to see if there is any hearing loss.
- Hearing protection available for those exposed to above 85 dBA TWA. If the TWA is above 90 dBA, or if it is above 85 dBA and the worker shows a permanent significant hearing loss, then hearing protection is required to be worn.
- Informing exposed workers about noise hazards (or effects) and the elements of a hearing conservation program.

The U.S. Environmental Protection Agency (EPA) recommends that, for an 8-hour work day, workers should not be exposed to noise levels above 85 dBA TWA. EPA's goal is to reduce that level to 75 dBA. EPA also recommends that individuals should not be exposed to 70 dBA TWA for an entire 24-hour day.

## **BIOLOGICAL HAZARDS**

Animal bites, insect stings, contact with plants and microbes, and exposure to medical/infectious wastes are examples of biological hazards that response personnel may encounter.

**Animal bites or insect stings** are usually nuisances (localized swelling, itching, and minor pain) that can be handled by first aid treatments. The bites of certain snakes, lizards, spiders, and scorpions contain sufficient poison to warrant medical attention.

There are diseases that can be transmitted by animal bites. Examples are Rocky Mountain spotted fever (tick), rabies (mainly dogs, skunks and foxes), malaria, and equine encephalitis (mosquito). The biggest hazard and most common cause of fatalities from animal bites—particularly bees, wasps, and spiders—is a sensitivity reaction. Anaphylactic shock due to stings can lead to severe reactions to the circulatory, respiratory, and central nervous system, and it can also cause death.

**Toxic effects from plants** are generally due to ingestion of nuts, fruits, or leaves. Of more concern to response personnel are certain plants, including poison ivy, poison oak, and poison sumac, which produce adverse effects from direct contact.

The usual effect is dermatitis - inflammation of the skin. The protective clothing and decontamination procedures used for chemicals also reduce the exposure risk from the plant toxins. Cleaning the skin thoroughly with soap and water after contact will reduce the risk.

Another source of infection for response workers is poor sanitation. Water borne and food borne diseases can be a problem if adequate precautions are not taken. Examples of water borne diseases are cholera, typhoid fever, viral hepatitis, salmonellosis, bacillary dysentery, and amebic dysentery. In an emergency response related to a disaster, water supplies may be affected. The source of water for a long-term remedial action is also important. In some locations, it may be necessary to transport water and food to the site. They must be handled properly and come from an uncontaminated source.

The response team must also avoid creating any sanitation problems by making sure that properly designed lavatory facilities are available at the worksite.

**Microbial hazards** can occur when the materials the workers are handling have biological as well as chemical contamination. This can be a problem if a chemical spill is into or mixed with sewage. Most bacteria that affect humans prefer a neutral environment (pH 7). Thus an extremely acid or alkaline environment would destroy or inhibit bacterial growth. However, during neutralization, the environment could become more conducive to bacteria growth. In these situations, the normal decontamination procedures will usually alleviate the problem.

**Medical/infectious wastes** include **blood borne pathogens** which are regulated by OSHA 29 CFR 1910.1030. This standard specifically addresses proper engineering controls, work practices, and personal protective equipment to reduce the risk of contact with blood borne pathogens.

## **RADIATION HAZARDS**

Radioactive materials that may be encountered at a site can emit three types of harmful radiation: alpha particles, beta particles, and gamma waves. All three forms harm living organisms by imparting energy which ionizes molecules in the cells. Therefore, the three are referred to as ionizing radiation. Ionization may upset the normal cellular function causing cell dysfunction or death.

An alpha particle is positively charged. The beta is an electron possessing a negative charge. Both particles have mass and energy. Both are emitted from the nucleus. They travel short distances in material before interactions with the material causes them to lose their energy. The outer layers of the skin and clothing generally protect against these particles. Therefore, they are considered hazardous primarily when they enter the body through inhalation or ingestion.

Gamma radiation is pure electromagnetic energy and is wave-like rather than particulate. Gamma waves pass through all materials to some degree. Clothing, including protective gear, will not prevent gamma radiation from interacting with body tissue.

Unlike many hazardous substances that possess certain properties which can alert response personnel to overexposures (odor, irritation, or taste), radiation has no such warning properties. Therefore, preventing radiation material from entering the body or protecting against external radiation is the best protection. As with biological and chemical hazards, the use of respiratory and personnel protective equipment, coupled with scrupulous personal hygiene, will afford good protection against radioactive particulates.

### **CONFINED SPACE HAZARDS**

NIOSH defines a **confined space** as any space which by design has limited openings for entry and exit; unfavorable natural ventilation which could contain or produce dangerous air contaminants, and which is not intended for continuous worker occupancy. Examples of confined spaces would include storage tanks, holds of ships, process vessels, pits, silos, boilers, ventilation and exhaust ducts, sewers, tunnels, underground utility vaults, and pipelines.

The NIOSH classifications of confined spaces use a checklist to prepare for and carry out confined space operations safely. These checklists are found in NIOSH's *Criteria for a Recommended Standard: Working in Confined Spaces*. This document should be studied completely by anyone responsible for the oversight of confined space work. Particular professional judgement, skill, and experience is required to conduct confined space operations safely. All items listed on the checklist must be in place and in use to ensure worker health and safety during the most dangerous hazardous materials work activity: that of confined space work.

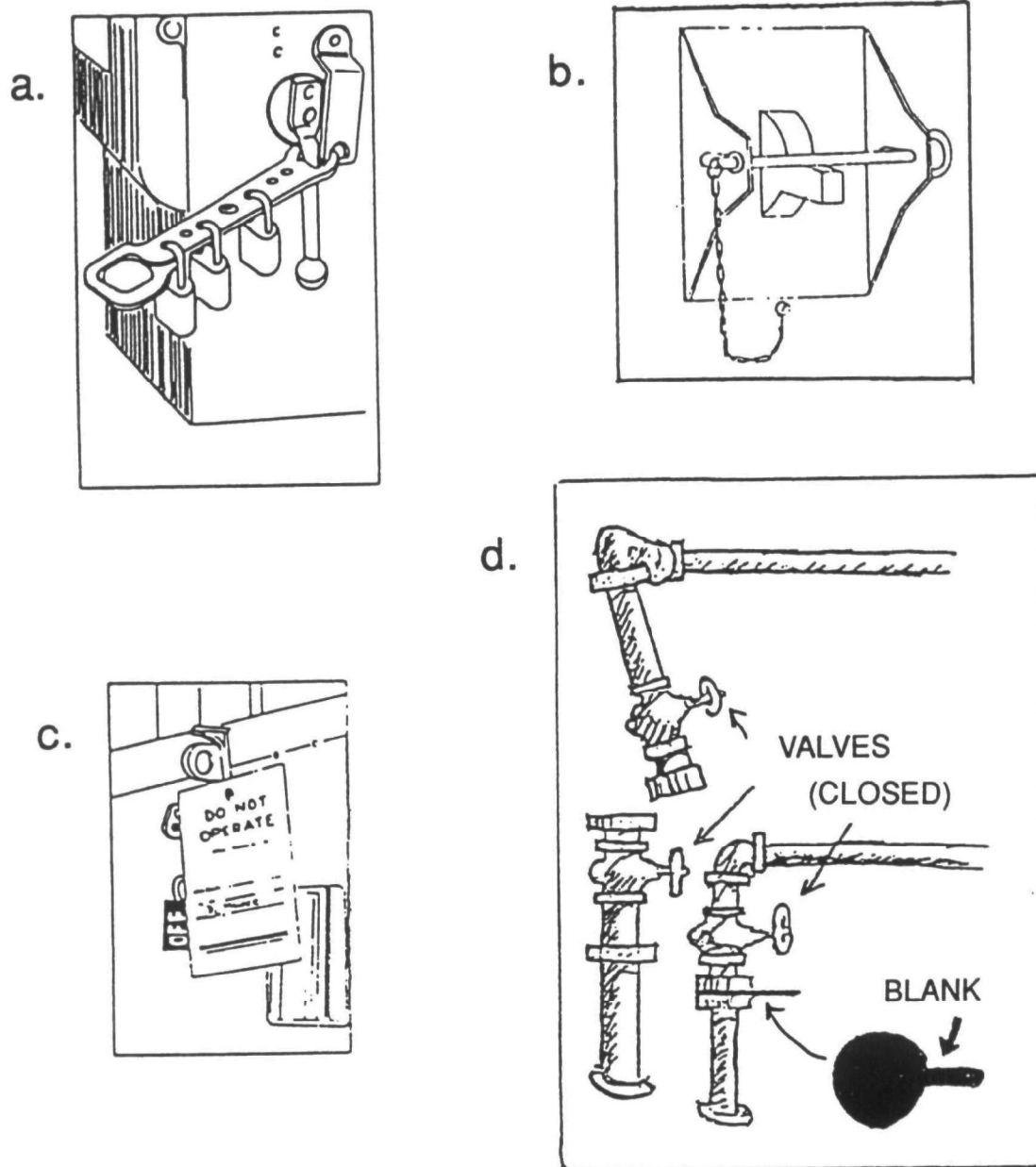
Although complete data are not available, working in confined spaces is recognized as the most dangerous type of work involving hazardous materials. The very nature of a confined space increases the likelihood of encountering a toxic atmosphere because the confined space encourages the accumulation of gases and vapor. A very high rate of accidents involving worker fatalities is associated with confined spaces. Again, while complete data are impossible to obtain, studies have suggested that as many as two-thirds of all confined space fatalities are would-be rescuers. For every worker that initially is overcome and eventually dies as a result to a confined space exposure, perhaps two would-be rescuers are succumbing also. The main reason that this occurs is that workers do not recognize the hazard presented by the confined space.

A closed building or room are examples of confined spaces that response personnel may encounter. Procedures for entry into a confined space are very similar to entry into a site. Because of poor ventilation, high concentrations of gases or vapors are more likely to exist in a confined space than at an open site. Also, certain confined spaces may contain hazardous materials. For example, hydrogen sulfide and methane are often in sewers. Also, a large amount of organic material in an enclosed space can combine with oxygen in the surrounding air to produce an oxygen deficient atmosphere.

Besides the problem with possible high concentration of gases or vapors, confined spaces also present an entrance and exit problem. Most of the spaces mentioned earlier have only small openings for entry and exit. This can interfere with use of equipment like self-contained breathing apparatus (SCBA). In some cases an airline respirator may have to be used in place of an SCBA. Because of this problem, and in case a worker is injured, a lifeline is often attached to the worker to aid in pulling him out. That way rescuers would not have to enter the space. A lifeline is especially important in spaces where access is through an opening in the top of the space.

**Lockout, blocking, or equivalent measures** may be needed to ensure that deactivated systems are not reactivated at inopportune times (**Figure 4**). These procedures are usually used when someone is working on or around equipment that could cause injury if it is accidentally turned on.

The general procedure is to turn off the equipment at a point where it can be locked so that the equipment cannot be turned on. An example is the main power disconnect on a fuse box. Most boxes have a tab and hole where a lock can be placed so the switch cannot be turned back on. For piping systems, not only can the valve be turned off, but the pipes can be disconnected or a "blank" - a flat plate inserted in the pipeline. These two methods may be used in lieu of actually locking a valve. The advantage of using an actual lock is that only one person has a key; therefore, only he can reactivate the equipment after he is done with repair work. In some cases, there may be several workers, each using a different lock on a switch so that all locks have to be removed before equipment can be used.



**FIGURE 4**  
**LOCKOUT, BLOCKING, AND TAGGING**

- (a) Multiple locks
- (b) Block on switch
- (c) Tag
- (d) Disconnecting and "blanking" pipeline

## **MEDICAL EMERGENCIES**

Hazardous material environments pose unique health hazards for personnel. A medical program is necessary to assess and monitor the workers' health and fitness both prior to work and during the course of work activities. It is important for personnel to recognize medical emergencies and to be trained on emergency procedures and treatment.

### **Heat Stress**

The human body is designed to function at a certain internal temperature. When metabolism or external sources (fire, hot summer day) cause the body temperature to rise, the body seeks to protect itself by triggering cooling mechanisms. Excess heat is dissipated by two means:

- Changes in blood flow to dissipate heat by convection, which can be seen as "flushing" or reddening of the skin in extreme cases.
- Perspiration, the release of water through skin and sweat glands. While working in hot environments, evaporation of perspiration is the primary cooling mechanism.

Protective clothing worn to guard against chemical contact effectively stops the evaporation of perspiration. Thus the use of protective clothing increases heat stress problems.

The major disorders due to heat stress are heat cramps, heat exhaustion, and heat stroke. **Heat cramps** are painful spasms which occur in the skeletal muscles of workers who sweat profusely in the heat and drink large quantities of water, but fail to replace the body's lost salts or electrolytes. Drinking water while continuing to lose salt tends to dilute the body's extracellular fluids. Soon water seeps by osmosis into active muscles and causes pain. Muscles fatigued from work are usually most susceptible to cramps.

**Heat exhaustion** is characterized by extreme weakness or fatigue, dizziness, nausea, and headache. In serious cases, a person may vomit or lose consciousness. The skin is clammy and moist, complexion pale or flushed, and body temperature normal or slightly higher than normal. Treatment is rest in a cool place and replacement of body water lost by perspiration. Mild cases may recover spontaneously with this treatment; severe cases may require care for several days. There are no permanent effects.

**Heat stroke** is a very serious condition caused by the breakdown of the body's heat regulating mechanism. The skin is very dry and hot with a red, mottled or bluish appearance. Unconsciousness, mental confusion, or convulsions may occur. Without quick and adequate treatment, the result can be death or permanent brain damage. Get medical assistance quickly! As first aid treatment, the person should be moved to a cool place. Body heat should be reduced artificially, but not too rapidly, by soaking the person's clothes with water and fanning them.



Steps that can be taken to reduce heat stress are:

- **Acclimatize the body.** Allow a period of adjustment to make further heat exposure endurable. It is recommended that a new worker start at 50% of the anticipated total work load for the first day and increase the work load gradually each succeeding day for about a week. Acclimatization can be "lost" if a worker is away from the heat for two weeks.
- **Drink more liquids** to replace body water lost during sweating.
- **Rest frequently.**
- **Increase salt consumption.** Sweat is mostly water with smaller amounts of sodium and potassium salts. Replacement fluids should be similar in composition. Thus, salt tablets usually are not necessary and can be harmful. It is better to increase salt on food or drink commercially available preparations that provide the proper balance of water and salts.
- **Wear personal cooling devices.** There are two basic designs; units with pockets for holding frozen packets and units that circulate a cooling fluid from a reservoir through tubes to different parts of the body. Both designs can be in the form of a vest, jacket, or coverall. Some circulating units also have a cap for cooling the head.
- **Wear supplied air suits or respirators** that are equipped with a vortex tube that either cools or warms the air being supplied. The vortex tube is not used with self-contained breathing apparatus because it uses large amounts of compressed air during operation.
- **Wear cotton long underwear** under chemical protective clothing. The cotton will absorb perspiration and will hold it close to the skin. This will provide the body with the maximum cooling available from the limited evaporation that takes place beneath chemical resistant clothing. It also allows for rapid cooling of the body when the protective clothing is removed.

There are instruments that measure air temperature, radiant heat, and humidity to give a heat index. NIOSH, the American Conference of Governmental Industrial Hygienists (ACGIH), and other groups use this index in their guidelines on heat stress. However, these guidelines are usually valid only for acclimatized personnel wearing light summer clothing and not chemical resistant or insulating protective gear.

### **Cold Exposure**

Cold temperatures can also cause medical problems. The severe effects are frostbite and hypothermia.

**Frostbite** is the most common injury resulting from exposure to cold. The extremities of the body are most often affected. The signs of frostbite are: the skin turns white or grayish-yellow, pain is

sometimes felt early but subsides later (often there is no pain), and the affected part feels intensely cold and numb.

Standard first aid for frostbite includes getting the victim to a warm shelter. Put frozen parts in warm water (100-105°F) but not hot water. Handle parts gently and do not rub or massage them. If toes and finger are affected, put dry, sterile gauze between them after warming them. Loosely bandage the injured parts. If the part has been thawed and refrozen, rewarm it at room temperature.

**Hypothermia** is characterized by shivering, numbness, drowsiness, muscular weakness and a low internal body temperature when the body feels warm externally. This can lead to unconsciousness and death. In the case of hypothermia, professional medical care should be sought immediately. A victim should be taken out of the cold and into dry clothing. The body should be warmed slowly.

### **Medical Surveillance**

Medical surveillance is important in two ways. First, since response workers are handling materials that can damage their bodies, they must be checked to determine if any damage is occurring. There are medical tests for determining if a worker has too much of a chemical in their system. For example, blood tests can detect lead and carbon monoxide, urine tests can detect arsenic, and there are tests to determine if the liver is functioning properly. Exhaled air and hair and nail clippings can also be analyzed for the presence of chemicals. Workers showing an abnormal amount of chemical in their systems should be removed from their assignments or have their operating procedures reevaluated.

The second reason for medical surveillance is to ensure the worker is capable of doing the job. Using respiratory protection strains the pulmonary system. OSHA General Industry Standard 29 CFR 1910.134(b)(10) states that "Persons should not be assigned to tasks requiring use of respirators unless it has been determined that they are physically able to perform the work and use the equipment." Heat stress can be a problem for workers wearing protective clothing. Thus, in some situations, it would be advisable to check workers for symptoms of heat stress.

### **Medical Emergencies and First Aid**

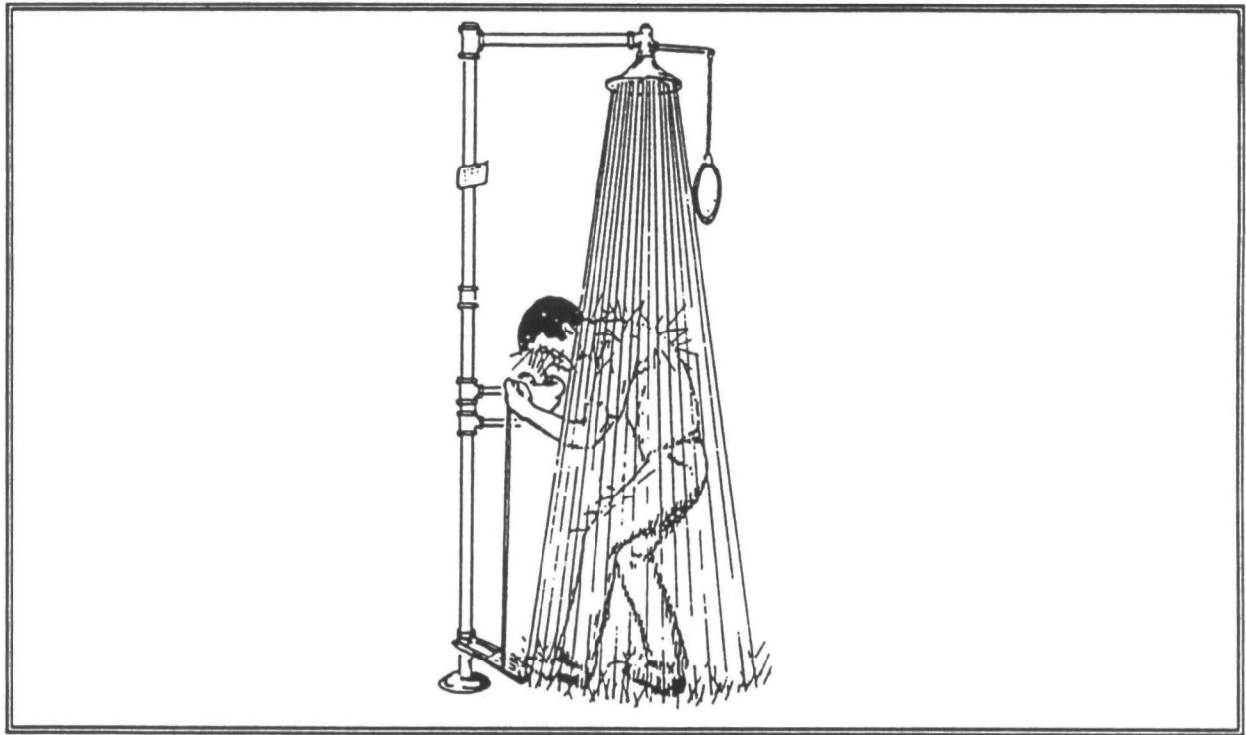
OSHA Construction Industry Standard 29 CFR 1926.50 - Medical Services and First Aid requires that:

- Medical personnel be available for advice and consultation on matters of occupational health.
- Prior to start of the project, provisions be made for prompt medical attention in case of serious injury.
- At least one and preferably more persons at the worksite be trained in first aid. The American Red Cross, some insurance carriers, local safety councils, and other organizations provide acceptable training.

- First aid supplies approved by a consulting physician be readily available. The supplies should be in sanitary and weatherproof containers with individually sealed packages for material such as gauze, bandages, and dressings that must be sterile.
- Proper equipment be provided for prompt transportation of an injured person to a physician or hospital, or a communication system for contacting necessary ambulance service.
- The telephone numbers of the physicians, hospitals, or ambulances be conspicuously posted.

Medical assistance will probably be available at an emergency response such as a truck or train wreck. It is important to remember that first aid is immediate temporary treatment given in the event of accident or illness before the doctor arrives. Some states have laws establishing limits on first aid given by the lay person. Trained employees should understand where first aid ends and professional medical treatment begins.

Additionally, OSHA's Medical Services and First Aid Standard (29 CFR 1910.151) for general industry require that the areas where workers may be exposed to splashes of corrosive materials should have facilities for flushing the chemicals out of eyes and from the body. If a decontamination line has been set up, it may provide the protection needed. Otherwise, additional facilities will be needed. For example, eyewashes and drench showers (Figure 5) may be necessary in such areas as laboratories, solvent-dispensing areas, and battery recharging stations where harmful material may be splashed in the eyes or on the skin. Such units can be hooked to a water line or may be portable with a self-contained water supply. It is important to remove chemicals from the body immediately even if protective clothing is worn because the clothing does not stop penetration or permeation of all chemicals.



**FIGURE 5**  
**COMBINATION DRENCH SHOWER AND EYEWASH**

*Source: "Occupational Safety and Health in Vocational Education", (NIOSH, 1979) page 97.*

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## **AIR MONITORING INSTRUMENTS**

Airborne contaminants can present a significant threat to human health. Identifying and quantifying these contaminants by air monitoring are essential components of a health and safety program at a hazardous waste site. Air monitoring data is useful for:

- Assessing the health risks to the public and response workers.
- Selecting personal protective equipment.
- Delineating areas where protection is needed.
- Determining actual or potential effects on the environment.
- Selecting actions to mitigate the hazards safely and effectively.

Direct-reading instruments were developed as early warning devices for use in industrial settings, where leaks or an accident could release a high concentration of a known chemical. Today, some direct-reading instruments can detect low concentrations of contaminants as little as one part contaminant per million parts of air (ppm). Direct-reading instruments provide information at the time of sampling and do not require sending samples to a laboratory for subsequent analysis. This characteristic of direct-reading instruments enables rapid decision-making.

### **Characteristics of Air Monitoring Instruments**

To be useful air monitoring instruments must be:

- Portable and rugged.
- Easy to operate.
- Able to generate reliable and useful results.
- Inherently safe.

**Portability.** A prime consideration for field instruments is portability. Transportation shock resulting from the movement from one place to another, together with unintentional abuse, shortens the usable life of an instrument. To reduce the effects of this trauma, instruments should be selected that have reinforced shells or frames, shock-mounted electronic packages, or padded containers for shipment.

Exposure to the elements and to the test atmosphere itself is of concern for those instruments repeatedly used in adverse conditions or as long-term monitors. Anodized or coated finishes, weather resistant packaging and remote sensors are effective in reducing downtime and increasing portability.

An internal power supply is important for portability. Some instruments use replaceable or rechargeable batteries and some do not require a power supply.

An instrument should not be so heavy or bulky that it is difficult for a response worker to carry.

**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 worker 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.

**Reliable and Useful Results.** The response time, sensitivity, selectivity, accuracy and precision of an instrument are important in evaluating the reliability and usefulness of the data the instrument generates.

Response time, the interval between an instrument "sensing" a contaminant and generating data, is important to producing reliable and useful results in the field. Response time depends on: test(s) to be performed, dead time between sample periods (the time for analysis, data generation, and data display), and the sensitivity of the instrument. Response times for direct-reading instruments may range from a few seconds to several minutes.

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. Sensitive instruments can detect small changes in concentration. The lower detection limit is the lowest concentration to which instrument will respond to. 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. It is important to use an instrument with an operating range that will accurately measure the concentration in the range of concern.

Amplification, a term often used synonymously (and incorrectly) with sensitivity, is the instrument's ability to increase very small electronic signals emanating from the detector to the readout. Changing the amplification of the detector does not change its sensitivity. However, it may be useful in calibration. Instruments with amplifier circuits can be affected by radio frequency from pulsed DC or AC power lines, transformers, generators, and radio wave transmitters.

Accuracy is defined as the relationship between a true value and the instrument reading. Precision is the indication of the reproducibility. These factors can be indicated by the error factor. For example, some detector tubes may have an error factor of  $\pm 35\%$  of the true value; meaning the actual concentration of the chemical being measured is within a range of 35% higher and lower than the tube reading.

Selectivity is the ability of an instrument to detect and measure a specific chemical or group of similar chemicals. Additionally, selectivity is dependent upon interfering compounds which may produce a similar response. Selectivity and sensitivity must be reviewed and interpreted together. Interferences can affect the accuracy of the instrument reading.



Another consideration is that the instrument must give results that are immediately useful. Instruments should be direct reading, with little or no need to interpolate, integrate, or compile large amounts of data.

When selecting an instrument, compare the desired sensitivity, range, accuracy, selectivity, and ability to vary amplification of detector signals with the available instrument characteristics.

**Inherent Safety.** The portable instrumentation used to characterize hazardous material spills or waste sites must be safe to use. Electrical devices, including instruments, must be constructed in such a fashion as 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. Several engineering, insurance, and safety organizations have standardized test methods, established inclusive definitions, and developed codes for testing electrical devices used in hazardous locations. The National Fire Protection Association (NFPA) has created minimum standards in its National Electrical Code (NEC) published every 3 years. This code spells out types of areas in which hazardous atmospheres can be generated and the types of materials that generate these atmospheres, and design safeguards acceptable for use in hazardous atmospheres.

### **Hazardous Atmospheres**

Depending upon the response worker's background, the term "hazardous atmosphere" conjures up 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 categories them according to their Class, Group, and Division.

#### **Class and Group**

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 1).

- Class II consists of combustible dusts like coal or grain and is divided into groups E, F, and G (Table 2).
- Class III is ignitable fibers such as produced by cotton milling.

TABLE 1 SELECTED CLASS I CHEMICALS BY GROUPS		
<b>Group A</b>	<b>Atmospheres</b>	
	acetylene	
<b>Group B</b>	<b>Atmospheres (not sealed in conduit 1/2 inch or larger)</b>	
	1,3-butadiene ethylene oxide formaldehyde (gas) hydrogen manufactured gas (containing greater than 30% H <sub>2</sub> by volume) propylene oxide propyl nitrate allyl glycidyl ether n-butyl glycidyl ether	
<b>Group C</b>	<b>Atmospheres (selected chemicals)</b>	
	acetaldehyde carbon monoxide crotonaldehyde dicyclopentadiene diethyl ether ethylene glycol monoethyl ether acetate methylacetylene	epichlorohydrin ethylene ethyl mercaptan hydrogen cyanide hydrogen selenide hydrogen sulfide dimethylamine nitropropane
		tetrahydrofuran triethylamine ethylene glycol monoethyl ether furfural chloroacetaldehyde tetramethyl lead (39 others)
<b>Group D</b>	<b>Atmospheres (selected chemicals)</b>	
	acetone methanol ammonia propane chlorobenzene	methane acrylonitrile naphtha butane vinyl chloride
		acetonitrile methyl ethyl ketone benzene styrene

Source: Classification of Gases, Vapors, and Dusts for Electrical Equipment in Hazardous (classified) Locations, 1986, National Fire Protection Association ANSI/NFPA 497M.

### Division

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.
- Division 2 is a location where the generation and release are only from ruptures, leaks or other failures from closed systems or containers.

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 transferring of the flammable liquids takes place at the site, or if releases of flammable gases/vapors is considered normal, the areas would be considered Class I, Division 1.

TABLE 2 SELECTED CLASS II CHEMICALS BY GROUPS	
<b>Group E</b>	<b>Conductive Dusts</b>  Atmospheres containing metal dusts, including aluminum, magnesium, and their commercial alloys, and other metals of similarly hazardous characteristics.
<b>Group F</b>	<b>Semivolatile Dusts</b>  Atmospheres containing carbonaceous dusts such as: charcoal, carbon black, coal or coke dust with more than 8% volatile material.
<b>Group G</b>	<b>Nonconductive Dusts</b>  Atmospheres containing flour, starch, grain, chemical thermoplastic, thermosetting and molding compounds.

*Source: Classification of Gases, Vapors, and Dusts for Electrical Equipment in Hazardous (classified) Locations, 1986, National Fire Protection Association ANSI/NFPA 497M.*

### Instrument Controls

The following three methods of construction exist to prevent a potential source from igniting a flammable atmosphere:

- **Explosion-proof:** Explosion-proof instruments allow the flammable atmosphere to enter. If an arc is generated, the ensuing explosion is contained within the specially built enclosure. Within it, any flames or hot gases are cooled prior to exiting into

the ambient flammable atmosphere so that the explosion does not spread into the environment.

- **Intrinsically Safe:** The potential for arcing among components is reduced by encasing them in a solid insulating material. Also, reducing the instrument's operational current and voltage below the energy level necessary for ignition of the flammable atmosphere provides protection. An "intrinsically safe" device, as defined by the National Electrical Code, is incapable "of releasing sufficient electrical or thermal energy under normal or abnormal conditions to cause ignition of a specific hazardous atmospheric mixture in its most easily ignited concentration. Abnormal conditions shall include accidental damage to any wiring, failure of electrical components, application of over-voltage, adjustment and maintenance operations and other similar conditions."
- **Purged:** The arcing or flame-producing device is buffered from the flammable atmosphere with an inert gas. In a pressurized or "purged" system, a steady stream of, nitrogen or helium is passed by the potential arcing device, keeping the flammable atmosphere from the ignition source. This type of control, however, does not satisfactorily control analytical devices that use flame or heat for analysis, such as a combustible gas indicator (CGI). It also requires a source of gas which would reduce instrument portability.

### **Certification**

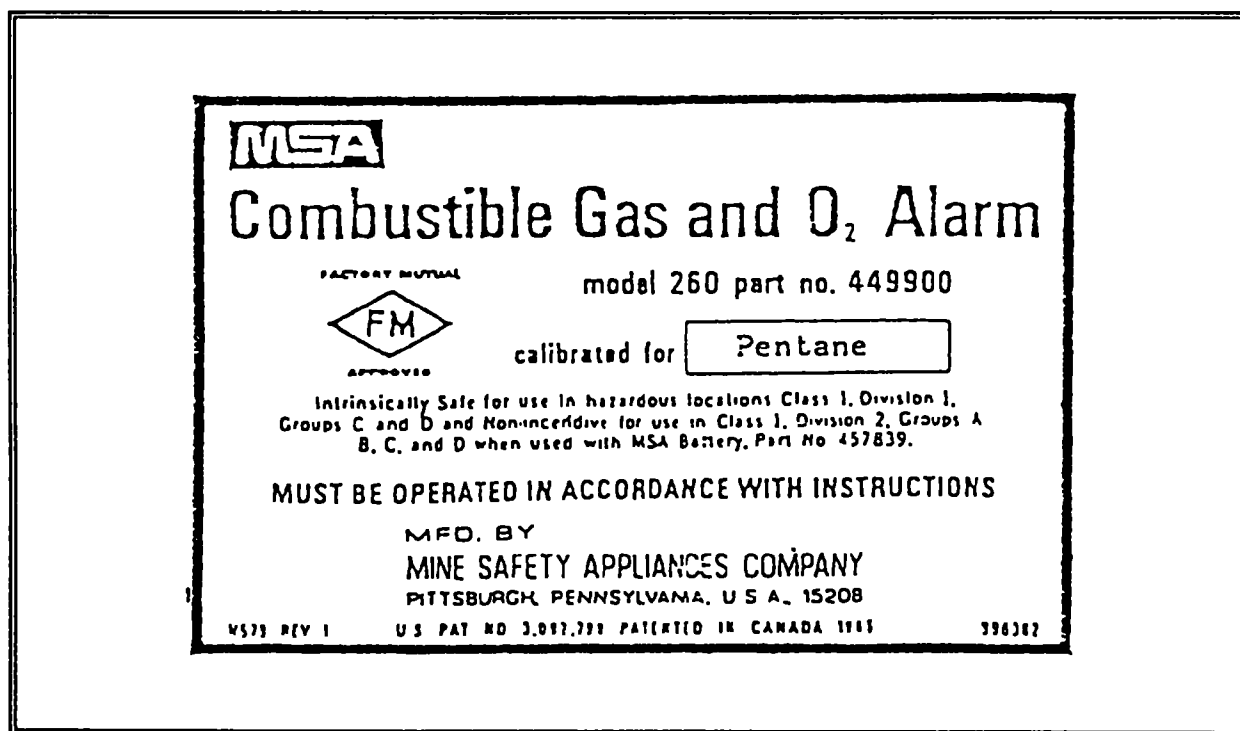
A device, certified as explosion-proof, intrinsically safe, or purged for a given Class, Division, and Group, which is used, maintained, and serviced according to the manufacturer's instructions, will not contribute to ignition. The device is not, however, certified for use in atmospheres other than 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 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 is done by such organizations as Underwriters' Laboratory Inc. (UL) or Factory Mutual Research Corp. (FM). Currently, these are the only two testing labs recognized by OSHA.

To ensure personnel safety, it is recommended that only approved instruments be used on-site 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 classification. 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 I (vapors, gases), Division 1 (areas of ignitable concentrations), Groups A, B, C, 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 is impossible 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.



**FIGURE 1**  
**CERTIFICATION LABEL FROM MSA MODEL 260**  
**COMBUSTIBLE GAS AND O<sub>2</sub> INDICATOR**

## **Calibration and Relative Response**

For an instrument to function properly in the field, it should be calibrated prior to use. Calibration is the process of adjusting the instrument readout so that it corresponds to the 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 calibrated with a 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 accurate readings are 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 may be different. This variability is called relative response. A combustible gas indicator calibrated to pentane will give a higher instrument reading for methane than the actual concentration (Table 3).

The relative response of an instrument to different chemicals can be calculated by dividing the instrument reading by the actual concentration and is expressed as a ratio or a percent. Note that for the calibration standard the relative response should be 1.00 or 100%.

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 ( $.27 \times \text{actual concentration} = 100 \text{ ppm}$ , then  $\text{actual concentration} = 100/.27 = 370 \text{ ppm}$ ). 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. As recalibration takes time, this is usually done only if the instrument is going to be used for many measurements of the special chemical.

**TABLE 3**  
**RELATIVE RESPONSE FOR A COMBUSTIBLE GAS**  
**INDICATOR CALIBRATED TO PENTANE**

<b>Chemical</b>	<b>Concentration (% LEL)</b>	<b>Meter Response (% LEL)</b>	<b>Relative Response</b>
Methane	50	85	170%
Acetylene	50	60	120%
Pentane	50	53	106%
1,4-Dioxane	50	37	74%
Xylene	50	27	54%

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

## **TYPES OF DIRECT-READING INSTRUMENTS**

Many hazards may be present when responding to hazardous materials spills or uncontrolled waste sites. There are several types of instrumentation for detecting hazardous atmospheres. These are commonly referred to as oxygen indicators, combustible gas indicators, and toxic atmosphere monitors.

### **Oxygen Indicators**

Oxygen indicators are used to evaluate an atmosphere for the following:

- Oxygen content for respiratory purposes. Normal air is 20.9% 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, some combustible gas indicators 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.
- 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.

Oxygen-deficient atmospheres may occur in unventilated areas or may be due to terrain variations in cases where heavier than air vapors may collect. Most indicators have meters which display the oxygen concentration from 0–25%. There are also oxygen indicators available which measure concentrations from 0–5% and 0–100%. The most useful range for response is the 0–25% oxygen content readout since decisions involving air-supplying respirators and the use of combustible gas indicators fall into this range.

Many instrument manufacturers make oxygen meters. They can be small hand-held units with or without pumps to draw the sample across the detector cell. Some pumps are single aspirating (hand-squeeze) bulbs, others are battery powered diaphragm pumps. Units that combine O<sub>2</sub> meters and combustible gas indicators into one instrument are available from a number of 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.

**Principle of Operation.** Oxygen indicators have two principle components for operation. These are the oxygen sensor and the meter readout. 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.

The oxygen detector uses 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 2).

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

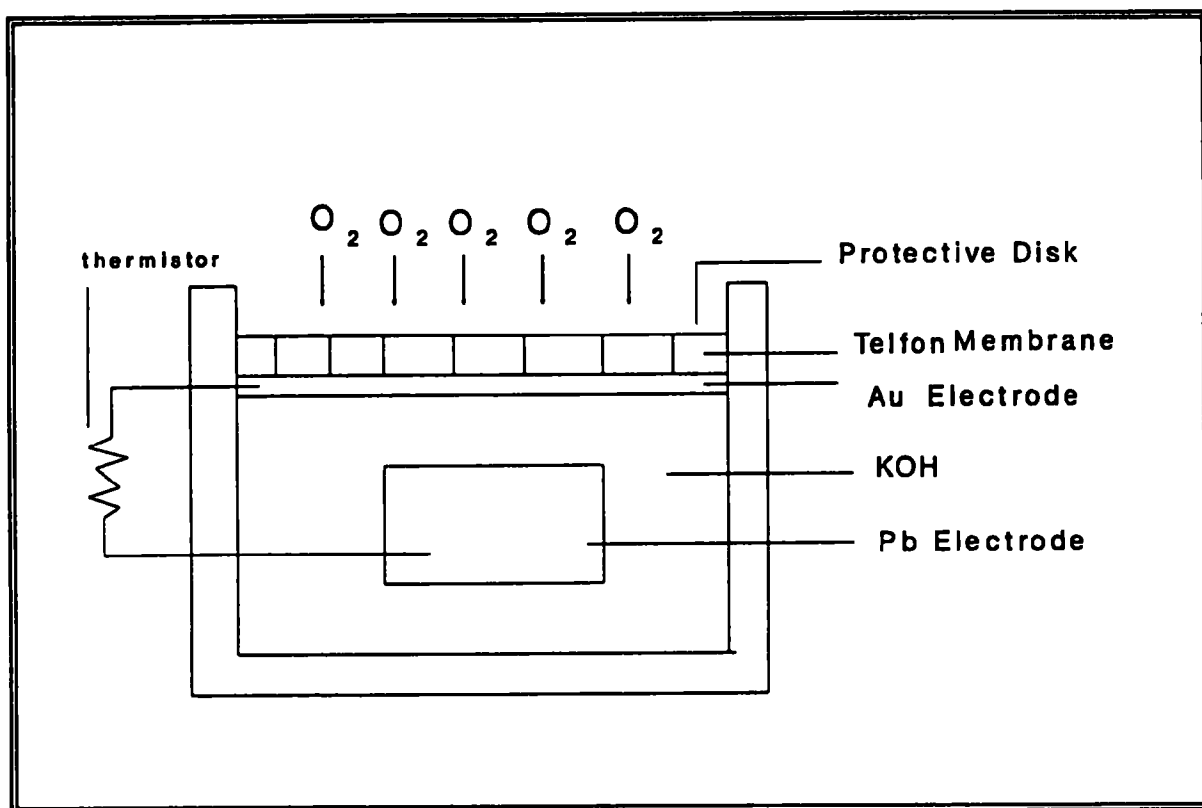
**Limitations and Considerations.** The operation of oxygen meters depends on the absolute atmospheric pressure. The concentration of natural oxygen (to differentiate it from manufactured or generated oxygen) is a function of the atmospheric pressure at a given altitude. While the actual percentage of oxygen does not change with altitude, at sea level the weight of the atmosphere above is greater, and more  $O_2$  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  $O_2$  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.

High concentrations of carbon dioxide ( $CO_2$ ) shorten the useful life of the oxygen sensor. As a general rule, the unit can be used in atmospheres greater than 0.5%  $CO_2$  only with frequent replacing or rejuvenating of the sensor. Lifetime in a normal atmosphere (0.04%  $CO_2$ ) can be from one week to one year depending on the manufacturer's design.

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 sensor may be damaged by the solution freezing. The instrument should be calibrated at the temperature at which it will be used.

Strong oxidizing chemicals, like ozone and chlorine, can cause increased readings and indicate high or normal  $O_2$  content when the actual content is normal or even low.





**FIGURE 2**  
**SCHEMATIC OF OXYGEN SENSOR**

*Selection from Product Literature, Rexnord Electronic Products Division, Biomarine Oxygen Sensor, by Rexnord, Inc., reprinted with permission of publisher.*

### Combustible Atmosphere Indicators

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. Above the UEL, the mixture is too "rich" to support combustion so ignition is not possible. Below the LEL there is insufficient fuel to support combustion. Concentrations between the LEL and the UEL are considered flammable.

CGIs are available in many styles and configurations. All units have some type of pump to draw the air sample into the detector. The pumps are either hand operated square bulbs or automatic (battery-powered) diaphragm types. Many units are "combination meters". This means they have an O<sub>2</sub> meter and 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 larger sampling lines, moisture traps, and dust filters are also available.

**Principle of Operation.** Combustible gas indicators 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. 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 0.5 (or 50%, 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 indicates that a 2.5% concentration is present. Thus, the typical meter readout indicates concentration up to the LEL of the gas (Figure 3a).

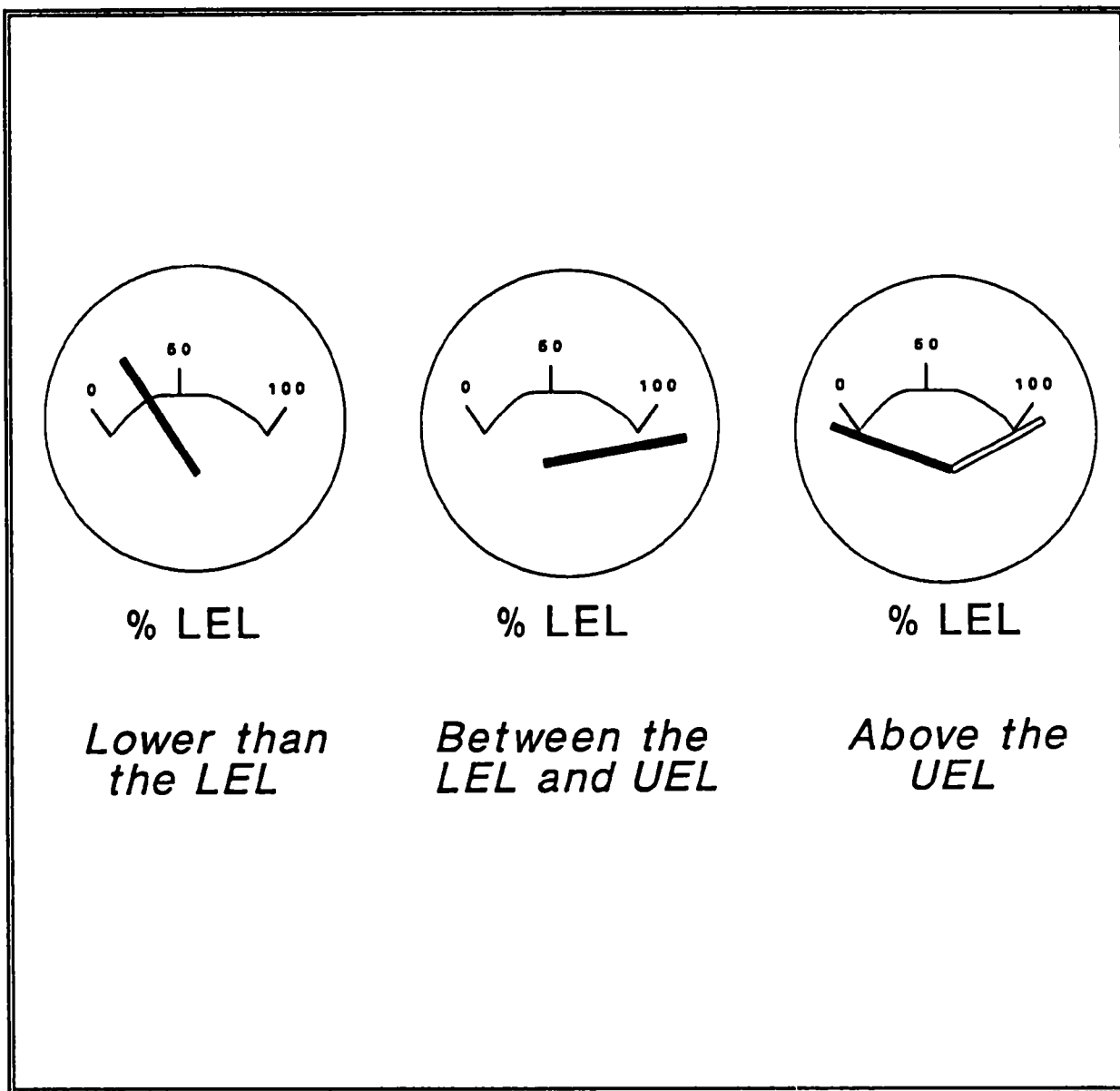
If a concentration greater than LEL and lower than the UEL is present, then the meter needle will stay beyond the 1.0 (100%) level on the meter (Figure 3b). This indicates that the ambient atmosphere is readily combustible. When the atmosphere has a gas concentration above the UEL the meter needle will usually rise above the 1.0 (100%) 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% and must be reset in an atmosphere below the LEL.

**Limitations and Considerations.** 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. It works best to calibrate and zero the instrument at the sample temperature.

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., gasoline vapors), 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.

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 can not tell if the reading is the contaminant or the methane. A pre-filter can be used to remove the vapors but 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.



**FIGURE 3**  
**COMPARISON OF METER READINGS TO**  
**COMBUSTIBLE GAS CONCENTRATIONS**

#### Toxic Atmosphere Monitors

Along with oxygen concentration and flammable gases or vapors, there is a concern about chemicals present at toxic concentrations.

This usually involves measurements at concentrations lower than would be indicated by oxygen indicators or combustible gas indicators. There is a need to determine if 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 concentrations that could pose a toxic risk to response workers and the public.
- Evaluate the need for and type of personal protective equipment.
- Set up work zones or areas where contaminants are or are not present.

There are several different groups of instruments that can be used for these functions.

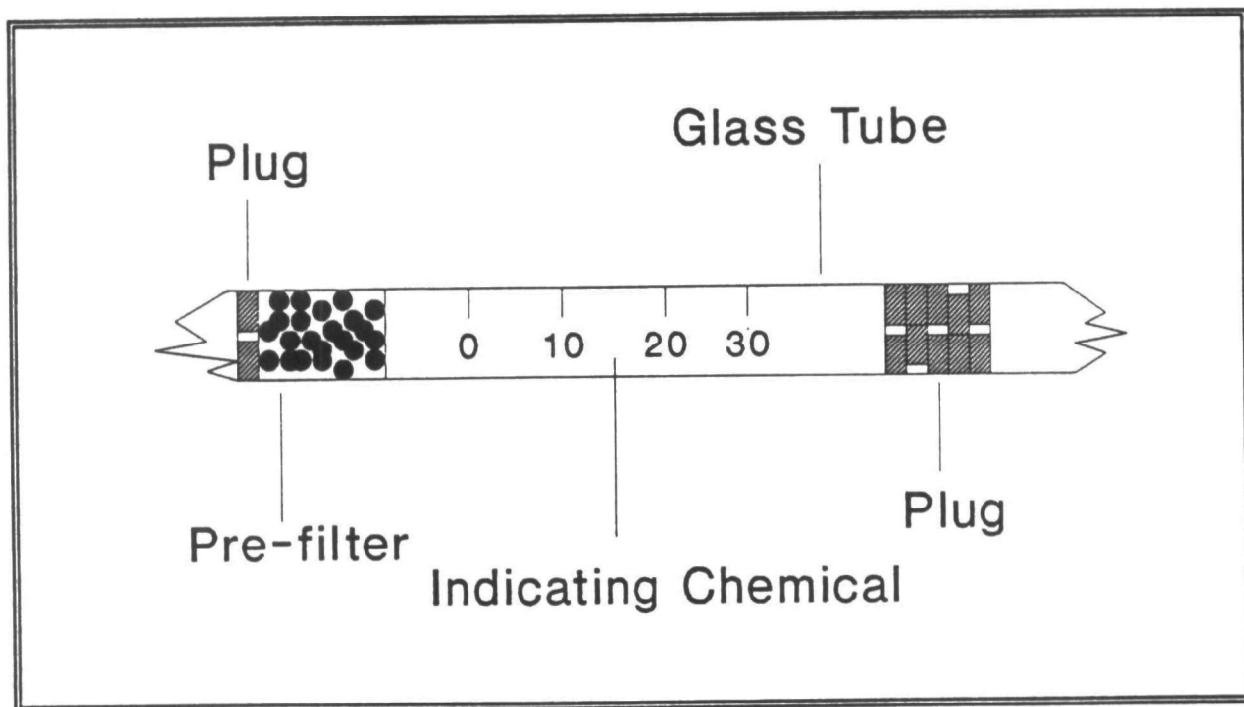
### **Colorimetric Indicator Tubes (Detector Tubes)**

**Principle of Operation.** Colorimetric indicator tubes consist of a glass tube impregnated with an indicating chemical (Figure 4). The tube is connected to a piston- or bellows- type pump. A known volume of contaminated air is pulled at a predetermined rate through the tube by the pump. The contaminant reacts with the indicator chemical in the tube, producing a change in color whose length is proportional to the contaminant concentration.

Detector tubes are normally chemical specific. There are different tubes for different gases; for example, chlorine detector tube for chlorine gas, acrylonitrile tube for acrylonitrile gas, etc. Some manufacturers do produce tubes for groups of gases, e.g., aromatic hydrocarbons, alcohols. Concentration ranges on the tubes may be in the ppm or percent range. A preconditioning filter may precede 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.

Hazmat kits are available from at least two manufacturers. 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. Detector tube manufacturers are listed at the end of this manual section.



**FIGURE 4**  
**DIRECT-READING COLORIMETRIC**  
**INDICATOR TUBE**

**Limitations and Considerations.** Detector tubes have the disadvantage of poor accuracy and precision. In the past, the National Institute for Occupational Safety and Health (NIOSH) tested and certified detector tubes that were submitted to them. For the tubes they tested they certified the accuracy to be  $\pm 35\%$  at concentrations at one-half the OSHA Permissible Exposure Limit (PEL) and  $\pm 25\%$  at 1–5 times the PEL. NIOSH has discontinued testing and certification. Special studies have reported error factors of 50% and higher for some tubes.

The chemical reactions involved in the use of the tubes are affected by temperature. Cold weather slows the reactions and thus the response time. To reduce this problem it is recommended that the tubes be kept warm (for example, inside a coat pocket) until they are used if the measurement is done in cold weather. Hot temperatures increase the reaction and can cause a problem by discoloring the indicator 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 refrigerated during storage.

Some tubes do not have a prefilter to remove humidity and may be affected by high humidity. The manufacturer's instructions usually indicate if humidity is a problem and list any correction factors to use if the tube is affected by humidity.

The chemical used in the tubes deteriorates over time. Thus the tubes are assigned a shelf life. This varies from 1–3 years. Shelf life can be extended by refrigeration, but the tube should equilibrate to ambient temperature before use.

An advantage that detector tubes have over some other instruments is that it is possible to select a tube that is specific to a chemical. However, some tubes will respond to interfering compounds. Fortunately, the manufacturers provide information with the tubes on interfering gases and vapors.

Interpretation of results can be a problem. Since the tube's length of color change indicates the contaminant concentration, the user must be able to see the end of the stain. Some stains are diffused and are not clear cut; others may have an uneven endpoint. When in doubt use the highest value that would be obtained from reading the different aspects of the tube.

The total volume to be drawn through the tube varies with the tubes. 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.

Because of these many considerations, it is very important to read the instructions that are provided with and are specific to a set of tubes. The information includes the number of pump strokes needed, time for each pump stroke, interfering gases and vapors, effects of humidity and temperature, shelf life, proper color change, and whether the tube is reusable.

While 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.

### **Specific Chemical Monitors**

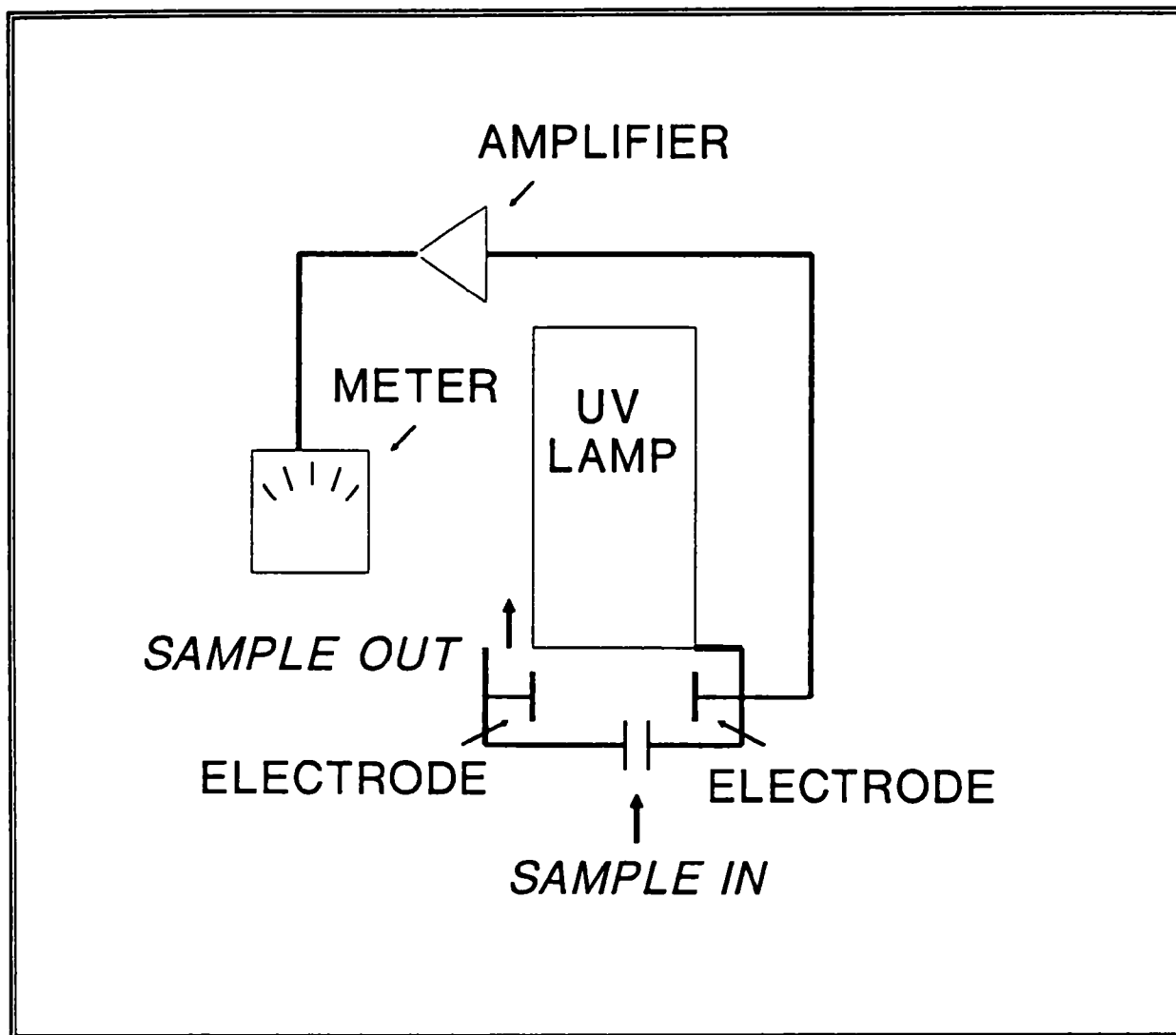
There are several gas monitors that use electrochemical cells or metal oxide semiconductors (MOS) for detecting specific chemicals. MOS detectors change conductivity when exposed to certain gases or vapors. They can be designed to respond to a large group of chemicals or to a specific chemical. The most common monitors are used to detect carbon monoxide or hydrogen sulfide, but there are also monitors available for hydrogen cyanide, ammonia, and chlorine. They are more accurate than detector tubes but there are only about a dozen different chemicals they can monitor.

### **Photoionization Detectors**

These instruments detect concentrations of gases and vapors in air by utilizing 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.

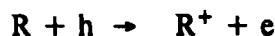
**Principle of Operation.** All atoms and molecules are composed of particles: electrons, protons, and neutrons. Electrons, negatively charged particles, rotate in orbit around the nucleus, the dense inner core. The nucleus consists of an equal number of protons (positively charged particles) as electrons found in the orbital cloud. The interaction of the oppositely charged particles and the laws of quantum mechanics keep the electrons in orbits outside the nucleus.

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 4). Ionization potentials are measured in electron volts (eV). High frequency radiation (ultraviolet and above) is capable of causing ionization and is hence called ionizing radiation. 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. Since 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 (Figure 5).



**FIGURE 5**  
**DIAGRAM OF PHOTOIONIZATION DETECTOR**  
**LAMP AND COLLECTING ELECTRODES**

The photoionization process can be illustrated as:



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

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

**TABLE 4**  
**IONIZATION POTENTIALS OF SELECTED CHEMICALS**

Chemical	Ionization Potential (eV)
Hydrogen cyanide	13.9
Carbon dioxide	13.8
Methane	13.0
Hydrogen chloride	12.5
Water	12.6
Oxygen	12.1
Chlorine	11.5
Propane	11.1
Hydrogen sulfide	10.5
Hexane	10.2
Ammonia	10.1
Vinyl chloride	10.0
Acetone	9.7
Benzene	9.2
Phenol	8.5
Ethyl amine	8.0

**Limitations and 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 can be seen from Table 4, there is a limit imposed by the components of air. That is, the lamp cannot be too energetic or oxygen and nitrogen will ionize and interfere with the readings for contaminants. The energy of lamps available are 8.3, 8.4, 9.5, 10.2, 10.6, 10.9, 11.4, 11.7, and 11.8 eV. Not all lamps are available from a single manufacturer. One use of 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 they could 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 (e.g., 11.7 or 11.8). 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 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. This problem will be detected during calibration and the lamp should be cleaned on a regular basis.

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 also reduces the ionization of chemicals and cause a reduction in readings.

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.

Photoionization detectors are calibrated to a single chemical. The instrument's response to chemicals other than the calibration gas/vapor can vary. Table 5 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 600 ppm for an instrument, a concentration of 900 ppm may only give a meter response of 700.

Units that use photoionization include the HNU PI 101, the Photovac TIP, and the Thermo Environmental Instrument's Model 580A.

TABLE 5 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
Phenol	0.78
Vinyl chloride	0.63
Acetone	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.*

### **HNU PI 101 Photoionization Detector**

The HNU PI 101 consists of two modules connected via a single power cord (Figure 6):

- A readout unit consisting of a 4.5-inch analog meter, 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 unit has a separate sensor unit because the lamps available—8.3, 9.5, 10.2 (standard), and 11.7 eV—require separate electronic circuits. To change the energy of ionization the whole sensor or probe has to be switched and not just the lamp. Lamps are replaceable.

### **Photovac TIP (Total ionizables present)**

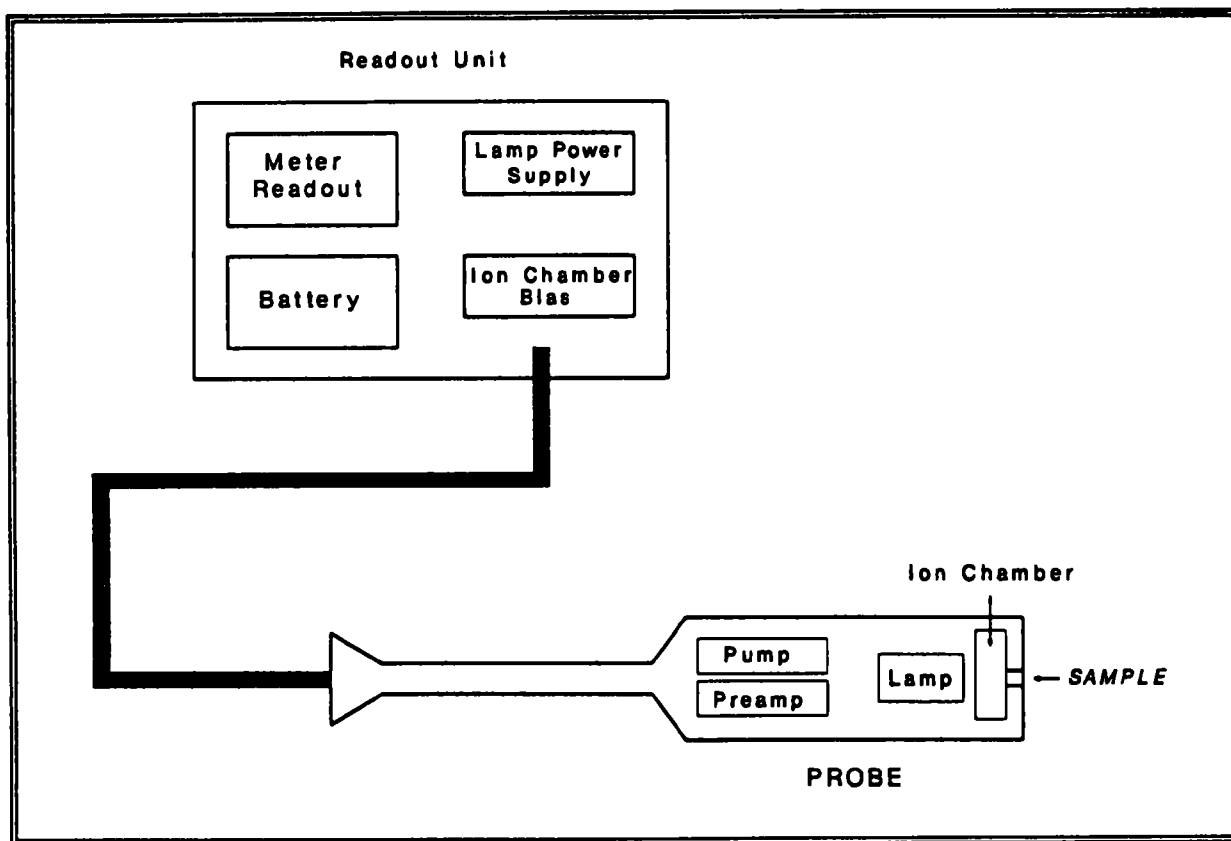
The TIP has components similar to those of the HNU, but they are all contained in an 18- and 2.5-inch diameter unit. The standard lamp is 10.6 eV, but it can easily be replaced with an 8.4, 9.5, 10.2, or 11.7 eV lamp. A separate sensor is not used. The readout is digital with a range of 0 to 2000. The instrument also has a replaceable dust filter to eliminate collection on the lamp.

### **Thermo Environmental Instruments Model 580A**

The Organic Vapor Meter (OVM) is 5 inches by 5 inches by 10 inches with a handle on top and in the center. It can use any of four different lamps—9.5, 10.0, 10.6 (standard), or 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 lockout 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 unit also has connections and software for interfacing the unit with a personal computer and a data logger for recording readings at coded locations so that the readings can be looked at later or unloaded into a computer.

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



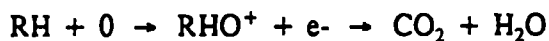
**FIGURE 6**  
**PORTABLE PHOTOIONIZATION DETECTOR**

*Selection from Instruction Manual for Model PI 101 Photoionization Detector, by HNU Systems, Inc., copyright 1975 by HNU Systems, Inc., reprinted with permission of publisher.*

### **Flame Ionization Detectors (FID)**

These units use combustion as the means to ionize airborne contaminants. Once they are ionized, they can be detected and measured.

**Principle of Operation.** Flame ionization detectors use a hydrogen flame as the means to ionize organic (toxic) vapors. FID responds to virtually all organic compounds, that is, compounds that contain carbon-hydrogen or carbon-carbon bonds. The flame detector analyzes by the mechanism of breaking bonds as the following reaction indicates:



Inside the detector chamber, the sample is exposed to a hydrogen flame which ionizes the organic vapors. When most organic vapors burn, positively charged carbon-containing ions are produced which are collected by a negatively charged collecting electrode in the 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 preamp 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 (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. Flame ionization detectors are the most sensitive for saturated hydrocarbons, alkanes, and unsaturated hydrocarbons alkenes. Substances that contain substituted functional groups such as hydroxide ( $\text{OH}^-$ ), and chloride ( $\text{Cl}^-$ ), tend to reduce the detector's sensitivity; however, overall, the detectabilities remain good.

Companies that manufacture FIDs include Beckman Industrial, The Foxboro Company and Thermo Environmental Instruments. The Foxboro Century Organic Vapor Analyzer (OVA) will be discussed as an example later.

**Limitations and Considerations.** Flame ionization detectors respond only to organic compounds. Thus, they do not detect inorganic compounds like chlorine, hydrogen cyanide, or ammonia.

As with all instruments, flame ionization detectors respond differently to different compounds. Table 6 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%.

Thus with all survey-type instruments, the identity of the chemical of interest must be ascertained before its concentration can be determined. However, the CENTURY OVA can be purchased as a dual mode survey-gas chromatograph and can separate and define the components present in a gas mixture. As with all instruments, individuals should be trained for best operation and performance. Experience in gas chromatography is an important aspect to successful operation of the chromatographic option.

<b>TABLE 6</b> <b>RELATIVE RESPONSES FOR SELECTED CHEMICALS</b> <b>USING THE OVA CALIBRATED TO METHANE</b>	
<b>Compound</b>	<b>Relative Response</b>
Methane	100
Ethane	90
Propane	64
n-Butane	61
n-Pentane	100
Ethylene	85
Acetylene	200
Benzene	150
Toluene	120
Acetone	100
Methyl ethyl ketone	80
Methyl isobutyl ketone	100
Methanol	15
Ethanol	25
Isopropyl alcohol	65
Carbon tetrachloride	10
Chloroform	70
Trichlorethylene	72
Vinyl chloride	35

*Selection from Product Literature, The Foxboro Company, with permission of the Foxboro Company.*

#### **Foxboro Century Organic Vapor Analyzer (OVA)**

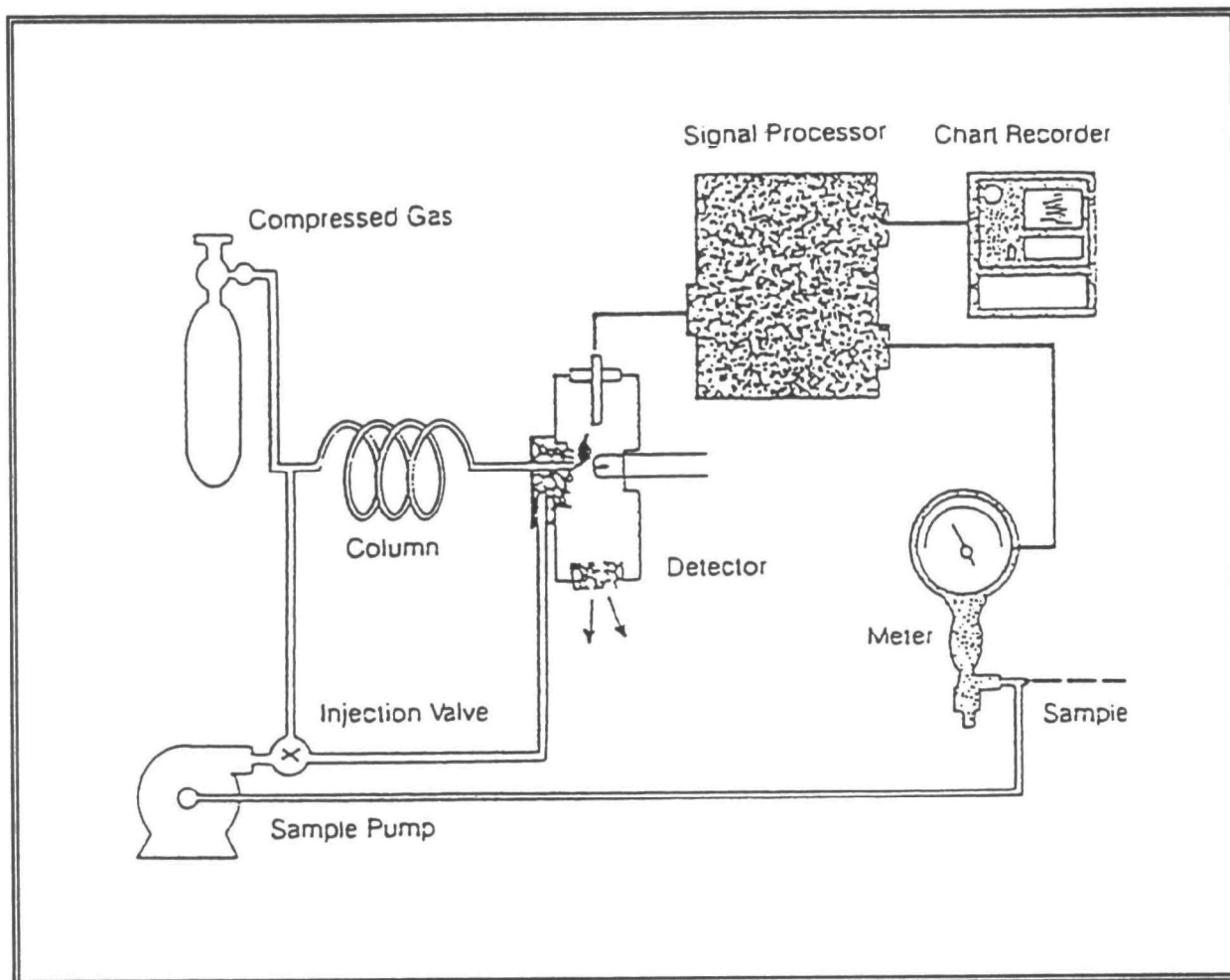
The Foxboro CENTURY OVA consists of two major parts: (1) a 12-pound package containing the sampling pump, battery pack, support electronics, flame ionization detector, hydrogen gas cylinder, and an optional gas chromatography (GC) column and (2) a hand-held meter/sampling probe assembly (**Figure 7**).

The OVA is generally calibrated to methane, but can be calibrated to the species of interest. The OVA can operate in two modes:

**Survey mode.** During normal survey mode operation, a sample is drawn into the probe and transmitted to the detector chamber by an internal pumping system. When the sample reaches the FID it is ionized as described before and the resulting signal is translated on the meter for direct-reading concentration as total organic vapors or recorded as a peak on a chart. The meter display is an integral part of the probe/readout assembly and has a scale from 0 to 10 which can be set to read 0–10, 0–100, or 0–1000 ppm.

**Gas chromatography mode.** Gas chromatography (GC) is a technique for separating components of a sample and qualitatively and quantitatively identifying them. The sample

to be separated is injected into a column packed with an inert solid. As the carrier gas (for the OVA it is hydrogen) forces the sample through the column, the separate components of the sample are retained on the column for different periods of time. The amount of time a substance remains on the column, which is called its retention time, is a function of its affinity for the column material, column length, column temperature, and flow rate of the carrier gas. Under preset instrumental conditions, each component elutes from the column at a different, but reproducible, length of time. Separate peaks are recorded for each component by connecting the output of the detector to a strip chart recorder. This readout is called a gas chromatogram (qualitative identification is made by measuring retention time).



**FIGURE 7**  
**ORGANIC VAPOR ANALYZER SCHEMATIC**

*Selection from Product Literature, The Foxboro Company, with permission of the Foxboro Company.*

Retention time is the time that elapses between the injection of the compound into the column and the elution of that compound as represented by a peak. Retention is expressed as a function of either time, or the measured distance, between the injection point and the peak on the strip chart recorder.

The unknown is tentatively identified if the retention time of an unknown chemical agrees with the retention time of a chemical recorded under the same set of analytical conditions.

Also, the area under the peak is proportional to the concentration of the corresponding sample component. Concentration of the sample components can be calculated by comparing these areas to the areas of standards recorded under identical analytical conditions.

### **Catalytic Combustion Detectors**

There are toxic monitors which use the same detection system as CGIs but are more sensitive. In a sense they are super sensitive CGIs with readouts in ppm instead of %LEL. Since the detection method is similar, they have the same limitations and considerations as CGIs.

Some of these instruments (e.g., the Bacharach TLV Sniffer), give only readings in parts per million (ppm). There are combination units (e.g., Gastec Models 1238 and 1314) that give ppm readings along with % LEL and oxygen readings.

### **Aerosol Monitors**

Not all toxic materials dispersed in air are in the form of a gas or vapor. Solids and liquids can become suspended in air by combustion, splashing liquids or by disturbing soil.

There are direct-reading instruments that measure aerosols, i.e., dust, mist, fume, smoke, fog, spray. Most of them use a light source and a light sensor that measures the amount of light scattered by the aerosol. Readouts are in milligrams per cubic meter ( $\text{mg}/\text{m}^3$ ). Some examples are MIE Incorporated RAM-1 and MINIRAM and TSI Incorporated's Model 5150.

Other methods of detection are the piezoelectric crystal mass monitor and beta attenuation. The piezoelectric crystal mass monitor uses a crystal that resonates at a certain frequency as electric current is applied to it. As particles collect on the crystal its resonant frequency changes and the change is measured. An instrument using this detector is TSI Incorporated's Model 3500.

Beta attenuation measures the attenuation of beta radiation by particles collected on a surface between the beta source and a beta detector. GCA Corporation's Model RDM-101 is an instrument using this type of detector.

Accessories for these types of instruments include (1) an attachment that only allows collection of "respirable" particles (i.e., ones that collect in the lungs) instead of the total particles in air and (2) integrators for giving average concentrations.

It is important to remember that these instruments give the total amount of particulate and not the type of particulate. Individual content, e.g., lead or arsenic, must be analyzed separately. However, if the content of the sample is known, then the direct-reading instrument could be used if content of the dust is assumed to remain constant. For example, if the dust being detected is 5% lead and 1% arsenic and the concentration of dust is  $2 \text{ mg}/\text{m}^3$  then the concentration of lead and arsenic are

0.1 mg/m<sup>3</sup> and 0.02 mg/m<sup>3</sup> respectively ( $0.05 \times 2 \text{ mg/m}^3 = 0.1 \text{ mg/m}^3$  and  $0.01 \times 2 \text{ mg/m}^3 = 0.02 \text{ mg/m}^3$ ).

### **Accessories/Options**

As mentioned earlier, instruments combining more than one detector can be found. For examples, "trimeters" and "quadmeters" combine an oxygen indicator, a combustible gas indicator, and one or two toxic monitors. Also there are units with alarms that indicate readings that are above or below a concentration of concern, strip chart (printed) outputs, and electronic outputs for data storage.

Some instruments have an integrator that averages concentrations while the instrument is operating or over a specified time (e.g., 15 minutes). This permits use of the instrument as a long-term monitor as well as a direct-reading instrument.

One of the more recent additions is the microprocessor. This can be used with a gas chromatograph so the microprocessor "reads" the output and compares it to calibration information in its memory. That way the instrument instead of the operator qualifies and quantifies the chemicals. In some cases the operator asks the microprocessor to check for a chemical and the unit uses its memory to match retention time and peak height. Microsensor's Micromonitor, the Photovac 10S50, and the Sentex Scentor use this capability. The main limitation with the microprocessors are the number of chemicals in their memory or "library." What the microprocessor doesn't recognize, it can't identify. Most portable units have libraries for up to 100 chemicals. Also the detection method (PID, FID, etc.) used must be considered as that limits the number of chemicals that can be identified.



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## TOXICOLOGY AND EXPOSURE GUIDELINES

"All substances are poisons; there is none which is not a poison. The right dose differentiates a poison and a remedy."

This early observation concerning the toxicity of chemicals was made by Paracelsus (1493–1541). The classic connotation of toxicology was "the science of poisons." Since that time, the science has expanded to encompass several disciplines. Toxicology is the study of the interaction between chemical agents and biological systems. While the subject of toxicology is quite complex, it is necessary to understand the basic concepts in order to make logical decisions concerning the protection of personnel from toxic injuries.

Toxicity can be defined as the relative ability of a substance to cause adverse effects in living organisms. This "relative ability" is dependent upon several conditions. As Paracelsus suggests, the quantity or the dose of the substance determines whether the effects of the chemical are toxic, nontoxic or beneficial. In addition to dose, other factors may also influence the toxicity of the compound such as the route of entry, duration and frequency of exposure, variations between different species (interspecies) and variations among members of the same species (intraspecies).

To apply these principles to hazardous materials response, the routes by which chemicals enter the human body will be considered first. Knowledge of these routes will support the selection of personal protective equipment and the development of safety plans. The second section deals with dose-response relationships. Since dose-response information is available in toxicology and chemistry reference books, it is useful to understand the relevance of these values to the concentrations that are actually measured in the environment. The third section of this chapter includes the effects of the duration and frequency of exposure, interspecies variation and intraspecies variation on toxicity. Finally, toxic responses associated with chemical exposures are described according to each organ system.

### Routes of Exposure

There are four routes by which a substance can enter the body: inhalation, skin (or eye) absorption, ingestion, and injection.

- **Inhalation:** For most chemicals in the form of vapors, gases, mists, or particulates, inhalation is the major route of entry. Once inhaled, chemicals are either exhaled or deposited in the respiratory tract. If deposited, damage can occur through direct contact with tissue or the chemical may diffuse into the blood through the lung-blood interface.

Upon contact with tissue in the upper respiratory tract or lungs, chemicals may cause health effects ranging from simple irritation to severe tissue destruction. Substances absorbed into the blood are circulated and distributed to organs which have an affinity for that particular chemical. Health effects can then occur in the organs which are sensitive to the toxicant.

- **Skin (or eye) absorption:** Skin (dermal) contact can cause effects that are relatively innocuous such as redness or mild dermatitis; more severe effects include destruction of skin tissue or other debilitating conditions. Many chemicals can also cross the skin barrier and be absorbed into the blood system. Once absorbed, they may produce systemic damage to internal organs. The eyes are particularly sensitive to chemicals. Even a short exposure can cause severe effects to the eyes or the substance can be absorbed through the eyes and be transported to other parts of the body causing harmful effects.
- **Ingestion:** Chemicals that inadvertently get into the mouth and are swallowed do not generally harm the gastrointestinal tract itself unless they are irritating or corrosive. Chemicals that are insoluble in the fluids of the gastrointestinal tract (stomach, small, and large intestines) are generally excreted. Others that are soluble are absorbed through the lining of the gastrointestinal tract. They are then transported by the blood to internal organs where they can cause damage.
- **Injection:** Substances may enter the body if the skin is penetrated or punctured by contaminated objects. Effects can then occur as the substance is circulated in the blood and deposited in the target organs.

Once the chemical is absorbed into the body, three other processes are possible: metabolism, storage, and excretion. Many chemicals are metabolized or transformed via chemical reactions in the body. In some cases, chemicals are distributed and stored in specific organs. Storage may reduce metabolism and therefore, increase the persistence of the chemicals in the body. The various excretory mechanisms (exhaled breath, perspiration, urine, feces, or detoxification) rid the body, over a period of time, of the chemical. For some chemicals elimination may be a matter of days or months; for others, the elimination rate is so low that they may persist in the body for a lifetime and cause deleterious effects.

### **The Dose-Response Relationship**

In general, a given amount of a toxic agent will elicit a given type and intensity of response. The dose-response relationship is a fundamental concept in toxicology and the basis for measurement of the relative harmfulness of a chemical. A dose-response relationship is defined as a consistent mathematical and biologically plausible correlation between the number of individuals responding and a given dose over an exposure period.

**Dose Terms.** In toxicology, studies of the dose given to test organisms is expressed in terms of the quantity administered:

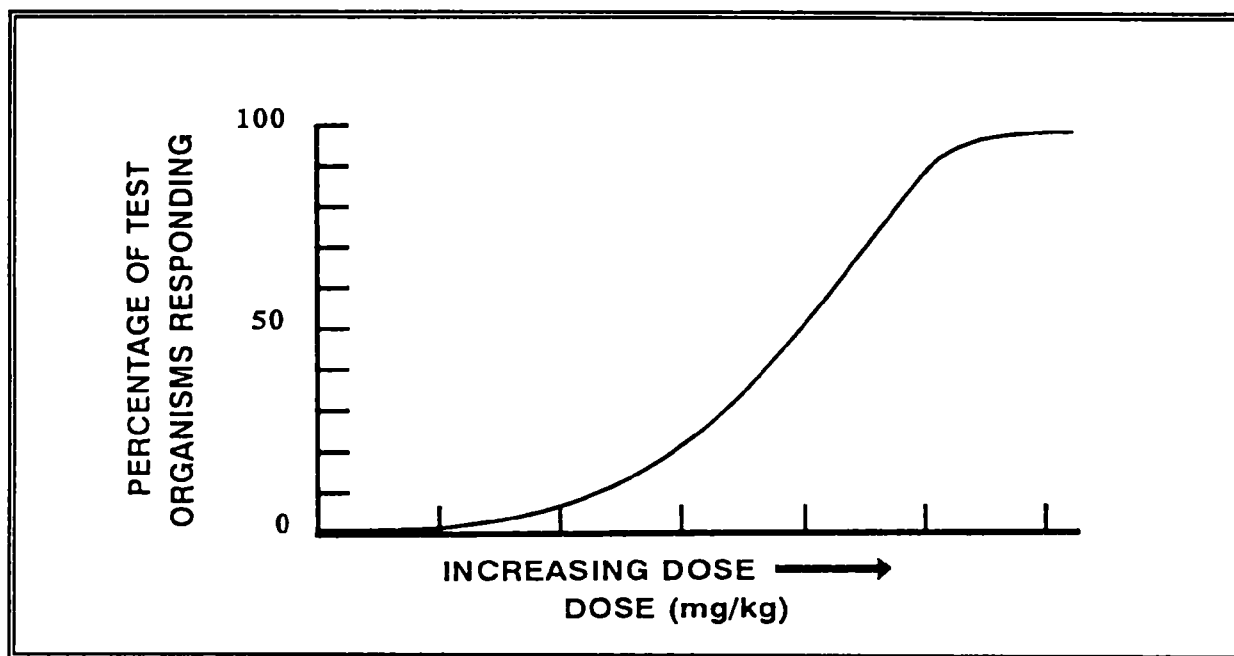
- **Quantity per unit mass (or weight).** Usually expressed as milligram per kilogram of body weight (mg/kg).
- **Quantity per unit area of skin surface.** Usually expressed as milligram per square centimeter (mg/cm<sup>2</sup>).

- **Volume of substance in air per unit volume of air.** Usually given as microliters of vapor or gas per liter of air by volume (ppm). Particulates and gases are also given as milligrams of material per cubic meter of air ( $\text{mg}/\text{m}^3$ ).

The period of time over which a dose has been administered is generally specified. For example, 5  $\text{mg}/\text{kg}/3 \text{ D}$  is 5 milligrams of chemical per kilogram of the subject's body weight administered over a period of three days. For dose to be meaningful it must be related to the effect it causes. For example, 50  $\text{mg}/\text{kg}$  of chemical "X" administered orally to female rats has no relevancy unless the effect of the dose, say sterility in all test subjects, is reported.

**Dose-Response Curves.** A dose-response relationship is represented by a dose-response curve. The curve is generated by plotting the dose of the chemical versus the response in the test population. There are a number of ways to present this data. One of the more common methods for presenting the dose-response curve is shown in Graph 1. In this example, the dose is expressed in " $\text{mg}/\text{kg}$ " and depicted on the "x" axis. The response is expressed as a "cumulative percentage" of animals in the test population that exhibit the specific health effect under study. Values for "cumulative percentage" are indicated on the "y" axis of the graph. As the dose increases, the percentage of the affected population increases.

Dose-response curves provide valuable information regarding the potency of the compound. The curves are also used to determine the dose-response terms that are discussed in the following section.



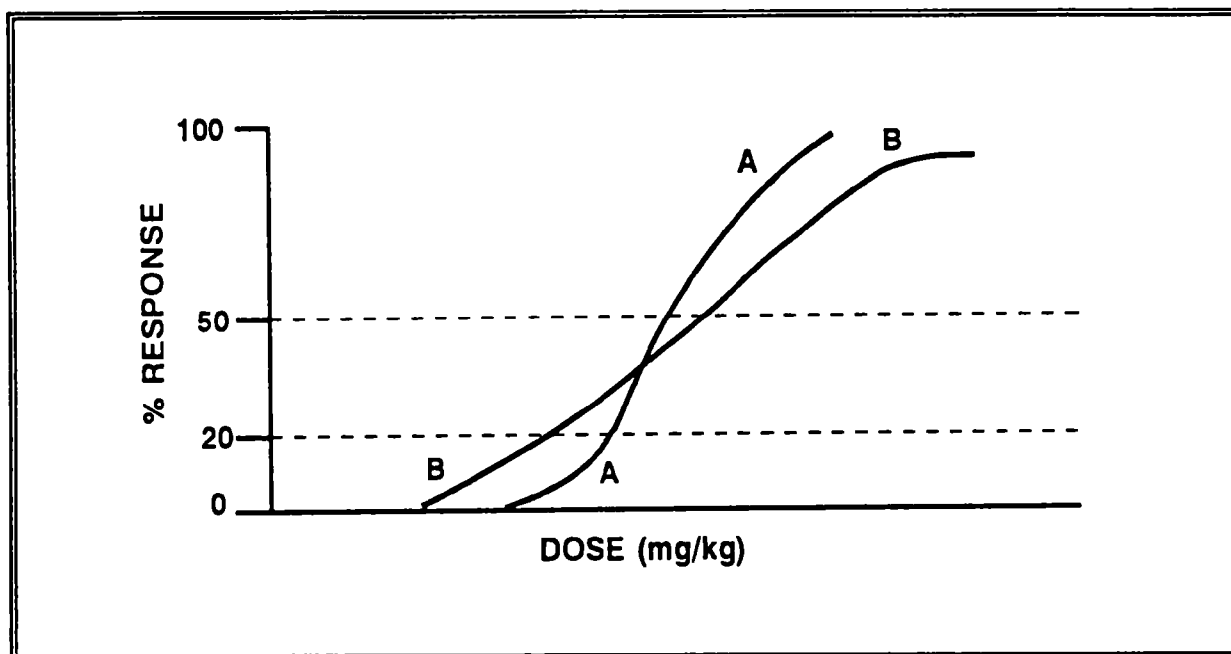
**GRAPH 1**  
**HYPOTHETICAL DOSE-RESPONSE CURVE**

**Dose-Response Terms.** The National Institute for Occupational Safety and Health (NIOSH) defines a number of general dose-response terms in the "Registry of Toxic Substances" (1983, p. xxxii). A summary of these terms is contained in Table 1.

- **Toxic dose low (TD<sub>LO</sub>):** The lowest dose of a substance introduced by any route, other than inhalation, over any given period of time, and reported to produce any toxic effect in humans or to produce tumorigenic or reproductive effects in animals.
- **Toxic concentration low (TC<sub>LO</sub>):** The lowest concentration of a substance in air to which humans or animals have been exposed for any given period of time that has produced any toxic effect in humans or produced tumorigenic or reproductive effects in animals.
- **Lethal dose low (LD<sub>LO</sub>):** The lowest dose, other than LD<sub>50</sub>, of a substance introduced by any route, other than inhalation, which has been reported to have caused death in humans or animals.
- **Lethal dose fifty (LD<sub>50</sub>):** A calculated dose of a substance which is expected to cause the death of 50 percent of an entire defined experimental animal population. It is determined from the exposure to the substance by any route other than inhalation.
- **Lethal concentration low (LC<sub>LO</sub>):** The lowest concentration of a substance in air, other than LC<sub>50</sub>, which has been reported to have caused death in humans or animals.
- **Lethal concentration fifty (LC<sub>50</sub>):** A calculated concentration of a substance in air, exposure to which for a specified length of time is expected to cause the death of 50 percent of an entire defined experimental animal population.

**Limitations of Dose-Response Terms.** Several limitations must be recognized when using dose-response data. First, it is difficult to select a test species that will closely duplicate the human response to a specific chemical. For example, human data indicates that arsenic is a carcinogen, while animal studies do not demonstrate these results. Second, most lethal and toxic dose data are derived from acute (single dose, short-term) exposures rather than chronic (continuous, long-term) exposures. A third shortcoming is that the LD<sub>50</sub> or LC<sub>50</sub> is a single value and does not indicate the toxic effects that may occur at different dose levels. For example, in **Graph 2** Chemical A is assumed to be more toxic than Chemical B based on LD<sub>50</sub>, but at lower doses the situation is reversed. At LD<sub>20</sub>, Chemical B is more toxic than Chemical A.

TABLE 1 SUMMARY OF DOSE-RESPONSE TERMS				
Category	Exposure Time	Route of Exposure	Toxic Effects	
			HUMAN	ANIMAL
TD <sub>Lo</sub>	Acute or chronic	All except inhalation	Any nonlethal	Reproductive, Tumorigenic
TC <sub>Lo</sub>	Acute or chronic	Inhalation	Any nonlethal	Reproductive, Tumorigenic
LD <sub>Lo</sub>	Acute or chronic	All except inhalation	Death	Death
LD <sub>50</sub>	Acute	All except inhalation	Not applicable	Death (statistically determined)
LC <sub>Lo</sub>	Acute or chronic	Inhalation	Death	Death
LC <sub>50</sub>	Acute	Inhalation	Not applicable	Death (statistically determined)



GRAPH 2  
COMPARISON OF DOSE-RESPONSE CURVES FOR TWO SUBSTANCES

**Factors Influencing Toxicity.** Many factors affect the reaction of an organism to a toxic chemical. The specific response that is elicited by a given dose varies depending on the species being tested and variations that occur among individuals of the same species. These must be considered when using information such as that found in (Table 2).

- **Duration and Frequency of Exposure.** There is a difference in type and severity of effects depending on how rapidly the dose is received (duration) and how often the dose is received (frequency). Acute exposures are usually single incidents of relatively short duration—a minute to a few days. Chronic exposures involve frequent doses at relatively low levels over a period of time ranging from months to years.

If a dose is administered slowly so that the rate of elimination or the rate of detoxification keeps pace with intake, it is possible that no toxic response will occur. The same dose could produce an effect with rapid administration.

<p style="text-align: center;"><b>TABLE 2</b> <b>CLASSIFICATION OF FACTORS INFLUENCING TOXICITY</b></p>	
<b>Type</b>	<b>Examples</b>
Factors related to the chemical	Composition (salt, free base, etc.); physical characteristics (particle size, liquid, solid, etc.); physical properties (volatility, solubility, etc.); presence of impurities; break down products; carrier.
Factors related to exposure	Dose; concentration; route of exposure (ingestion, skin absorption, injection, inhalation); duration.
Factors related to person exposed	Heredity; immunology; nutrition; hormones; age; sex; health status; preexisting diseases.
Factors related to environment	Carrier (air, water, food, soil); additional chemical present (synergism, antagonism); temperature; air pressure.

- **Routes of Exposure.** Biological results can be different for the same dose, depending on whether the chemical is inhaled, ingested, applied to the skin, or injected. Natural barriers impede the intake and distribution of material once in the body. These barriers can attenuate the toxic effects of the same dose of a chemical. The effectiveness of these barriers is partially dependent upon the route of entry of the chemical.
- **Interspecies Variation.** For the same dose received under identical conditions, the effects exhibited by different species may vary greatly. A dose which is lethal for one species may have no effect on another. Since the toxicological effects of chemicals on humans is usually based on animal studies, a test species must be selected that most closely approximates the physiological processes of humans.

- **Intraspecies Variations.** Within a given species, not all members of the population respond to the same dose identically. Some members will be more sensitive to the chemical and elicit response at lower doses than the more resistant members which require larger doses for the same response.
  - **Age and Maturity.** Infants and children are often more sensitive to toxic action than younger adults. Elderly persons have diminished physiological capabilities for the body to deal with toxic insult. These age groups may be more susceptible to toxic effects at relatively lower doses.
  - **Gender and Hormonal Status.** Some chemicals may be more toxic to one gender than the other. Certain chemicals can affect the reproductive system of either the male or female. Additionally, since women have a larger percentage of body fat than men, they may accumulate more fat-soluble chemicals. Some variations in response have also been shown to be related to physiological differences between males and females.
  - **Genetic Makeup.** Genetic factors influence individual responses to toxic substances. If the necessary physiological processes are diminished or defective the natural body defenses are impaired. For example, people lacking in the G6PD enzyme (a hereditary abnormality) are more likely to suffer red blood cell damage when given aspirin or certain antibiotics than persons with the normal form of the enzyme.
  - **State of Health.** Persons with poor health are generally more susceptible to toxic damage due to the body's decreased capability to deal with chemical insult.
- **Environmental Factors.** Environmental factors may contribute to the response for a given chemical. For example, such factors as air pollution, workplace conditions, living conditions, personal habits, and previous chemical exposure may act in conjunction with other toxic mechanisms.
- **Chemical Combinations.** Some combinations of chemicals produce different effects from those attributed to each individually:
  - **Synergists:** chemicals that, when combined, cause a greater than additive effect. For example, hepatotoxicity is enhanced as a result of exposure to both ethanol and carbon tetrachloride.
  - **Potentiation:** is a type of synergism where the potentiator is not usually toxic in itself, but has the ability to increase the toxicity of other chemicals. Isopropanol, for example, is not hepatotoxic in itself. Its combination with carbon tetrachloride, however, increases the toxic response to the carbon tetrachloride.
  - **Antagonists:** chemicals, that when combined, lessen the predicted effect. There are four types of antagonists.



(1) functional: Produces opposite effects on the same physiologic function. For example, phosphate reduces lead absorption in the gastrointestinal tract by forming insoluble lead phosphate.

(2) chemical: Reacts with the toxic compound to form a less toxic product. For example, chelating agents bind up metals such as lead, arsenic, and mercury.

(3) dispositional: Alters absorption, metabolism, distribution, or excretion. For example, some alcohols use the same enzymes in their metabolism:

ethanol----->	acetaldehyde----->	acetic acid
methanol----->	formaldehyde----->	formic acid

The aldehydes cause toxic effects (hangover, blindness). Ethanol is more readily metabolized than methanol, so when both are present, methanol is not metabolized and can be excreted before forming formaldehyde. Another dispositional antagonist is Antabuse which, when administered to alcoholics, inhibits the metabolism of acetaldehyde, giving the patient a more severe prolonged hangover.

(4) receptor: Occurs when a second chemical either binds to the same tissue receptor as the toxic chemical or blocks the action of receptor and thereby reduces the toxic effect. For example, atropine interferes with the receptor responsible for the toxic effects of organophosphate pesticides.

### **Sources of Toxicity Information**

Information on the toxic properties of chemical compounds and dose-response relationships is obtained from animal studies, epidemiological investigations of exposed human populations, and clinical studies or case reports of exposed humans.

- **Toxicity Tests.** The design of any toxicity test incorporates:
  - a test organism, which can range from cellular material and selected strains of bacteria through higher order plants and animals
  - a response or biological endpoint, which can range from subtle changes in physiology and behavior to death
  - an exposure or test period
  - a dose or series of doses.

The objective is to select a test species that is a good model of humans, a response that is not subjective and can be consistently determined for a given dose, and a test period that is relatively short.

- **Epidemiological and Clinical Studies.** Epidemiological investigations and clinical cases are another means of relating human health effects and exposure to toxic substances. Epidemiological investigations are based upon a human population exposed to a chemical compared to an appropriate, nonexposed group. An attempt is made to determine whether there is a statistically significant association between health effects and chemical exposure. Clinical cases involve individual reports of chemical exposure.

### Uses of Toxicity Information

**Comparison of Toxicity Data.** Comparing the LD<sub>50</sub> of chemicals in animals gives a relative ranking of potency or toxicity of each. For example, DDT (LD<sub>50</sub> for rats = 113 mg/kg) would be considered more toxic than ethyl alcohol (LD<sub>50</sub> for rats = 14,000 mg/kg). Using the LD<sub>50</sub> (mg/kg) for a test species and multiplying by 70 kg (average mass of man) gives a rough estimate of the toxic potential of the substance for humans, assuming that humans are as sensitive as the subjects tested.

Because the extrapolation of human data from animal studies is complex, this value should only be considered as an approximation for the potency of the compound and used in conjunction with additional data (Tables 3 and 4).

**Establishing Exposure Guidelines.** Toxicity data from both animal experimentation and epidemiological studies is used to establish exposure guidelines. The method for deriving a guideline is dependent upon the type of chemical as well as duration and frequency of exposure. It is also important to make the distinction between an experimental dose (mg/kg) and an environmental concentration (mg/m<sup>3</sup> or ppm). In order to make safety decisions, exposure guidelines are presented as concentrations so that these values can be compared to concentrations measured by air monitoring instrumentation.

TABLE 3 TOXICITY RATING	
Toxicity Rating or Class	Oral Acute LD <sub>50</sub> for Rats
Extremely toxic	1 mg/kg or less (dioxin, botulinum toxin)
Highly toxic	1 to 50 mg/kg (strychnine)
Moderately toxic	50 to 500 mg/kg (DDT)
Slightly toxic	0.5 to 5 g/kg (morphine)
Practically nontoxic	5 to 15 g/kg (ethyl alcohol)

**TABLE 4**  
**LD<sub>50</sub> VALUES FOR RATS FOR A GROUP OF WELL-KNOWN CHEMICALS**

Chemical	LD <sub>50</sub> (mg/kg)
Sucrose (table sugar)	29,700
Ethyl alcohol	14,000
Sodium chloride (common salt)	3,000
Vitamin A	2,000
Vanillin	1,580
Aspirin	1,000
Chloroform	800
Copper sulfate	300
Caffeine	192
Phenobarbital, sodium salt	162
DDT	113
Sodium nitrite	85
Nicotine	53
Aflatoxin B1	7
Sodium cyanide	6.4
Strychnine	2.5

### **Health Effects**

Human health effects caused by exposure to toxic substances fall into two categories: short-term and long-term effects. Short-term effects (or **acute effects**) have a relatively quick onset (usually minutes to days) after brief exposures to relatively high concentrations of material (acute exposures). The effect may be local or systemic. Local effects occur at the site of contact between the toxicant and the body. This site is usually the skin or eyes, but includes the lungs if irritants are inhaled or the gastrointestinal tract if corrosives are ingested. Systemic effects are those that occur if the toxicant has been absorbed into the body from its initial contact point, transported to other parts of the body, and cause adverse effects in susceptible organs. Many chemicals can cause both local and systemic effects.

Long-term effects (or **chronic effects**) are those with a long period of time (years) between exposure and injury. These effects may occur after apparent recovery from acute exposure or as a result of repeated exposures to low concentrations of materials over a period of years (chronic exposure).

Health effects manifested from acute or chronic exposure are dependent upon the chemical involved and the organ it effects. Most chemicals do not exhibit the same degree of toxicity for all organs.

Usually the major effects of a chemical will be expressed in one or two organs. These organs are known as target organs which are more sensitive to that particular chemical than other organs. The organs of the body and examples of effects due to chemical exposures are listed below.

**Respiratory Tract.** The respiratory tract is the only organ system with vital functional elements in constant, direct contact with the environment. The lung also has the largest exposed surface area of any organ on a surface area of 70 to 100 square meters versus 2 square meters for the skin and 10 square meters for the digestive system.

The respiratory tract is divided into three regions: (1) Nasopharyngeal—extends from nose to larynx. These passages are lined with ciliated epithelium and mucous glands. They filter out large inhaled particles, increase the relative humidity of inhaled air, and moderate its temperature. (2) Tracheobronchial—consists of trachea, bronchi, and bronchioles and serves as conducting airway between the nasopharyngeal region and alveoli. These passage ways are lined with ciliated epithelium coated by mucous, which serves as an escalator to move particles from deep in the lungs back up to the oral cavity so they can be swallowed. These ciliated cells can be temporarily paralyzed by smoking or using cough suppressants. (3) Pulmonary acinus—is the basic functional unit in the lung and the primary location of gas exchange. It consists of small bronchioles which connect to the alveoli. The alveoli, of which there are 100 million in humans, contact the pulmonary capillaries.

Inhaled particles settle in the respiratory tract according to their diameters:

- 5–30 micron particles are deposited in the nasopharyngeal region.
- 1–5 micron particles are deposited in the tracheobronchial region.
- Less than 1 micron particles are deposited in the alveolar region by diffusion and Brownian motion.

In general, most particles 5–10 microns in diameter are removed. However, certain small inorganic particles, settle into smaller regions of the lung and kill the cells which attempt to remove them. The result is fibrous lesions of the lung.

Many chemicals used or produced in industry can produce acute or chronic diseases of the respiratory tract when they are inhaled (Table 5). The toxicants can be classified according to how they affect the respiratory tract.

- **Asphyxiants:** gases that deprive the body tissues of oxygen
- **Simple asphyxiants** are physiologically inert gases that at high concentrations displace air leading to suffocation. Examples: nitrogen, helium, methane, neon, argon.
- **Chemical asphyxiants** are gases that prevent the tissues from getting enough oxygen. Examples: carbon monoxide and cyanide. Carbon monoxide binds to hemoglobin 200 times more readily than oxygen. Cyanide prevents the transfer of oxygen from blood to tissues by inhibiting the necessary transfer enzymes.
- **Irritants:** chemicals that irritate the air passages. Constriction of the airways occurs and may lead to edema (liquid in the lungs) and infection. Examples: hydrogen fluoride, chlorine, hydrogen chloride, and ammonia.

- **Necrosis producers:** Chemicals that result in cell death and edema. Examples: ozone and nitrogen dioxide.
- **Fibrosis producers:** Chemicals that produce fibrotic tissue which, if massive, blocks airways and decreases lung capacity. Examples: silicates, asbestos, and beryllium.
- **Allergens:** Chemicals that induce an allergic response characterized by bronchoconstriction and pulmonary disease. Examples: isocyanates and sulfur dioxide.
- **Carcinogens:** Chemicals that are associated with lung cancer. Examples: cigarette smoke, coke oven emissions, asbestos, and arsenic.

Not only can various chemicals affect the respiratory tract, but the tract is also a route for chemicals to reach other organs. Solvents, such as benzene and tetrachloroethane, anesthetic gases, and many other chemical compounds can be absorbed through the respiratory tract and cause systemic effects.

<b>TABLE 5</b> <b>EXAMPLES OF INDUSTRIAL TOXICANTS THAT PRODUCE</b> <b>DISEASE OF THE RESPIRATORY TRACT</b>			
<b>Toxicant</b>	<b>Site of Action</b>	<b>Acute Effect</b>	<b>Chronic Effect</b>
Ammonia	Upper airways	Irritation, edema	Bronchitis
Arsenic	Upper airways	Bronchitis, irritation, pharyngitis	Cancer, bronchitis, laryngitis
Asbestos	Lung parenchyma	- -	Fibrosis, cancer
Chlorine	Upper airways	Cough, irritation, asphyxiant (by muscle cramps in larynx)	- -
Isocyanates	Lower airways, alveoli	Bronchitis, pulmonary edema, asthma	- -
Nickel Carbony	Alveoli	Edema (delayed symptoms)	- -
Ozone	Bronchi, alveoli	Irritation, edema, hemorrhage	Emphysema, bronchitis
Phosgene	Alveoli	Edema	Bronchitis, fibrosis, pneumonia
Toluene	Upper airways	Bronchitis, edema, bronchospasm	- -
Xylene	Lower airways	Edema, hemorrhage	- -

**Skin.** The skin is, in terms of weight, the largest single organ of the body. It provides a barrier between the environment and other organs (except the lungs and eyes) and is a defense against many chemicals.

The skin consists of the epidermis (outer layer) and the dermis (inner layer). In the dermis are sweat glands and ducts, sebaceous glands, connective tissue, fat, hair follicles, and blood vessels. Hair follicles and sweat glands penetrate both the epidermis and dermis. Chemicals can penetrate through the sweat glands, sebaceous glands, or hair follicles.

Although the follicles and glands may permit a small amount of chemicals to enter almost immediately, most pass through the epidermis, which constitutes the major surface area. The top layer is the stratum corneum, a thin cohesive membrane of dead surface skin. This layer turns over every 2 weeks by a complex process of cell dehydration and polymerization of intracellular material. The epidermis plays the critical role in skin permeability.

Below the epidermis lies the dermis, a collection of cells providing a porous, watery, nonselective diffusion medium. Intact skin has a number of functions:

- Epidermis: Prevents absorption of chemicals and is a physical barrier to bacteria.
- Sebaceous glands: Secrete fatty acids which are bacteriostatic and fungistatic.
- Melanocytes (skin pigment): Prevent damage from ultraviolet radiation in sunlight.
- Sweat glands: Regulate heat.
- Connective tissue: Provides elasticity against trauma.
- Lymph-blood system: Provide immunologic responses to infection.

The ability of skin to absorb foreign substances depends on the properties and health of the skin and the chemical properties of the substances. Absorption is enhanced by:

- Breaking top layer of skin by abrasions or cuts.
- Increasing hydration of skin.
- Increasing temperature of skin which causes sweat cells to open up and secrete sweat, which can dissolve solids.
- Increasing blood flow to skin.
- Increasing concentrations of the substance.
- Increasing contact time of the chemical on the skin.
- Increasing the surface area of affected skin.
- Altering the skin's normal pH of 5.
- Decreasing particle size of substance.
- Adding agents which will damage skin and render it more susceptible to penetration.
- Adding surface-active agents or organic chemicals. DMSO, for example, can act as a carrier of the substance.
- Inducing ion movement by an electrical charge.

Absorption of a toxic chemical through the skin can lead to **local effects** through direct contact, such as irritation and necrosis, and **systemic effects**.

Many chemicals can cause a reaction with the skin resulting in inflammation called dermatitis. These chemicals are divided into three categories:

- **Primary irritants:** Act directly on normal skin at the site of contact (if chemical is in sufficient quantity for a sufficient length of time). Skin irritants include: acetone, benzyl chloride, carbon disulfide, chloroform, chromic acid and other soluble

chromium compounds, ethylene oxide, hydrogen chloride, iodine, methyl ethyl ketone, mercury, phenol, phosgene, styrene, sulfur dioxide, picric acid, toluene, xylene.

- **Photosensitizers:** Increase in sensitivity to light, which results in irritation and redness. Photosensitizers include: tetracyclines, acridine, creosote, pyridine, furfural, and naphtha.
- **Allergic sensitizers:** May produce allergic-type reaction after repeated exposures. They include: formaldehyde, phthalic anhydride, ammonia, mercury, nitrobenzene, toluene diisocyanate, chromic acid and chromates, cobalt, and benzoyl peroxide.

**Eyes.** The eyes are affected by the same chemicals that affect skin, but the eyes are much more sensitive. Many materials can damage the eyes by direct contact:

- **Acids:** Damage to the eye by acids depends on pH and the protein-combining capacity of the acid. Unlike alkali burns, the acid burns that are apparent during the first few hours are a good indicator of the long-term damage to be expected. Some acids and their properties are:
  - sulfuric acid. In addition to its acid properties, it simultaneously removes water and generates heat.
  - picric acid and tannic acid. No difference in damage they produce in entire range of acidic pHs.
  - hydrochloric acid. Severe damage at pH 1, but no effect at pH 3 or greater.
- **Alkalies:** Damage that appears mild initially but can later lead to ulceration, perforation, and clouding of the cornea or lens. The pH and length of exposure have more bearing on the amount of damage than the type of alkali. Some problem alkalies are:
  - sodium hydroxide (caustic soda) and potassium hydroxide.
  - ammonia penetrates eye tissues more readily than any other alkali; calcium oxide (lime) forms clumps when it contacts eye tissue and is very hard to remove.
- **Organic solvents:** Organic solvents (for example, ethanol, toluene, and acetone) dissolve fats, cause pain, and dull the cornea. Damage is usually slight unless the solvent is hot.
- **Lacrimators:** Lacrimators cause instant tearing at low concentrations. They are distinguished from other eye irritants (hydrogen chloride and ammonia) because they induce an instant reaction without damaging tissues. At very high concentrations lacrimators can cause chemical burns and destroy corneal material. Examples are chloroacetophenone (tear gas) and mace.

In addition, some compounds act on eye tissue to form cataracts, damage the optic nerve, or damage the retina. These compounds usually reach the eye through the blood system having been inhaled, ingested or absorbed rather than direct contact.

Examples of compounds that can provide systemic effects damaging to the eyes are:

- Naphthalene: Cataracts and retina damage.
- Phenothiazine (insecticide): Retina damage
- Thallium: cataracts and optic nerve damage.
- Methanol: Optic nerve damage.

**Central Nervous System.** Neurons (nerve cells) have a high metabolic rate but little capacity for anaerobic metabolism. Subsequently, inadequate oxygen flow (anoxia) to the brain kills cells within minutes. Some may die before oxygen or glucose transport stops completely.

Because of their need for oxygen, nerve cells are readily affected by both simple asphyxiants and chemical asphyxiants. Also, their ability to receive adequate oxygen is affected by compounds that reduce respiration and thus reduce oxygen content of the blood (barbiturates, narcotics). Other examples are compounds such as arsine, nickel, ethylene chlorohydrin, tetraethyl lead, aniline, and benzene that reduce blood pressure or flow due to cardiac arrest, extreme hypotension, hemorrhaging, or thrombosis.

Some compounds damage neurons or inhibit their function through specific action on parts of the cell. The major symptoms from such damage include: dullness, restlessness, muscle tremor, convulsions, loss of memory, epilepsy, idiocy, loss of muscle coordination, and abnormal sensations. Examples are:

- Fluoroacetate: Rodenticide.
- Triethyltin: Ingredient of insecticides and fungicides.
- Hexachlorophene: Antibacterial agent.
- Lead: Gasoline additive and paint ingredient.
- Thallium: Sulfate used as a pesticide and oxide or carbonate used in manufacture of optical glass and artificial gems.
- Tellurium: Pigment in glass and porcelain.
- Organomercury compounds: Methyl mercury used as a fungicide; is also a product of microbial action on mercury ions. Organomercury compounds are especially hazardous because of their volatility and their ability to permeate tissue barriers.

Some chemicals are noted for producing weakness of the lower extremities and abnormal sensations (along with previously mentioned symptoms):

- Acrylamide: Soil stabilizer, waterproofer.
- Carbon disulfide: Solvent in rayon and rubber industries.
- n-Hexane: Used as a cleaning fluid and solvent. Its metabolic product, hexanediol, causes the effects.
- Organophosphorus compounds: Often used as flame retardants (triorthocresyl phosphate) and pesticides (Leptofor and Mipafox).



Agents that prevent the nerves from producing proper muscle contraction and may result in death from respiratory paralysis are DDT, lead, botulinum toxin, and allethrin (a synthetic insecticide). DDT, mercury, manganese, and monosodium glutamate also produce personality disorders and madness.

**Liver.** Liver injury induced by chemicals has been known as a toxicologic problem for hundreds of years. It was recognized early that liver injury is not a simple entity, but that the type of lesion depends on the chemical and duration of exposure. Three types of response to hepatotoxins can be identified:

- **Acute.** Cell death from:
  - carbon tetrachloride: Solvent, degreaser.
  - chloroform: Used in refrigerant manufacture solvent.
  - trichloroethylene: Solvent, dry cleaning fluid, degreaser.
  - tetrachloroethane: Paint and varnish remover, dry cleaning fluid.
  - bromobenzene: Solvent, motor oil additive.
  - tannic acid: Ink manufacture, beer and wine clarifier.
  - kepone: Pesticide.
- **Chronic.** Examples include:
  - cirrhosis: a progressive fibrotic disease of the liver associated with liver dysfunction and jaundice. Among agents implicated in cirrhosis cases are carbon tetrachloride, alcohol, and aflatoxin.
  - carcinomas: malignant, growing tissue. For example, vinyl chloride (used in polyvinyl chloride production) and arsenic (used in pesticides and paints) are associated with cancers.
- **Biotransformation of toxicants.** The liver is the principal organ that chemically alters all compounds entering the body. For example:

ethanol---> acetaldehyde---> acetic acid---> water+carbon dioxide

This metabolic action by the liver can be affected by diet, hormone activity, and alcohol consumption. Biotransformation in the liver can also lead to toxic metabolites. For example:

carbon tetrachloride---> chloroform

**Kidneys.** The kidney is susceptible to toxic agents for several reasons: (1) The kidneys constitute 1 percent of the body's weight, but receive 20–25 percent of the blood flow (during rest). Thus, large amounts of circulating toxicants reach the kidneys quickly. (2) The kidneys have high oxygen and nutrient requirements because of their work load. They filter one-third of the plasma reaching them and reabsorb 98–99% of the salt and water. As they are reabsorbed, salt concentrates in the kidneys. (3) Changes in kidney pH may increase passive diffusion and thus cellular concentrations of toxicants. (4) Active secretion processes may concentrate toxicants. (5) Biotransformation is high.

A number of materials are toxic to the kidneys:

- Heavy metals, may denature proteins as well as produce cell toxicity. Heavy metals (including mercury, chromium, arsenic, gold, cadmium, lead, and silver) are readily concentrated in the kidneys, making this organ particularly sensitive.
- Halogenated organic compounds, which contain chlorine, fluorine, bromine, or iodine. Metabolism of these compounds, like that occurring in the liver, generates toxic metabolites. Among compounds toxic to the kidneys are carbon tetrachloride, chloroform, 2,4,5-T (a herbicide), and ethylene dibromide (a fumigant).
- Miscellaneous, including carbon disulfide (solvent for waxes and resins) and ethylene glycol (automobile antifreeze).

**Blood.** The blood system can be damaged by agents that affect blood cell production (bone marrow), the components of blood (platelets, red blood cells, and white blood cells), or the oxygen-carrying capacity of red blood cells.

**Bone Marrow.** Bone marrow is the source of most components in blood. Agents that suppress the function of bone marrow include:

- Arsenic, used in pesticides and paints.
- Bromine, used to manufacture gasoline antiknock compounds, ethylene dibromide, and organic dyes.
- Methyl chloride, used as a solvent, refrigerant, and aerosol propellant.
- Ionizing radiation, produced by radioactive materials and x-rays is associated with leukemia.
- Benzene, a chemical intermediate associated with leukemia.

**Blood Components.** Among platelets (thrombocytes) are blood components that help prevent blood loss by forming blood clots. Among chemicals that affect this action are:

- Aspirin, which inhibits clotting.
- Benzene, which decreases the number of platelets.
- Tetrachloroethane, which increases the number of platelets.

Leukocytes (white blood cells) are primarily responsible for defending the body against foreign organisms or materials by engulfing and destroying the material or by producing antibodies. Chemicals that increase the number of leukocytes include naphthalene, magnesium oxide, boron hydrides, and tetrachloroethane. Agents that decrease the number of leukocytes include benzene and phosphorous.

Erythrocytes (red blood cells) transport oxygen in the blood. Chemicals that destroy (hemolyze) red blood cells include arsine (a gaseous arsenic compound and contaminant in acetylene), naphthalene (used to make dyes), and warfarin (a rodenticide).

**Oxygen Transport.** Some compounds affect the oxygen carrying capabilities of red blood cells. A notable example is carbon monoxide which combines with hemoglobin to form

carboxyhemoglobin. Hemoglobin has an affinity for carbon monoxide 200 times greater than that for oxygen.

While carbon monoxide combines reversibly with hemoglobin, some chemicals cause the hemoglobin to change such that it cannot combine reversibly with oxygen. This condition is called methemoglobinemia. Some chemicals that can cause this are:

- Sodium nitrite, used in meat curing and photography.
- Aniline, used in manufacture of rubber accelerators and antioxidants, resins, and varnishes.
- Nitrobenzene and dinitrobenzene, used in manufacture of dyestuffs and explosives.
- Trinitrotoluene (TNT), used in explosives.
- Mercaptans, used in manufacture of pesticides and as odorizers for hazardous odorless gases.
- 2-nitropropane, used as a solvent.

**Spleen.** The spleen filters bacteria and particulate matter (especially deteriorated red blood cells) from the blood. Iron is recovered from the hemoglobin for recycling. In the embryo, the spleen forms all types of blood cells. In the adult, however, it produces only certain kinds of leukocytes. Examples of chemicals that damage the spleen are:

- Chloroprene, used in production of synthetic rubber.
- Nitrobenzene, used as chemical intermediate.

**Reproductive System.** Experimental results indicate that certain agents interfere with the reproductive capabilities of both sexes, causing sterility, infertility, abnormal sperm, low sperm count, and/or affect hormone activity in animals. Many of these also affect human reproduction. Further study is required to identify reproductive toxins and their effects. Some examples of chemicals that have been implicated in reproductive system toxicity include:

- **Male:** Anesthetic gases (halothane, methoxyflurane) cadmium, mercury, lead, boron, methyl mercury, vinyl chloride, DDT, kepone, chlordane, PCBs, dioxin, 2,4-D, 2,4,5-T, carbaryl, paraquat, dibromochloropropane, ethylene dibromide, benzene, toluene, xylene, ethanol, radiation, and heat.
- **Female:** DDT, parathion, carbaryl, diethylstilbestrol (DES), PCBs, cadmium, methyl mercury, hexafluoroacetone, and anesthetic gases.

### Types of Toxic Effects

**Teratogenic.** Teratology is derived from Latin and means the study of monsters. In a modern context, teratology is the study of congenital malformations. Teratology is a relatively new discipline that started in 1941 with the correlation of German measles to birth defects. In the 1960s, the first industrial link to teratogens was discovered. The chemical involved was methyl mercury.

The following conditions have been associated with **congenital malformations**: heredity, maternal diseases such as German measles and viral infections during pregnancy, maternal malnutrition, physical injury, radiation, and exposure to chemicals.

Most major structural abnormalities occur during the embryonic period, 5–7 weeks, whereas physiologic and minor defects occur during the fetal period, 8–36 weeks. Studies using lab animals show the need to evaluate exposure of chemicals for each day of pregnancy. Thalidomide, for example, caused birth defects in rats only when administered during the 12th day of gestation.

A number of chemicals are reactive or can be activated in the body during the gestation period. The degree and nature of the fetal effects then depend upon:

- Developmental state of embryo or fetus when chemical is administered.
- Dose of chemical, route, and exposure interval.
- Transplacental absorption of chemical and levels in tissues of embryo/fetus.
- Ability of maternal liver and placenta to metabolize or detoxify chemical.
- Biologic half-life of chemical or metabolites.
- State of cell cycle when chemical is at toxic concentrations.
- Capacity of embryonic/fetal tissues to detoxify or bioactivate chemicals.
- Ability of damaged cells to repair or recover.

Teratogenic potential has been suggested by animal studies under various conditions:

- Dietary deficiency: Vitamins A, D, E, C, riboflavin, thiamine, nicotinamide, folic acid, zinc, manganese, magnesium, and cobalt.
- Hormonal deficiency: Pituitary, thyroxine, and insulin.
- Hormonal excess: Cortisone, thyroxine, insulin androgens, estrogens, and epinephrine.
- Hormone and vitamin antagonists: 3-acetylpyridine, 6-aminonicotinamide, and thiouracils.
- Vitamin excess: Vitamin A and nicotinic acid.
- Antibiotics: Penicillin, tetracyclines, and streptomycin.
- Heavy metals: Methyl mercury, mercury salts, lead, thallium, selenium, and chelating agents.
- Azo dyes: Trypan blue, Evans blue, and Niagara sky blue 6B.
- Producers of anoxia: Carbon monoxide and carbon dioxide.
- Chemicals: Quinine, thiadiazole, salicylate, 2,3,7,8-TCDD, caffeine, nitrosamines, hydroxyurea, boric acid, insecticides, pesticides, DMSO, chloroform, carbon tetrachloride, benzene, xylene, cyclohexanone, propylene glycol, acetamides, formamides, and sulfonamides.
- Physical conditions: hypothermia, hyperthermia, radiation, and anoxia.
- Infections: Ten viruses (including German measles and cytomegalovirus), syphilis, and gonorrhea.

Far fewer agents have been conclusively shown to be teratogenic in humans: anesthetic gases, organic mercury compounds, ionizing radiation, German measles and thalidomide.

**Mutagenic.** Mutagens are agents that cause changes (mutations) in the genetic code, altering DNA. The changes can be chromosomal breaks, rearrangement of chromosome pieces, gain or loss of entire chromosomes, or a change within a gene.

Among agents shown to be mutagenic in humans are:

- Ethylene oxide, used in hospitals as a sterilant.
- Ethyleneimine, an alkylating agent.
- Ionizing radiation.
- Hydrogen peroxide, a bleaching agent.
- Benzene, a chemical intermediate.
- Hydrazine, used in rocket fuel.

The concern over mutagenic agents covers more than the effect that could be passed into the human gene pool (germinal or reproductive cell mutations). There is also interest in the possibility that somatic cell mutations may produce carcinogenic or teratogenic responses.

**Carcinogenic.** Two types of carcinogenic mechanisms have been identified.

- **Genotoxic:** Electrophilic carcinogens that alter genes through interaction with DNA. There are three types:
  - **Direct or primary carcinogens:** Chemicals that act without any bioactivation; for example, bis(chloromethyl) ether, ethylene dibromide, and dimethyl sulfate.
  - **Procarcinogens:** Chemicals that require biotransformation to activate them to a carcinogen; for example, vinyl chloride and 2-naphthylamine.
  - **Inorganic carcinogen:** Some of these are preliminarily categorized as genotoxic due to potential for DNA damage. Other compounds in the group may operate through epigenetic mechanisms.
- **Epigenetic:** These are carcinogens that do not act directly with genetic material. Several types are possible:
  - **Cocarcinogen:** Increases the overall response of a carcinogen when they are administered together; for example, sulfur dioxide, ethanol, and catechol.
  - **Promoter:** Increases response of a carcinogen when applied after the carcinogen but will not induce cancer by itself; for example, phenol and dithranol.
  - **Solid-state:** Works by unknown mechanism, but physical form vital to effect; for example, asbestos and metal foils.
  - **Hormone:** Usually is not genotoxic, but alters endocrine balance; often acts as promoter (e.g., DES and estrogens).
  - **Immunosuppressor:** Mainly stimulates virally induced, transplanted, or metastatic neoplasms by weakening host's immune system (e.g., antilymphocytic serum, used in organ transplants).

Genotoxic carcinogens are sometimes effective after a single exposure, can act in a cumulative manner, or act with other genotoxic carcinogens which affect the same organs. Some epigenetic carcinogens, however, only cause cancers when concentrations are high and exposure long. The implication is that while there may be a "safe" threshold level of exposure for some carcinogens, others may have "zero" threshold; that is, one molecule of the chemical can induce a cancer.

Various considerations indicate that DNA is a critical target for carcinogens:

- Many carcinogens are or can be metabolized so that they react with DNA. In these cases, the reaction can usually be detected by testing for evidence of DNA repair.
- Many carcinogens are also mutagens.
- Inhibitors and inducers of carcinogens affect mutagenic activity.
- Chemicals often are tested for mutagenic and carcinogenic activity in the same cell systems.
- Defects in DNA repair predispose to cancer development.
- Several inheritable or chromosomal abnormalities predispose to cancer development.
- Initiated dormant tumor cells persist, which is consistent with a change in DNA.
- Cancer is inheritable at the cellular level and, therefore, may result from an alteration of DNA.
- Most, if not all, cancers display chromosomal abnormalities.

Although cancer ranks as the second most common cause of death in the United States, the process of carcinogenesis is not yet clearly defined. As a result, there are several problems encountered when evaluating the carcinogenic potential of various agents in the environment. First, human health can be affected by a wide range of factors including the environment, occupation, genetic predisposition and lifestyle (i.e., cigarette smoking and diet). Therefore, it is often difficult to determine the relationship between any one exposure and the onset of cancer. Second, many cancers are latent responses; that is, the disease may not be manifested until many years after the initial exposure. Third, the mechanisms for carcinogenesis may differ according to the type and the site of cancer.

### **EXPOSURE GUIDELINES**

It is necessary, during response activities involving hazardous materials, to acknowledge and plan for the possibility that response personnel will be exposed to the materials present at some time and to some degree. Most materials have levels of exposure which can be tolerated without adverse health effects. However, it is most important to identify the materials involved and then determine (1) the exposure levels considered safe for each of these materials; (2) the type and extent of exposure; and (3) possible health effects of overexposure.

Several reference sources are available that contain information about toxicological properties and safe exposure limits for many different materials. These sources can be grouped into two general categories: 1) sources that provide toxicological data and general health hazard information and warnings and 2) sources that describe specific legal exposure limits or recommended exposure guidelines.

Both types of sources, considered together, provide useful information that can be used to assess the exposure hazards that might be present at a hazardous materials incident. In the following discussion, these sources are described in greater detail.

## **General Guidelines**

The effects of chemical exposure with the route and dosage required can be found in NIOSH's *Registry of Toxic Effects of Chemical Substances*. However, because most of the data is for animal exposures, there may be problems in trying to use the data for human exposure guidelines.

Other sources give some general guides on chemical exposure. They may say that the chemical is an irritant or corrosive, or they may give a warning like "AVOID CONTACT" or "AVOID BREATHING VAPORS." This gives the user information about the possible route of exposure and effects of the exposure. However, this does not give a safe exposure limit. One may question whether the warning means to "AVOID ANY POSSIBLE CONTACT" or whether there is a certain amount that a person can contact safely for a certain length of time.

Two sources of information go a little further and use a ranking system for exposure to chemicals. Irving Sax, in *Dangerous Properties of Industrial Materials*, gives a Toxic Hazard Rating (THR) for certain chemicals. These ratings are NONE, LOW, MODERATE, and HIGH. The route of exposure is also given. For example, butylamine is listed as a HIGH toxic hazard via oral and dermal routes and a MODERATE toxic hazard via inhalation. HIGH means that the chemical is "capable of causing death or permanent injury due to the exposures of normal use; incapacitating and poisonous; requires special handling."

In the book, *Fire Protection Guide on Hazardous Materials*, the National Fire Protection Association (NFPA) also uses a ranking system to identify the toxic hazards of a chemical. These numbers are part of the NFPA 704 M identification system. The numbers used range from 0 to 4 where 0 is for "materials which on exposure under fire conditions would offer no health hazard beyond that of ordinary combustible material" and 4 is for materials where "a few whiffs of the gas or vapor could cause death; or the gas, vapor, or liquid could be fatal on penetrating the fire fighters' normal full protective clothing which is designed for resistance to heat." The degree of hazard is based upon the inherent properties of the chemical and the hazard that could exist under fire or other emergency conditions. This rating is based on an exposure of "a few seconds to an hour" and the possibility of large quantities of material being present. Thus it is not completely applicable to long-term exposure to small quantities of chemicals. It is more useful for spills or fires where a person could come in contact with a large amount of the chemical.

The Sax and NFPA sources provide information about the routes of exposures and some effects along with a rating system which indicates which chemicals require extra precaution and special protective equipment.

## **Sources for Specific Guidelines for Airborne Contaminants**

While there are many sources for general exposure guidelines, there are only a few that give more specific information about what is considered a safe exposure limit. Many of the following organizations have exposure guidelines for exposures to hazards other than airborne contaminants (e.g., heat stress, noise, and radiation). This part will deal only with chemical exposures.

**American Conference of Governmental Industrial Hygienists (ACGIH).** One of the first groups to develop specific exposure guidelines was the American Conference of Governmental Industrial

Hygienists (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 Threshold Limit Values (TLVs).

Along with the TLVs, ACGIH publishes Biological Exposure Indices (BEIs). BEIs are intended to be used as guides for evaluation of exposure where inhalation is not the only possible route of exposure. Since the TLVs are for inhalation only, they may not be protective if the chemical is ingested or is absorbed through the skin. Biological monitoring (e.g., urine samples, breath analysis) can be used to assess the overall exposure. This monitoring 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 their booklet, *Threshold Limit Values and Biological Exposure Indices*.

**American National Standards Institute (ANSI).** The American National Standards Institute (ANSI) has published standards that are a consensus of the people who have a concern about the subject the standard covers (e.g., hard hats and respirators). An ANSI standard is intended as a guide to aid manufacturers, consumers, and the general public. ANSI has standards covering many aspects of the working environment. Many of these have been adopted by OSHA (see later discussion) as legal requirements.

Some of the standards were exposure guidelines. They gave "acceptable concentrations" which were "concentrations of air contaminants to which a person may be exposed without discomfort or ill effects." These exposure limits were withdrawn in 1982. However, some were adopted by OSHA before the withdrawal and still may be in use.

**Occupational Safety and Health Administration (OSHA).** In 1971, the Occupational Safety and Health Administration (OSHA) promulgated Permissible Exposure Limits (PELs). These limits were extracted from the 1968 TLVs, the 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 have been incorporated into specific standards for chemicals (e.g., 29 CFR 1910.1028 - Benzene). There are also standards for thirteen carcinogens in which there is no allowable inhalation exposure.

In 1989, OSHA published major revisions to the PELs. Since only a few of the PELs had been updated since 1971, it was decided to update the entire list of PELs by changing existing ones and adding new ones. Again, OSHA looked to the TLVs, but also considered recommendations from the National Institute for Occupational Safety and Health (NIOSH).

Because OSHA is a regulatory agency, their PELs are legally enforceable standards and apply to all private industries and federal agencies. They may also apply to state and local employees depending upon the state laws.

**National Institute for Occupational Safety and Health (NIOSH).** The National Institute for Occupational Safety and Health (NIOSH) was formed at the same time as OSHA to act as a research



organization. It is charged in part, with making recommendations for new standards and revising old ones as more information is accumulated. The exposure levels NIOSH has researched have been used to develop new OSHA standards, but there are many Recommended Exposure Limits (RELs) that have not been adopted. Thus, they are in the same status as the exposure guidelines of ACGIH and other groups. The RELs are found in the "NIOSH Recommendations for Occupational Health Standards" (see Appendix II).

**American Industrial Hygiene Association (AIHA).** The American Industrial Hygiene Association 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. Appendix III has the current list of WEELs. While the list is not as large as others, AIHA has chosen chemicals for which other groups do not have exposure guidelines. Thus, they are providing information to fill the gaps left by others.

### Types of Exposure Guidelines

Several organizations develop exposure guidelines. However, the types of guidelines they produce are similar.

**Time-Weighted Average (TWA).** This exposure is determined by averaging the concentrations of the exposure with each concentration weighted based on the duration of exposure. For example, an exposure to acetone at the following concentrations and durations:

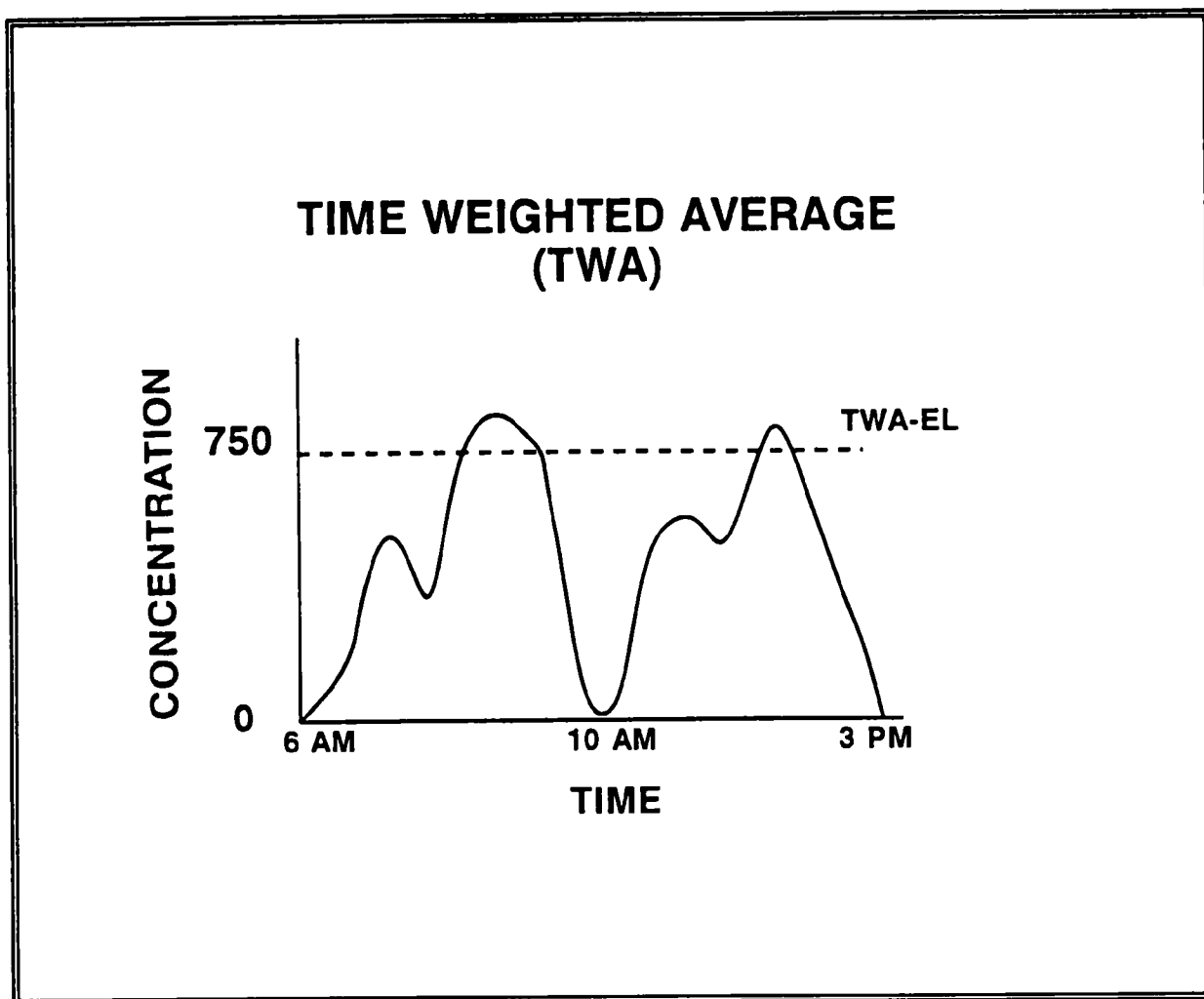
*1000 ppm for 3 hours  
500 ppm for 2 hours  
200 ppm for 3 hours*

would have an 8-hour, TWA exposure of:

$$\begin{aligned} & \frac{(3 \text{ hrs})(1000 \text{ ppm}) + (2 \text{ hrs})(500 \text{ ppm}) + (3 \text{ hrs})(200 \text{ ppm})}{8 \text{ hrs}} \\ &= \frac{3000 \text{ ppm} + 1000 \text{ ppm} + 600 \text{ ppm}}{8} \\ &= 575 \text{ ppm} \end{aligned}$$

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

A TWA can be the average concentration over any period of time. However, most TWAs are the average concentration of a chemical most workers can be exposed to during a 40-hour week and a normal 8-hour work day without showing any toxic effects. NIOSH TWA recommendations, on the other hand, can also be based on exposures up to 10 hours. The time-weighted average permits exposure to concentrations above the limit, when they are compensated by equal exposure below the TWA. (Graph 3) shows an example that illustrates this point for a chemical with a TWA exposure limit of 750 ppm.

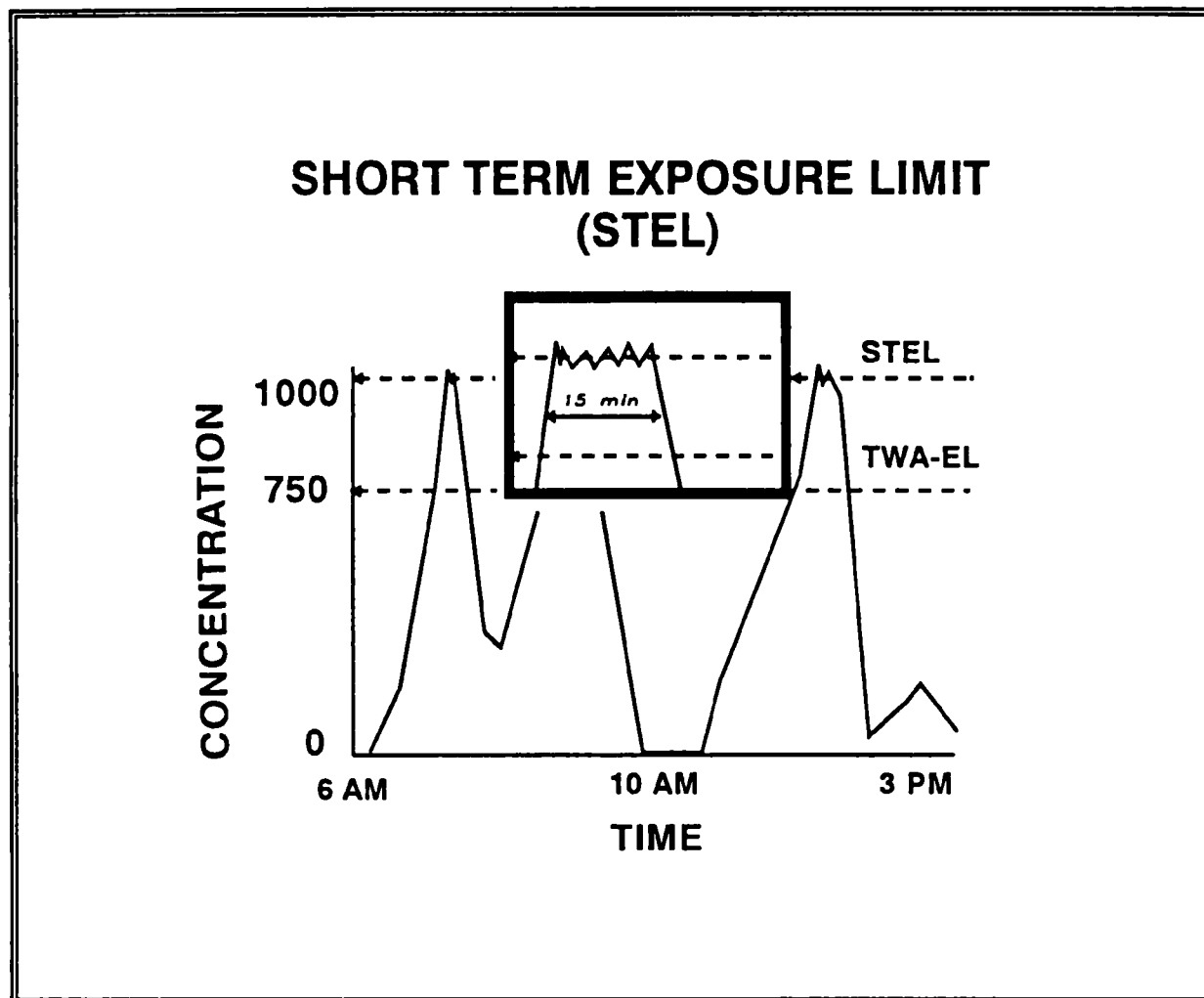


**GRAPH 3**  
**EXAMPLE OF AN EXPOSURE COMPARED TO A TWA EXPOSURE LIMIT**

**Short-Term Exposure Limit (STEL).** The excursions allowed by the TWA could involve very high concentrations and cause an adverse effect, but still be within the allowable average. Therefore, some organizations felt there was a need for a limit to these excursions. In 1976, ACGIH added STELs to its TLVs. The STEL is a 15 minute, TWA exposure. Excursions to the STEL should be at least 60 minutes apart, no longer than 15 minutes in duration and should not be repeated more than 4 times per day. Because the excursions are calculated into the 8-hour TWA, the exposure must be limited to avoid exceeding the TWA. Graph 4 illustrates an exposure that exceeds the 15 minute limit for an STEL of 1000 ppm.

The STEL supplements the TWA. It reflects an exposure limit that protects 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. OSHA added STELs to its PELs with the 1989 revisions.

AIHA has some short-term TWAs 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.



**GRAPH 4**  
**EXAMPLE OF AN EXPOSURE COMPARED TO AN STEL AND A TWA**

**Ceiling (C).** Ceiling values exist for substances where exposure results in a rapid and particular type of response. It is used where a TWA (with its allowable excursions) would not be appropriate. ACGIH and OSHA state that a ceiling value should not be exceeded even instantaneously. They denote a ceiling value by a "C" preceding the exposure limit.

NIOSH also uses ceiling values. However, their ceiling values are more like a STEL. Many have time limits (from 5 to 60 minutes) associated with the exposure. **Graph 5** illustrates an exposure that does not exceed a ceiling value of 5 ppm.



**"Skin" Notation.** While these exposure guidelines are based on exposure to airborne concentrations of chemicals. However, OSHA, NIOSH, ACGIH and AIHA recognize that there are other routes of exposure in the workplace. In particular, there can be a contribution to the overall exposure from skin contact with chemicals that can be absorbed through the skin. Unfortunately, there is very little data available that quantifies the amount of allowable skin contact. But some organizations provide qualitative information about skin absorbable chemicals. When a chemical has the potential to contribute to the overall exposure by direct contact with the skin, mucous membranes or eyes, it is given a "skin" notation.

This "skin" notation not only points out chemicals that are readily absorbed through the skin, but also notes that if there is skin contact, the exposure guideline for inhalation may not provide adequate protection. The inhalation exposure guidelines are designed for exposures only from inhalation. If additional routes of exposure are added, there can be detrimental effects even if the exposure guideline is not exceeded.

**Immediately Dangerous to Life or Health (IDLH).** In the May 1987 "NIOSH Respirator Decision Logic", IDLH is defined as a condition "that poses a threat of exposure to airborne contaminants when that exposure is likely to cause death or immediate or delayed permanent adverse health effects or prevent escape from such an environment. The purpose of establishing an IDLH exposure level is to ensure that the worker can escape from a given contaminated environment in the event of failure of the respiratory protection equipment."

Other organizations, such as ANSI, OSHA, and the Mine Safety and Health Administration (MSHA), have defined IDLH similarly. It is accepted by all of these groups that IDLH conditions include not only toxic concentrations of contaminants, but also oxygen-deficient atmospheres and explosive, or near-explosive (above, at, or near the lower explosive limits), environments.

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 concentrations values for many substances can be found in the NIOSH "Pocket Guide to Chemical Hazards." Guidelines for potentially explosive, oxygen deficient, or radioactive environments can be found in the U.S. EPA "Standard Operating Safety Guidelines" and the NIOSH/OSHA/USCG/EPA *Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities*.

### **Exposure Limits for Chemical Mixtures**

The exposure limits that have been discussed are based upon exposure to single chemicals. Since 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 calculation used is:

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

where:

*E<sub>m</sub> is the equivalent exposure for the mixture.*

*C is the concentration of a particular contaminant.*

*L is the exposure limit for that substance.*

*The value of E<sub>m</sub> should not exceed unity (1).*

*An example using this calculation would be as follows:*

*Chemical A    C = 200 ppm   L = 750 ppm*

*Chemical B    C = 100 ppm   L = 500 ppm*

*Chemical C    C = 50 ppm   L = 200 ppm*

$$E_m = 200 \div 750 + 100 \div 500 + 50 \div 200$$

$$E_m = 0.27 + 0.20 + 0.25$$

$$E_m = 0.72$$

Since  $E_m$  is less than unity, the exposure combination is within acceptable limits.

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.

### **Application of Exposure Guidelines**

In 29 CFR 1910.120, "Hazardous Waste Operations and Emergency Response" standard, OSHA specifies the use of certain exposure limits. The exposure limits 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*.

**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, published literature and material safety data sheets (MSDS) will be used for evaluation. In these circumstances, a combination of engineering controls, work practices and PPE shall be used to reduce and maintain exposures.

**Personal Protective Equipment.** Since PPE must be selected based on the hazards present at the site, the exposure limits are used to evaluate the effectiveness of the PPE. Comparing the actual or expected exposure to the PEL or other exposure limits gives the wearer information on selection of the proper PPE.

**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.

## **Limitations/Restrictions of Exposure Guideline Use**

The exposure guidelines discussed in this part 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 for 1992–1993* 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, and 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 by 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, all toxicological data should be consulted.

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## **RESPIRATORY PROTECTION**

The respiratory system is able to tolerate exposures to toxic gases, vapors, and particulates, but only to a limited degree. Some chemicals can impair or destroy portions of the respiratory tract, or they may be absorbed directly into the bloodstream from the lungs. Chemicals that enter the blood may eventually affect the function of other organs and tissues. The respiratory system can be protected by avoiding or minimizing exposure to harmful substances. Engineering controls such as ventilation help decrease exposure. When these methods are not feasible respirators may provide protection. Certain respirators can filter gases, vapors, and particulates in the ambient atmosphere, other respirators are available which can supply clean breathing air to the wearer.

The use of respirators is regulated by the Occupational Safety and Health Administration (OSHA). Regulations stipulate the use of approved respirators, proper selection, and individual fitting of respirator users.

Respiratory protection must be used when the concentration of a substance in the ambient atmosphere exceeds a personal exposure limit. Several exposure limits used to determine the need for respiratory protection. In order of precedence, these are the OSHA Permissible Exposure Limits (PELs), NIOSH Recommended Exposure Limits (RELs), and the ACGIH Threshold Limit Values (TLVs). If none of these are available, other published data may be used.

### **Respiratory Hazards**

The normal atmosphere consists of 78% nitrogen, 21% oxygen, 0.9% inert gases, and 0.04% carbon dioxide. An atmosphere containing toxic contaminants, even at very low concentrations, could be a hazard to the lungs and body. A concentration large enough to decrease the percentage of oxygen in the air can lead to asphyxiation, even if the contaminant is an inert gas.

**Oxygen Deficiency.** The body requires oxygen to live. If the oxygen concentration decreases, the body reacts in various ways (Table 1). Death occurs rapidly when the concentration decreases to 6%.

Physiological effects of oxygen deficiency are not apparent until the concentration decreases to 16%. The various regulations and standards dealing with respirator use recommend that concentrations ranging from 16 to 19.5% be considered indicative of an oxygen deficiency. Such numbers take into account individual physiological responses, errors in measurement, and other safety considerations. In hazardous materials response operations 19.5% oxygen in air is considered the lowest "safe" working concentration. Below 19.5% available oxygen, a supplied air respirator must be used.

**TABLE 1**  
**PHYSIOLOGICAL EFFECTS OF OXYGEN DEFICIENCY**

<b>% Oxygen (by volume) at Sea Level</b>	<b>Effects</b>
21-16	Nothing abnormal.
16-12	Loss of peripheral vision, increased breathing volume, accelerated heartbeat, impaired attention and thinking, impaired coordination.
12-10	Very faulty judgment, very poor muscular coordination, muscular exertion causes fatigue that may cause permanent heart damage, intermittent respiration.
10-6	Nausea, vomiting, inability to perform vigorous movement, or loss of all movement, unconsciousness, followed by death.
< 6	Spasmodic breathing, convulsive movements, death in minutes.

**Aerosols.** Aerosol is a term used to describe fine particulates (solid or liquid) suspended in air. Particulates ranging in diameter from 5 to 30 microns are deposited in the nasal and pharyngeal passages. The trachea and smaller conducting tubes collect particulates 1-5 microns in diameter. For particulates to diffuse from the bronchioles into alveoli they must be less than 0.5 microns in diameter. Larger particles do reach the alveoli due to gravity. The smallest particulates may never be deposited in the alveoli and so may diffuse back into the conducting tubes to be exhaled.

Aerosols can be classified in two ways: by their physical form and origin and by the physiological effect on the body.

- **Physical Classification Examples:**

- Mechanical dispersoid: liquid or solid particle mechanically produced.
- Condensation dispersoid: liquid or solid particle often produced by combustion.
- Spray: visible liquid mechanical dispersoid.
- Fume: extremely small solid condensation dispersoid.
- Mist: liquid condensation dispersoid.
- Fog: mist dense enough to obscure vision.
- Smoke: liquid or solid organic particles resulting from incomplete combustion.
- Smog: mixture of smoke and fog.

- **Physiological Classification Examples:**

- Nuisance: no lung injury but proper lung functioning inhibited.
- Inert pulmonary reaction causing: non-specific reaction.

- Pulmonary fibrosis causing: effects ranging from nodule production in lungs to serious diseases such as asbestosis.
- Chemical irritation: irritation, inflammation, or ulceration of lung tissue.
- Systemic poison: diseases in other parts of the body.
- Allergy-producing: causes allergic hypersensitivity reactions such as itching or sneezing.

**Gaseous Contaminants.** Gases and vapors are filtered to some degree on their trip through the respiratory tract. Soluble gases and vapors are absorbed by the conducting tubes en route to the alveoli. Not all will be absorbed so that along with insoluble gases, they finally diffuse into the alveoli where they can be directly absorbed into the bloodstream.

Gaseous contaminants can be classified as chemical and physiological hazards.

- **Chemical Contaminants:**

- Acidic: acids or react with water to form acids.
- Alkaline: bases or react with water to form bases.
- Organic: compounds which contain carbon; may range from methane to chlorinated organic solvents.
- Organometallic: organic compounds containing metals.
- Hydrides: compound in which hydrogen is bonded to another metal.
- Inert: no chemical reactivity.

- **Physiological Contaminants:**

- Irritants: corrosive substances which injure and inflame tissue.
- Asphyxiants: substances which displace oxygen or prevent the use of oxygen in the body.
- Anesthetics: substances which depress the central nervous system, causing a loss of sensation or intoxication.
- Systemic poisons: substances which can cause disease in various organ systems.

### **Respirator Use and Selection**

The health of a respirator wearer is based on how the respirator is used. The American National Standards Institute (ANSI) has prepared the *American National Standard Practices for Respiratory Protection* and updates it periodically. The latest version, Z88.2-1980, was issued in 1980 as a voluntary standard. It addresses all phases of respirator use and is highly recommended as a guide to respiratory protection.

The Occupational Safety and Health Administration (OSHA), in 29 CFR Part 1910.120, refers to 29 CFR Part 1910.134 as the source of respiratory protection regulations issued in 1975. In 29 CFR Part 1910.134, OSHA cites ANSI Z88.2-1969 as the reference for these enforceable regulations.

Section b of 29 CFR 1910.134, as well as Z88.2-1980, requires a "minimal acceptable program" to ensure sound respiratory protection practices. The balance of the regulations discusses specific requirements for respiratory use. The requirements for a minimal acceptable program are quoted from 29 CFR 1910.134 as follows:

- Written standard operating procedures governing the selection and use of respirators shall be established.
- Respirators shall be selected on the basis of the hazards to which the worker is exposed.
- The user shall be instructed and trained in the proper use of respirators and their limitations.
- Respirators shall be regularly cleaned and disinfected. Those used by more than one worker shall be thoroughly cleaned and disinfected after each use.
- Respirators shall be stored in a convenient, clean, and sanitary location.
- Respirators used routinely shall be inspected during cleaning. Worn or deteriorated parts shall be replaced. Respirators for emergency use such as self-contained devices shall be thoroughly inspected at least once a month and after each use.
- Appropriate surveillance of work area conditions and degree of employee exposure or stress shall be maintained.
- There shall be regular inspection and evaluation to determine the continued effectiveness of the program.
- Persons should not be assigned to tasks requiring use of respirators unless it has been determined that they are physically able to perform the work and use the equipment. The local physician shall determine what health and physical conditions are pertinent. The respirator user's medical status should be reviewed periodically (for instance annually).
- Approved respirators shall be used. The respirator furnished shall provide adequate respiratory protection against the particular hazard for which it is designed in accordance with approvals established by the National Institute for Occupational Safety and Health (NIOSH).

In general ANSI Z88.2-1980 states that the selection of the proper approved respirator depends upon:

- The nature of the hazard.
- The characteristics of the hazardous operation or process.
- The location of the hazardous area with respect to a safe area having respirable air.

- The period of time for which respiratory protection may be needed.
- The activity of workers in the hazardous area.
- The physical characteristics, functional capabilities, and limitations of respirators of various types.
- The respirator/protection factors and respirator fit.

All of these criteria must be considered in the selection of a respirator. The Joint NIOSH/OSHA Standards Completion Respirator Committee devised a "Respirator Decision Logic" based on the above criteria. ANSI Z88.2-1980 also describes the suitability of a particular respiratory protective device for oxygen deficient or immediately dangerous to life or health (IDLH) atmosphere. This information supplies only a portion of the information required to select the appropriate respirator.

### **Respirator Approval**

OSHA regulations require the use of approved respirators. Respirators are tested at the NIOSH Testing Laboratory in Morgantown, West Virginia, in accordance with the requirements of 30 CFR Part 11 and are jointly approved by the Mine Safety and Health Administration (MSHA).

An MSHA/NIOSH approval indicates that the respirator in use is identical to the one submitted for the original approval. If a manufacturer changes any part of the respirator without resubmitting it to the NIOSH Testing Lab, the approval is invalid and will be rescinded. This is intended to protect the respirator user. Also, any unauthorized changes or hybridization of a respirator by the user invalidates the respirator approval and all the guarantees understood with the approval.

Many agencies were responsible for respirator certification at one time or another. Thus respirators in use today may bear approval numbers issued to the manufacturers by the Bureau of Mines, MESA, and MSHA. The approval number must be displayed on the respirator or its container. It consists of the prefix TC (Testing and Certification), the schedule number, followed by the approval number. For example in TC-13F-69, "13" is the schedule for self-contained breathing apparatus, "F" indicates the number of revisions to the schedule, and 69 is the consecutive approval number. Also, the approval label includes the certifying agencies.

Periodically, NIOSH publishes a list of all approved respirators and respirator components. The current edition, issued in 1991, is entitled the *NIOSH Certified Equipment List* as of December 31, 1991 (DHHS [NIOSH] Publication No. 91-101). This document is used to answer two basic questions about respiratory protection:

- Is this respirator appropriate (approved) for the existing work conditions?
- Is this respirator (mask and purifying-elements) an approved assembly?

If the answer to either of these questions is "no," then the worker is prohibited from using that respirator (or type of respirator).

## **AIR-PURIFYING RESPIRATORS**

Air-purifying respirators (APRs) refer to respirators that remove contaminants by passing the breathing air through a purifying element. There is a wide variety of APRs available to protect against specific contaminants but they all fall into two subclasses: (1) particulate APRs that employ a mechanical filter element and (2) gas and vapor removing APRs that use chemical sorbents contained in a cartridge or canister.

APRs may be used only if all of the following requirements are met:

- The identity and concentration of the contaminant are known.
- The ambient concentration of a contaminant is below the IDLH concentration.
- The oxygen content in the atmosphere is greater than 19.5%.
- The respirator assembly is approved for protection against the specific concentration of a contaminant.
- There is periodic monitoring of the work area.
- The respirator assembly has been successfully fit-tested on the user.

### **Requirements for APR Use**

The use of an APR is contingent upon a number of criteria. If the conditions spelled out in this section of the text cannot be met, then use of an APR is prohibited.

- **Oxygen Content.** The normal atmosphere contains approximately 21 % oxygen. The physiological effects of reduced oxygen begin to be evident at 16%. Without regard to contaminants, the atmosphere must contain a minimum of 19.5% oxygen to permit use of an APR. This is a legal requirement of 30 CFR Part 11 and a recommendation of ANSI Z88.2 - 1980. Below 19.5% oxygen, atmosphere-supplying respirators must be used instead.
- **Identification of Contaminants.** It is absolutely imperative that the contaminant(s) be known so that: the toxic effects of inhaling the contaminant can be determined; appropriate particulate filters or cartridges/canisters can be chosen; it can be determined that adequate warning properties exist for the contaminant; and, the appropriate facepiece be selected (full-face mask is necessary if the agent causes eye irritation).
- **Known Contaminant Concentration.** The maximum concentration depends on the contaminant and the respirator: the concentration must not exceed IDLH; the Maximum Use Limit of the respirator cannot be exceeded ( $MUL = APF \times EL$ ); the Maximum Use Concentration of a particular type and size cartridge or canister must

not be surpassed; and the expected service life (cartridge/canister efficiency) should be determined.

- **Periodic Monitoring of Hazards.** Because of the importance of knowing the identity and concentration of the contaminant(s), monitoring of the work area with appropriate equipment must occur at least periodically during the work day. This is done to ensure that no significant changes have occurred and the respirators being used are adequate for the work conditions.
- **Approval of Respirators.** The respirator assembly (facepiece and air-purifying elements) is approved for protection against the contaminant at the concentration which is present in the work area. The concentration must not exceed the NIOSH/MSHA designated MUC for that type and size cartridge or canister.
- **Fit-test.** The wearer must pass a qualitative fit-test for the make, model, and size of air-purifying device used. The OSHA regulations, in 29 CFR 1910.134(e)(5)(i), state:

Every respirator wearer shall receive fitting instructions including demonstrations and practice in how the respirator is worn, how to adjust it, and how to determine if it fits properly.

Respirators shall not be worn when conditions prevent a good face seal. Such conditions may be growth of beard, sideburns, a skull cap that projects under the facepiece, or temple pieces on glasses. Also, the absence of one or both dentures can seriously affect the fit of a facepiece. The worker's diligence in observing these factors shall be evaluated by periodic check. To assure proper protection, the facepiece fit shall be checked by the wearer each time he puts on the respirator. This may be done by giving fitting instructions.

### **Air-Purifying Elements**

Respiratory hazards can be broken down into two classes: particulates and vapors/gases. Particulates are filtered by mechanical means, while vapors and gases are removed by sorbents that react chemically with them. Respirators using a combination of mechanical filter and chemical sorbent will effectively remove both hazards.

- **Particulate-Removing Filters**

Particulates can occur as dusts, fumes, or mists. The particle size can range from macroscopic to microscopic, and their toxicological effects can be severe or innocuous. The hazard posed by a particulate can be determined by its exposure limit (EL). A nuisance particulate will have an EL of 10 mg/m<sup>3</sup>, while a toxic particulate may have an EL well below 0.05 mg/m<sup>3</sup>.

Mechanical filters are classified according to the protection for which they are approved under schedule 21C of 30 CFR Part 11. Most particulate filters are approved only for dusts

and/or mists with ELs equal to or greater than 0.05 mg/m<sup>3</sup>. These dusts are usually considered to produce pneumoconiosis and fibrosis. Such filters have an efficiency of 80–90% for 0.6-micron particles.

Respirators approved for fumes are more efficient, removing 90–99% for 0.6-micron particles. This type of respirator is approved for dusts, fumes, and mists with ELs equal to or greater than 0.05 mg/m<sup>3</sup>.

Finally there is a high-efficiency filter, which is 99.97% effective against particles 0.3 microns in diameter. It is approved for dusts, mists, and fumes with an EL less than 0.05 mg/m<sup>3</sup>.

Mechanical filters load with particulates as they are used. As they do, they become more efficient, but also become more difficult to breathe through. When a mechanical filter becomes difficult to breathe through it should be replaced.

- **Gas and Vapor-Removing Cartridges and Canisters**

When selecting a gas- or vapor-removing element, it must be chosen for protection against a specific type of contaminant. Some of the commonly employed types of chemical cartridges and canisters and their OSHA-required color coding are listed in Table 2. This table has been excerpted from the OSHA respirator regulations for general industry (29 CFR 1910.134).

Gas and vapor elements are available in different styles. The physical differences are: (1) size and (2) means of attachment to the facepiece. The smallest elements are cartridges which contain 50–200 cm<sup>3</sup> of sorbent and attach directly to the facepiece, usually in pairs. Chin canisters have a volume of 250–500 cm<sup>3</sup> and are attached to a full-facepiece. Gas mask, or industrial-size canisters contain 1000–2000 cm<sup>3</sup> and are attached by a harness to the wearer's front or back and connected to the full-facepiece by a breathing hose.

The difference in applications is the **Maximum Use Concentration (MUC)** for which the cartridge or canister can be used in accordance with its NIOSH/MSHA approval. For example, organic vapors can be removed by the appropriate cartridges, chin canister, or gas-mask canister. Cartridges are approved for use in atmospheres up to 1,000 ppm (0.1%) organic vapors, chin style canisters up to 5000 ppm (0.5%), and gas mask canisters up to 20,000 ppm (2.0%). However, no air-purifying respirator is permitted in an IDLH atmosphere.

Each sorbent has a finite capacity for removing contaminants and when this limit is reached the cartridge or canister is said to be saturated. At this point the element will allow the contaminant to pass through and enter the facepiece. The length of time a cartridge or canister will effectively sorb the contaminant is known as the **service life** of the element. Service life of a type of cartridge or canister is dependent on several factors: the breathing rate of the wearer, contaminant concentration, and sorption efficiency.



**TABLE 2**  
**CHEMICAL CARTRIDGE TYPES AND COLOR CODING**  
**§1910.134 and 29 CFR Ch. XVII (7-1-86 Edition)**

<b>Atmospheric Contaminants to be Protected Against</b>	<b>Colors Assigned<sup>1</sup></b>
Acid gases	White
Hydrocyanic acid gas	White with 1/2-inch green stripe completely around the canister near the bottom
Chlorine gas	White with 1/2-inch yellow stripe completely around the canister near the bottom
Organic vapors	Black
Ammonia gas	Green
Acid gases and ammonia gas	Green with 1/2-inch white stripe completely around the canister near the bottom
Carbon monoxide	Blue
Acid gases and organic vapors	Yellow
Hydrocyanic acid gas and chloropicrin vapor	Yellow with 1/2-inch blue stripe completely around the canister near the bottom
Acid gases, organic vapors, and ammonia gases	Brown
Radioactive materials, excepting tritium and noble gases	Purple (Magenta)
Particulates (dusts, fumes, mists, fogs, or smokes) in combination with any of the above gases or vapors	Canister color for contaminant, as designated above, with 1/2-inch gray stripe completely around the canister near the top
All of the above atmospheric contaminants	Red with 1/2-inch gray stripe completely around the canister near the top

<sup>1</sup> Gray shall not be assigned as the main color for a canister designed to remove acids or vapors.

**Note:** Orange shall be used as a complete body or as a stripe color to represent gases not included in this table. The user will need to refer to the canister label to determine the degree of protection the canister will afford.

If the breathing rate of the user is rapid, the flow rate of the contaminated air drawn through the cartridge is greater than it is at a moderate or slow respiration rate. A higher flow rate brings a larger amount of contaminant in contact with the sorbent in a given period of time which, in turn, increases the rate of sorbent saturation and shortens service life.

The expected service life of an organic vapor cartridge decreases as ambient contaminant concentration increases. As concentration goes up, the mass flow rate increases, bringing more contaminant in contact with the sorbent in a given period of time. For example, at any constant breathing rate, ten times as much contaminant contacts the element when the concentration is 500 ppm compared to 50 ppm.

Chemical sorbents vary in their ability to remove contaminants from air. Table 3 compares the efficiency of organic vapor cartridges for a number of solvents by recording the amount of time until a 1% breakthrough concentration was measured in the cartridge-filtered air. The initial test concentration is 1000 ppm of solvent vapor; the breakthrough concentration is 10 ppm. From the table it can be seen that it takes 107 minutes for chlorobenzene to reach a 1% breakthrough, while it only takes 3.8 minutes for vinyl chloride. The sorbent (activated carbon) in the organic vapor cartridge is much better for removing chlorobenzene than vinyl chloride under the test conditions. Cartridge efficiencies need to be considered when selecting and using APRs.

A warning property is used as a sign that a cartridge or canister in use is beginning to lose its effectiveness. A warning property can be detected as an odor, taste, or irritation. At the first such signal, the old cartridge or canister must be exchanged for a fresh one. Without a warning property, respirator efficiency may drop without the knowledge of the wearer, ultimately causing a health hazard.

Most substances have warning properties at some concentration. A warning property detected only at dangerous levels—that is, greater than EL—is not considered adequate. An odor, taste, or irritation detected at extremely low concentrations is also not adequate because the warning is being given all the time or long before the filter begins to lose its effectiveness. In this case, the wearer would never realize when the filter actually becomes ineffective.

The best concentration for a warning property to be first detected is around the EL. For example, toluene has an odor threshold of 40 ppm and an EL of 100 ppm. This is usually considered an adequate warning property. Conversely, dimethylformamide has an EL of 10 ppm and an odor threshold of 100 ppm. An odor threshold ten times the EL is not an adequate warning property.

If a substance causes rapid olfactory fatigue (i.e., the sense of smell is no longer effective), its odor is not an adequate warning property. For example, upon entering an atmosphere containing hydrogen sulfide, the odor is quite noticeable. After a short period of time, it is no longer detectable.

<b>TABLE 3</b> <b>EFFECTS OF SOLVENT VAPOR ON RESPIRATOR CARTRIDGE EFFICIENCY<sup>1</sup></b>	
<b>Solvent</b>	<b>Time to Reach 1% Breakthrough (10 ppm) (minutes<sup>2</sup>)</b>
<b>Aromatics<sup>3</sup></b>	
Benzene	73
Toluene	94
Ethyl benzene	84
m-Xylene	99
Cumene	81
Mesitylene	86
<b>Alcohols<sup>3</sup></b>	
Methanol	0.2
Ethanol	28
Isopropanol	54
Allyl alcohol	66
n-Propanol	70
sec-Butanol	96
Butanol	115
2-Methoxyethanol	116
Isoamyl alcohol	97
4-Methyl-2-pentanol	75
2-Ethoxyethanol	77
Amyl alcohol	102
2-Ethyl-1-butanol	76.5
<b>Monochlorides<sup>3</sup></b>	
Methyl chloride	0.05
Vinyl chloride	3.8
Ethyl chloride	5.6
Allyl chloride	31
1-Chloropropane	25
1-Chlorobutane	72
Chlorocyclopentane	78
Chlorobenzene	107
1-Chlorohexane	77
0-Chlorotoluene	102
1-Chloroheptane	82
3-(Chloromethyl heptane)	63

<sup>1</sup> Nelson, G.O , and C A. Harder Respirator Cartridge Efficiency Studies, University of California, Livermore. 1976.

<sup>2</sup> Cartridge pairs tested at 1000 ppm, 50% relative humidity, 22°C, and 53.3 liters/minute (equivalent to a moderately heavy work rate). Pair cartridges preconditioned at room temperature and 50% relative humidity for at least 24 hours prior to testing.

<sup>3</sup> Mine Safety Appliances Cartridges.

## **Determining Respirator Protection**

The protection provided the wearer is a function of how well the facepiece (mask) fits. No matter how efficient the purifying element, there is little protection afforded if the respirator mask does not provide a leak-free facepiece-to-face seal. Facepieces are available in three basic configurations which relate to their protective capacity:

- A **quarter-mask** fits over the bridge of the nose, along the cheek, and across the top of the chin. The headbands which hold the respirator in place are attached at two or four places of the mask. Limited protection is expected because the respirator can be easily dislocated, creating a breach in the seal.
- A **half-mask** fits over the bridge of the nose, along the cheek, and under the chin. Headbands have a four-point suspension. Because they maintain a better seal and are less likely to be dislocated, half-masks give better protection than quarter masks.
- A **full-facepiece** fits across the forehead, down over the temples and cheeks, and under the chin. They typically have a head harness with a five or six-point suspension. These masks give the greatest protection because they are held in place more securely and because it is easier to maintain a good seal along the forehead than it is across the top of the nose. An added benefit is the eye protection from the clear lens in the full-facepiece.

The use of respirators is prohibited when conditions prevent a good facepiece-to-face seal. Some examples of these conditions are facial hair, skullcaps, long hair, makeup, temple pieces on eyeglasses. Because maintaining a leak-free seal is so important, personnel required to wear respirators must successfully pass a **fit-test** designed to check the integrity of the seal. There are two types of fit-tests: quantitative and qualitative. The **quantitative** test is an analytical determination of the concentration of a test agent inside the facepiece compared to that outside the mask. This concentration ratio is called the assigned protection factor (APF) and is a measure of the relative protection offered by a respirator. For example, if the ambient concentration of the test agent is 1000 and the concentration inside the mask is 10 ppm, the respirator gives the tested individual an APF of 100. Therefore:

$$\text{APF} = \frac{\text{Concentration outside mask}}{\text{Concentration inside mask}}$$

Because quantitative tests are expensive and tedious, qualitative tests are most often performed to check respirator fit. A **qualitative** fit-test is not an analytical measurement. It is a subjective test where an irritant or aroma is used to determine if there is a good facepiece-to-face seal. If the test subject does not respond (by smelling, tasting, coughing, etc.) to the test agent, he/she can wear the tested respirator with the APF for that type of mask. **Table 4** lists several types of respirators and their APFs.

A protection factor is used to determine the maximum use limit (MUL) of a successfully fit-tested respirator. The MUL is the highest concentration, not exceeding IDLH concentration, of a specific contaminant in which a respirator can be worn:

$$\text{MUL} = \text{APF} \times \text{TLV}$$

For example, if a contaminant has a TLV-TWA of 10 ppm, then the MUL for any half-mask respirator is 100 ppm. The MUL for a full-facepiece APR or demand self-contained breathing apparatus (SCBA) is 1000 ppm. If the ambient concentration is greater than 1000 ppm, then a pressure-demand SCBA is required because the MUC for organic vapor cartridges is 1000 ppm.

Fit testing and assigned protection factors are only two of the several considerations for selecting the proper type of respirator.

<b>TABLE 4</b> <b>RESPIRATOR ASSIGNED PROTECTION FACTORS<sup>1</sup></b>	
<b>Type of Respirator</b>	<b>NIOSH APF (Qualitative Test)</b>
Air-purifying Quarter-mask Half-mask	5 10
Air-line Quarter-mask Half-mask	10 10
Hose mask Full facepiece	10
SCBA, demand Quarter-mask Half-mask	10 10
Air-purifying Full facepiece	50
Air-line, demand Full facepiece	50
SCBA, demand Full facepiece	50
Air-line, pressure-demand, with escape provision Full facepiece (no test required)	10,000
SCBA, pressure-demand or positive pressure Full facepiece (no test required)	10,000

<sup>1</sup> For more detailed information consult Table 5, "Respirator Protection Factors" in ANSI Z88.2-1980.

## **ATMOSPHERE-SUPPLYING RESPIRATORS**

Atmosphere-supplying respirators refer to another classification of respirators. These types of respirators provide a substitute source of breathing air. The respirable air may be supplied to the wearer by a portable breathing air source (SCBA) or by a stationary source such as an air-line (a supplied-air respirator).

### **Types of Atmosphere-Supplying Respirators**

Respiratory apparatus must frequently be used during response to hazardous materials incidents. If the contaminant is unknown, or the requirements for using air-purifying respirators cannot be met, then an atmosphere-supplying respirator is required. Several types of atmosphere-supplying devices are available.

- **Hose Mask.** This type of respirator consists of a facepiece attached to a large diameter hose which transports clean air from a remote area. In units where the wearer breathes the air in, the hose lines can go up to 75 feet. With powered units the hose length can vary from 50 to 250 feet.
- **Airline Respirator.** The airline respirator is similar to the hose mask, except that breathing grade air is delivered to the wearer under pressure; either from a compressor or a bank of compressed air cylinders. The air may flow continuously, or it may be delivered as the wearer breathes (demands it). The air source must not be depletable, and no more than 300 feet of airline is allowed. An SCBA escape device is required for entry into an IDLH atmosphere.
- **Oxygen-Generating.** One of the oldest respirators is the oxygen-generating respirator, which uses a canister of potassium superoxide. The chemical reacts with water vapor to produce oxygen which replenishes the wearer's exhaled breath. Exhaled CO<sub>2</sub> is removed by a scrubber device containing LiOH. This reoxygenated air is then returned to the wearer. Oxygen-generating respirators have been used by the military and for escape purposes in mines. It generally is not used for hazardous material applications because of the chemical reaction taking place within the respirator itself.
- **Self-Contained Breathing Apparatus.** The SCBA consists of a facepiece and regulator mechanism connected to a cylinder of compressed air or oxygen carried by the wearer. The SCBA is generally used because it allows the wearer to work without being confined by a hose or airline. The wearer of the SCBA depends on it to supply clean breathing air.

### **Modes of Operation**

The SCBA and the supplied-air respirator may be differentiated by the type of air flow supplied to the facepiece:

- **Negative-pressure.** In a negative-pressure mode (also referred to as demand mode), a negative pressure is created inside the facepiece and breathing tubes when the wearer inhales (Table 5). This negative pressure draws down a diaphragm in the SCBA's regulator. The diaphragm depresses and opens the admission valve, allowing air to be inhaled. As long as the negative pressure remains, air flows to the facepiece.

The problem with demand operation is that the wearer can inhale contaminated air through any gaps in the facepiece-to-face sealing surface. Hence, a demand apparatus with a full facepiece is assigned a protection factor of only 100, the same as for a full-face, air-purifying respirator.

- **Positive-pressure.** In the positive-pressure mode (also referred to as a pressure-demand mode) a positive pressure is maintained inside the facepiece at all times. The system is designed so that the admission valve remains open until enough pressure is built up to close it. The pressure builds up because air is prevented from leaving the system until the wearer exhales. Less pressure is required to close the admission valve than is required to open the spring-loaded exhalation valve.

At all times, the pressure in the facepiece is greater than the ambient pressure outside the facepiece. If any leakage occurs, it is outward from the facepiece. Because of this, the pressure-demand (positive-pressure) SCBA has been assigned a protection factor of 10,000.

<b>TABLE 5</b> <b>RELATIVE PRESSURE INSIDE AND OUTSIDE SCBA FACEPIECE</b>		
<b>Action</b>	<b>Demand</b>	<b>Pressure Demand (positive pressure)</b>
Inhalation	-	+
Exhalation	+	+
Static (between breaths)	same	+

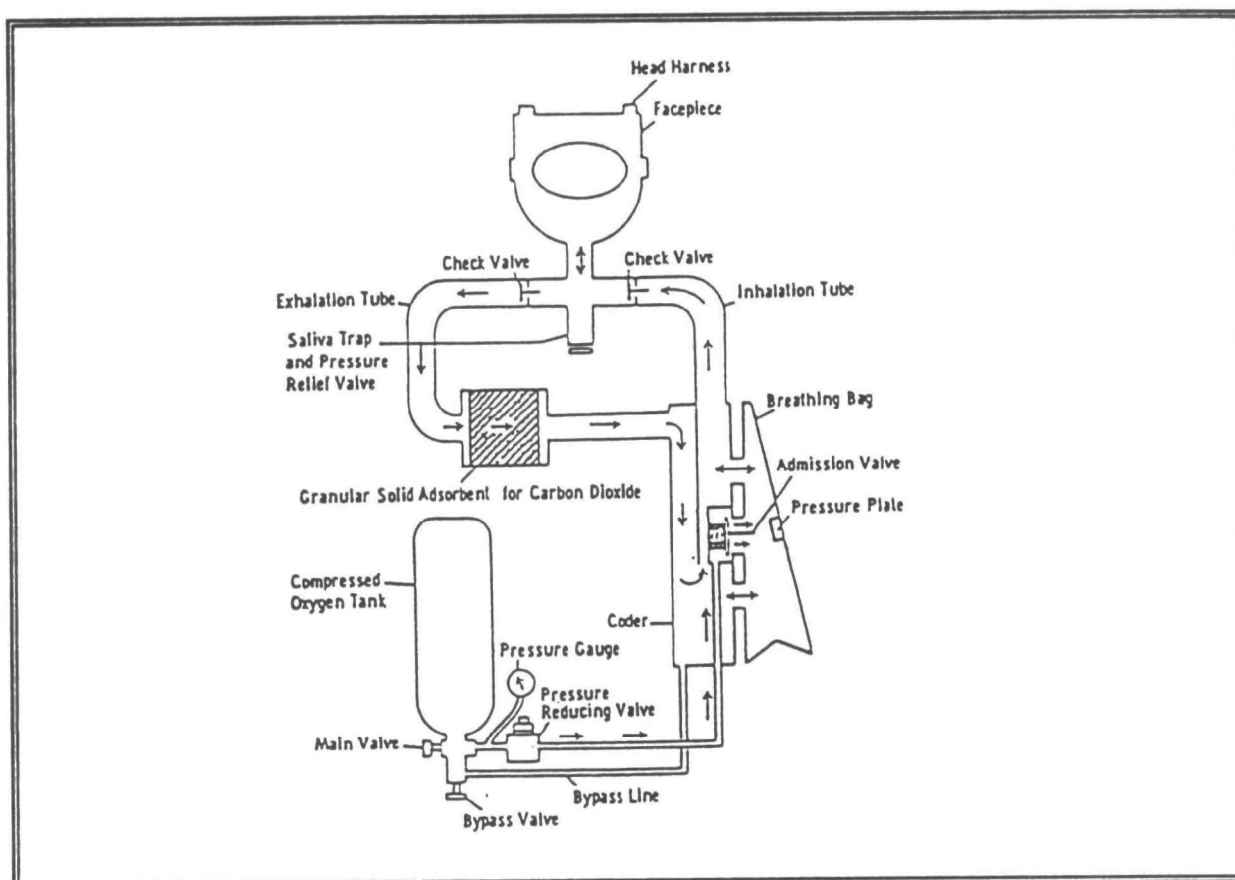
### **Types of SCBAs**

There are two types of SCBA apparatus: closed-circuit, which use compressed oxygen, and open-circuit, which use compressed air. SCBAs may operate in one of two modes, demand (negative-pressure) or pressure-demand (positive-pressure). The length of time an SCBA operates is based on the air supply. The units available operate from 5 minutes to over 4 hours. The pressure-demand (positive pressure) is the only approved type of open-circuit SCBA for use in hazardous environments by the U.S. Environmental Protection Agency (EPA) and NFPA.

- **Closed-Circuit SCBA**

The closed-circuit SCBA (Figure 1), commonly called the rebreather, was developed especially for oxygen-deficient situations. Because it recycles exhaled breath and

carries only a small oxygen supply, the service time can be considerably greater than an open-circuit device, which must carry all of the user's breathing air.



**FIGURE 1**  
**CLOSED-CIRCUIT SCBA**

The air for breathing is mixed in a flexible breathing bag. This air is inhaled, deflating the breathing bag. The deflation depresses the admission valve, allowing the oxygen to enter the bag. There it mixes with exhaled breath, from which carbon dioxide has just been removed by passage through a CO<sub>2</sub> scrubber.

Most rebreathers operate in the demand mode. Several rebreathers are designed to provide a positive pressure in the facepiece. The approval schedule 13F under 30 CFR Part II for closed-circuit SCBA makes no provisions for testing "demand" or "pressure-demand" rebreathers. The approval schedule was set up to certify only rebreathers that happen to operate in the demand mode. Thus, rebreathers designed to operate in the positive pressure mode can be approved strictly as closed-circuit apparatus. Since regulations make no distinction, and selection is based on approval criteria, rebreathers designed to maintain a positive pressure can only be considered as a demand-type apparatus. Rebreathers use either compressed oxygen or liquid oxygen. To assure the quality of the air to be breathed, the oxygen must be at least medical grade breathing oxygen which meets the requirements set by the "U.S. Pharmacopeia."



- **Open-Circuit SCBA**

The open-circuit SCBA requires a supply of compressed breathing air. The user simply inhales and exhales. The exhaled air is exhausted from the system. Because the air is not recycled, the wearer must carry the full air supply, which limits a unit to the amount of air that the wearer can easily carry. Available SCBAs can last from 5 to 60 minutes. Units that have 5- to 15-minute air supplies are only applicable to escape situations.

The air used in open-circuit apparatus must meet the requirements in the Compressed Gas Association's Pamphlet G-7.1, which calls for at least "Grade D." Grade D air must contain 19.5 to 23.5% oxygen with the balance being predominantly nitrogen. Condensed hydrocarbons are limited to 5 mg/m<sup>3</sup>, carbon monoxide to 20 parts per million (ppm) and carbon dioxide to 1,000 ppm. An undesirable odor is also prohibited. Air quality can be checked using an oxygen meter, carbon monoxide meter and detector tubes.

### **Components of an Open-Circuit, Positive-Pressure SCBA**

The user should be completely familiar with the SCBA being worn. Checkout procedures have been developed for inspecting an SCBA prior to use, allowing the user to recognize potential problems. An individual who checks out the unit is more comfortable and confident wearing it. If the wearer is not properly trained to wear the SCBA or it is not properly cared for, then it may fail to provide the protection expected.

- **Backpack and harness.** A backpack and harness support the cylinder and regulator, allowing the user to move freely. Weight should be supported on the hips not the shoulders.
- **Cylinder.** Compressed air is considered a hazardous material. For this reason, any cylinder used with an SCBA must meet the Department of Transportation's (DOT) "General Requirements for Shipments and Packaging" (49 CFR Part 173) and "Shipping Container Specifications" (49 CFR Part 178).

A hydrostatic test must be performed on a cylinder at regular intervals: for steel & aluminum cylinders, every 5 years; for composite cylinders (glass fiber/aluminum), every 3 years. Composite cylinders are relatively new, designed with fiberglass. Composite cylinders have a DOT exemption because there are no set construction requirements at this time. Overall difference is in weight. The construction technology reduces the weight of the cylinder and thereby the overall weight of the SCBA.

Air volume of 45 cubic feet of Grade D air at a pressure of 2,216 pounds per square inch (psi) is needed for a 30-minute supply. Cylinders are filled using a compressor or a cascade system of several large cylinders of breathing air. If the cylinder is overfilled, a rupture disc releases the pressure. The rupture disc is located at the cylinder valve, along with a cylinder pressure gauge to be accurate within  $\pm 5\%$ . Because the gauge is exposed and subject to abuse, it should be used only for judging if the cylinder is full, and not for monitoring air supply to the wearer.

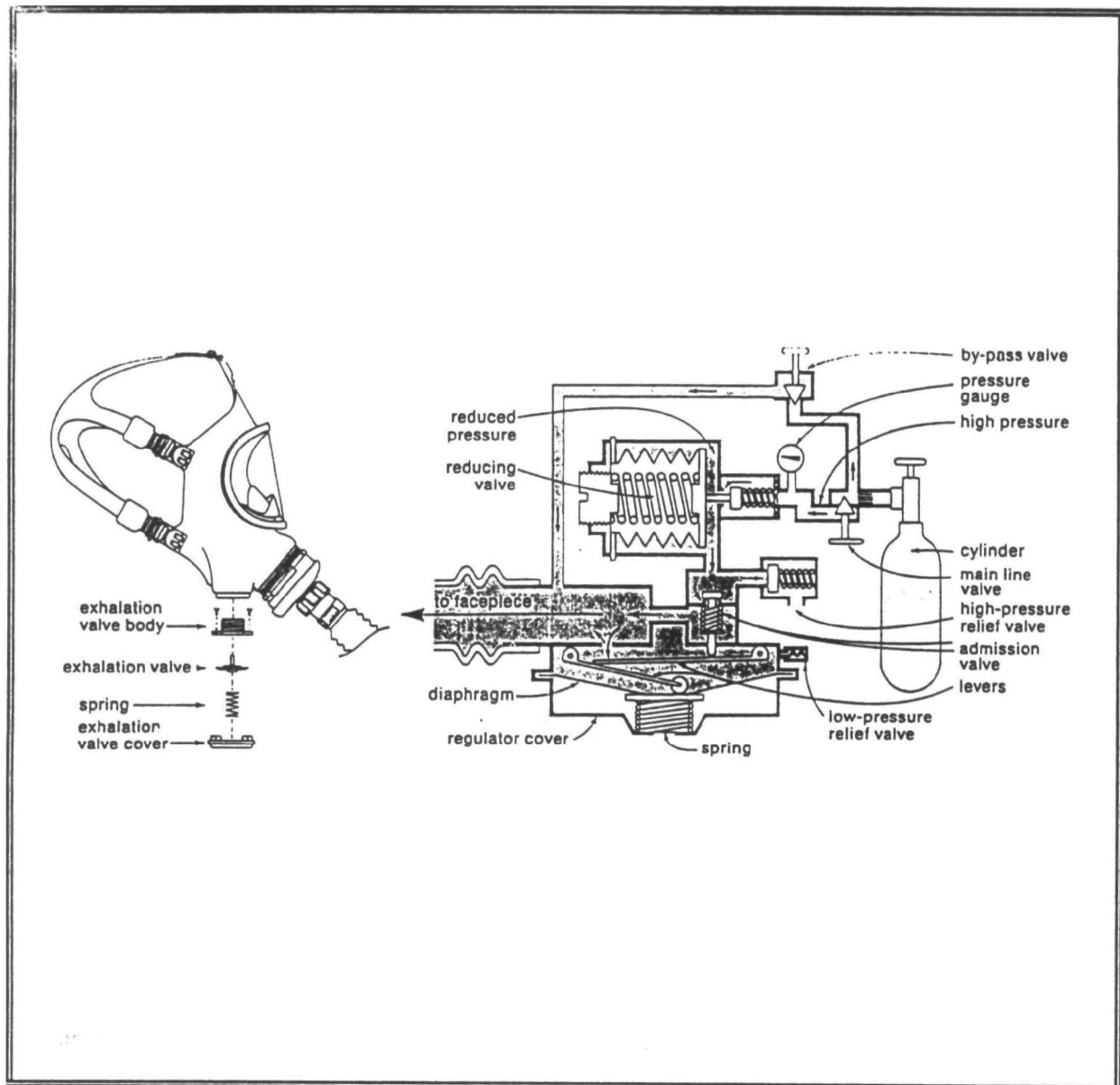
- **High-Pressure Hose.** The high-pressure hose connects the cylinder and the regulator. The hose should be connected to the cylinder only by hand, never with a wrench. An O-ring inside the connector assures a good seal.
- **Alarm.** A low-pressure warning alarm is located near the connection to the cylinder. This alarm sounds to alert the wearer that only 20-25% of the full cylinder air supply is available for retreat, usually 5 to 8 minutes.
- **Regulator Assembly.** Air travels from the cylinder through the high-pressure hose to the regulator (Figure 2). There it can travel one of two paths. If the by-pass valve is opened, air travels directly through the breathing hose into the facepiece. If the mainline valve is opened, air passes through the regulator and is controlled by that mechanism. Also at the regulator (before air enters one of the valves) is another pressure gauge which also must be accurate to + 5%. Because it is visible and well protected, this gauge should be used to monitor the air supply.

Under normal conditions, the bypass valve is closed and the mainline valve opened so air can center the regular. Once in the regulator, the air pressure is reduced from the actual cylinder pressure to approximately 50-100 psi by reducing mechanism. A pressure relief valve is located after the pressure reducer for safety should the pressure reducer malfunction.

- **Breathing Hose and Facepiece.** The breathing hose connects the regulator to the facepiece. Rubber gaskets at both ends provide tight seals. The hose is usually constructed of neoprene and is corrugated to allow stretching.

Above the point in the mask where the hose is connected, is a one way check valve. This valve allows air to be drawn from the hose when the wearer inhales but prevents exhaled air from entering the breathing hose. If the check valve is not in place, the exhaled air may not be completely exhausted from the facepieces.

The facepiece is normally constructed of neoprene, but sometimes of silicone rubber. Five- or six-point suspension is used to hold the mask to the face. The visor lens is made of polycarbonate or other clear, shatter proof, and chemically resistant material. At the bottom of the facepiece is an exhalation value. Some masks include an air-tight speaking diaphragm, which facilitates communications while preventing contaminated air from entering.



**FIGURE 2**  
**REGULATOR ASSEMBLY**

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### **SCBA Inspection and Checkout**

The SCBA must be inspected according to manufacturer and 29 CFR recommendations. In addition, the SCBA should be checked out immediately prior to use. Checkout and inspection procedures should be followed closely to ensure safe operation of the unit.

A cylinder on an SCBA typically carries the following information (Figure 3):

- DOT exemption for composite cylinder
- DOT rated pressure and air volume
- Cylinder number
- Manufacturer's name, symbol and part number
- Original hydrostatic test date, month/year



**FIGURE 3**  
**INFORMATION ON TYPICAL SCBA CYLINDER LABEL**

#### National Fire Protection Association Standards for SCBAs

The National Fire Protection (NFPA) has developed a standard for performance requirements and appropriate testing procedures designed to simulate various environmental conditions that fire fighter's SCBA can be exposed to during use and storage. These requirements are in addition to the basic NIOSH/MSHA certification requirements. This Standard, NFPA 1981, now applies only to open circuit SCBA.

- **Basic Design Requirements.** The basic design requirements for SCBA units under 1981 are:
  - That the units be NIOSH/MSHA certified positive-pressure.
  - The maximum weight shall not exceed 35 pounds, in accordance with NIOSH/MSHA certification.

- The rated service time shall be 30 minutes or more.
  - No positive-pressure unit that can be switched to demand mode.
  - The unit shall not be approved under the Bureau of Mines Schedule.
  - The manufacturer shall provide with each SCBA instructions on maintenance, storage, disinfecting, inspection, use, operations, limitations, and training materials.
- **General Requirements.** Additionally, SCBA units must meet certain general requirements, which include:
    - Labeling showing that the unit meets the requirements.
    - Initial, annual and fifth year testing of the SCBA.
    - Retesting of unit after any modifications.
    - Test series to include three categories, with one SCBA used per category.
  - **Performance Tests: Airflow.** This test increases the current NIOSH breathing machine requirements of 40 liters per minute to 100 liters per minute. The 100 liters per minute volume was derived from a review of several studies indicating that a ventilation rate of 100 standard liters per minute encompasses the 98th percentile of all firefighters' studies.
 

*Note:* An airflow test is then performed after each of the following tests, with the exception of the fabric component test, to ensure breathing apparatus performance.
  - **Thermal Resistance Test.** This series of test expose the breathing apparatus to various temperature extremes and temperature cycles that breathing apparatus might be exposed to during actual firefighting operations.
  - **Vibration and Shock.** This test is designed to provide a reasonable level of assurance that when the breathing apparatus is exposed to vibration, such as being carried on a rig that often travels over rough road surfaces, the apparatus will perform and function properly.
  - **Fabric Components Test.** Flame, heat and thread tests are added to provide a reasonable level of assurance that the fabric components of a harness assembly used to hold the backplate to the wearer's body will remain intact during firefighting operations.
  - **Accelerated Corrosion Resistance Test.** This test is to provide a reasonable level of assurance that the breathing apparatus is designed to resist corrosion that may form and interfere with the apparatus performance and function.
  - **Particulate Resistance Test.** This test exposes the breathing apparatus to a specified concentration of particulates to provide a reasonable level of assurance that the apparatus is designed to properly function when exposed to dust conditions commonly present during firefighting operations.

- **Facepiece Lens Abrasion Resistance Test.** This test is designed to provide a reasonable level of assurance that the facepiece lens of the breathing apparatus is not easily scratched during firefighting operations that could result in reduced visibility for the fire fighter.
- **Communications Test.** This test is designed to assure that the facepiece of the breathing apparatus does not significantly reduce a fire fighter's normal voice communications.

# CHEMICAL PROTECTIVE CLOTHING

Chemical protective clothing (CPC) is worn to prevent harmful chemicals from coming in contact with the skin or eyes. It provides a barrier between the body and chemicals which have a detrimental effect on the skin or which can be absorbed through the skin affecting other organs. Used with respiratory protection, properly selected clothing can protect personnel who work in chemical environments.

Protecting workers against skin exposure requires using the most effective CPC. Of primary importance is selecting clothing made from a material which is the most resistant against the attack chemical. Other selection criteria which should be considered include style, the probability of being exposed, ease of decontamination, mobility while wearing clothing, durability of clothing, and to a lesser degree, cost.

A variety of manufactured materials are used as the fabric for CPC. Each of these materials provides a degree of skin protection against a range of chemicals. Not one material affords the maximum protection against all chemicals. The CPC that is selected must be made from a material that affords the greatest deterrent against the chemicals known or expected to be encountered.

Properly selected clothing can minimize risk of exposure to chemical substances, but may not protect against physical hazards such as fires, radiation hazards and electrical hazards. The use of other personal protective equipment must also be determined for complete protection. Head protection is provided by hard hats, eye and face protection by goggles or impact-resistant lenses, hearing protection by earmuffs or earplugs, and foot protection by impact- and chemical-resistant safety boots.

## **Performance Requirements for Chemical Protective Clothing**

A number of performance requirements must be considered when selecting the appropriate protective material. Their relative importance is determined by the particular work activity and site specific conditions.

- **Chemical Resistance:** The ability of a material to withstand chemical and physical change. A material's chemical resistance is the most important performance requirement. The material must maintain its structural integrity and protective qualities upon contact with a hazardous substance.
- **Durability:** The ability to withstand wear. The ability to resist punctures, abrasions, and tears. The materials' inherent strength.
- **Flexibility:** The ability to bend or flex; pliability. It is extremely important both for glove and full-body suit materials, for it directly impacts the worker's mobility, agility, and range of motion.

- **Temperature Resistance:** The ability of a material to maintain its chemical resistance during temperature extremes (especially heat) and to remain flexible in cold weather. A general tendency for most materials is that higher temperatures reduce their chemical resistance; lower temperatures reduce flexibility.
- **Service Life:** The ability of a material to resist aging and deterioration. Factors such as chemicals, extreme temperatures, moisture, ultraviolet light, oxidizing agents, and others decrease a material's service life. Storage away from and proper care against these conditions can help prevent aging. Manufacturers should be consulted regarding any recommendations on a suit's shelf-life.
- **Cleanability:** The ability to effectively decontaminate protective materials. Cleanability is a relative measure of the ability of a material to release the contact substance. Some materials are nearly impossible to decontaminate, so it may be important to cover those materials with disposable garments to prevent gross contamination.
- **Design:** The way a suit is constructed, including its general type and special features. A variety of suit styles and features that should be considered are:
  - Fully encapsulating or nonencapsulating
  - One, two, or three piece suits
  - Hoods, facepieces, gloves, and boots (attached or unattached)
  - Location of zipper, buttons, storm flaps, and seams (front, side and back)
  - Pockets, cloth collars, and velcro straps
  - Exhalation valves or ventilation ports
  - Ease of compatibility with wearing respiratory protection
- **Size:** The physical dimensions or proportions of clothing. Size is directly related to comfort and influences the number of unnecessary physical accidents. Ill-fitting clothing limits a worker's mobility, dexterity and concentration. Manufacturers offer standard sizes in boots and gloves for both men and women, however standard suit sizes for women are not available.
- **Color:** Brightly colored suit material make it easier to maintain visual contact between personnel. Suits of darker colors (black, green) absorb radiant heat from external sources and transfer it to the worker increasing heat related problems.
- **Cost:** The cost of CPC varies considerably. Cost will often play a role in the selection and frequency of use of CPC. In many situations, less expensive, single use garments are more appropriate and as safe as more costly clothing. Other situations require high quality, costly clothing which may have to be discarded after limited use.



## **Chemical Resistance**

The effectiveness of materials to protect against chemicals is based on their resistance to penetration, degradation, and permeation. Each of these properties must be evaluated when selecting the style of CPC and the material from which it is made. In choosing protective materials, remember that:

- There is no protective material that is impermeable,
- There is no one material that affords protection against all chemicals, and
- For certain contaminants and chemical mixtures there are no materials available that will protect for more than an hour after initial contact.

**Penetration** is the transport of chemicals through openings in a garment. A chemical may penetrate due to design or garment imperfections. Stitched seams, button holes, pinholes, zippers, and woven fabrics can provide an avenue for the chemical to penetrate the garment. A well-designed and constructed garment prevents this by using self-sealing zippers, seams overlaid with tape, flap closures, and nonwoven fabrics. Rips, tears, punctures, or abrasions to the garment also allow penetration.

**Degradation** is a chemical action involving the molecular breakdown of the material due to chemical contact. Degradation is evidenced by physical changes to the material. The action may cause the material to shrink or swell, become brittle or soft, or completely change its chemical properties.

Other changes may be a slight discoloration, rough or gummy surface, or cracks in the material. Such changes may enhance permeation or allow penetration by the contaminant.

Degradation test data for specific chemical or generic classes of chemical (Table 1) is available from product manufacturers, suppliers, or other sources. The published data provides the user with a general degradation resistance rating. The rating is subjectively expressed as excellent, good, fair, or poor. Degradation data can help in assessing the protective capability of a material but should not replace permeation test data. The reason for this is that a material with excellent degradation resistance can have poor permeation properties. Degradation and permeation are not directly related and cannot be used interchangeably. The manufacturer should be consulted by the user to determine on which degradation changes the rating is based.

**Permeation** is a chemical action involving the movement of chemicals, on a molecular level, through intact material. Permeation is a process which involves the sorption of the chemical on the outside surface, diffusion through, and desorption of the chemical from the inside surface of the protective material. A concentration gradient (high on the outside, low on the inside) is established. Because the tendency is to achieve concentration equilibrium, molecular forces "drive" the chemical into the material toward the area of no or lower concentration. Eventually the highest flow of permeating chemical exists and is referred to as the steady flow state.

Permeation is measured as a rate. Permeation rate is the quantity of chemical that will move through an area of protective material in a given time. It is usually expressed in micrograms of chemical permeated per square centimeter per minute of exposure ( $\mu\text{g}/\text{cm}^2/\text{min}$ ). Several factors influence the rate of permeation including the type of material and thickness. A general rule of thumb is that the

permeation rate is inversely proportional to the thickness ( $2 \times \text{thickness} = 1/2 \times \text{permeation rate}$ ). Other important factors are chemical concentration, contact time, temperature, material grade, humidity, and solubility of the material in the chemical.

**TABLE 1**  
**EFFECTIVENESS OF PROTECTIVE MATERIALS AGAINST**  
**CHEMICAL DEGRADATION (BY GENERIC CLASS)<sup>1</sup>**

Generic Class	Butyl Rubber	Polyvinyl Chloride	Neoprene	Natural Rubber
Alcohols	E	E	E	E
Aldehydes	E-G	G-F	E-G	E-F
Amines	E-F	G-F	E-G	G-F
Esters	G-F	P	G	F-P
Ethers	G-F	G	E-G	G-F
Halogenated hydrocarbons	G-P	G-P	G-F	F-P
Hydrocarbons	F-P	F	G-F	F-P
Inorganic acids	G-F	E	E-G	F-P
Inorganic bases and salts	E	E	E	E
Ketones	E	P	G-F	E-F
Natural fats and oils	G-F	G	E-G	G-F
Organic acids	E	E	E	E

<sup>1</sup> E - Excellent  
G - Good  
F - Fair  
P - Poor

*Source: Survey of Personal Protective Clothing and Respiratory Apparatus, U.S. Department of Transportation, U.S. Coast Guard, Office of Research and Development (September, 1974).*

**Note:** For material and thickness, a general rule of thumb is that the permeation rate is inversely proportional to the thickness ( $2 \times \text{thickness} = 1/2 \times \text{permeation rate}$ ). Other important factors are chemical concentration, contact time, temperature, material grade, humidity, and solubility of the material in the chemical.

Another measure of permeation is **breakthrough time**, expressed in minutes. Breakthrough is the elapsed time between initial contact of a chemical with the outside surface and detection at the inside surface of the material. Like permeation rate, breakthrough time is chemical specific for a particular

material and is influenced by the same factors. A rule of thumb concerning breakthrough time is that it is directly proportional to the square of the thickness ( $2 \times \text{thickness} = 4 \times \text{breakthrough time}$ ).

Permeation and breakthrough test data are available from manufacturers which give specific rates and times (Table 2). A given manufacturer's recommendations serve as a relative guideline to properly selecting their products. This data is obtained using the American Society for Testing and Materials (ASTM) standard test method F739-81. Although ASTM has a standard method for permeation testing, considerable variation exists between manufacturer's test data. The differences are due to material thickness and grade, manufacturing processes, temperature, chemical concentrations, and analytical detection method. Therefore, caution should be used when comparing different manufacturers results. The results for the same material/chemical combination will differ considerably between manufacturers. ASTM also has test methods for penetration and degradation resistance.

The best protective material against a specific chemical is one that has a low permeation rate (if any) and a long breakthrough time. However, these properties do not always correlate. Compare propyl acetate (Table 2) and 1,1,1-trichloroethane against nitrile NBR or dimethyl sulfoxide and acetone against neoprene. As indicated, a long breakthrough time does not always correlate with a low permeation rate or vice versa. A long breakthrough time is usually desired.

The literature on material testing also notes that permeation rates and breakthrough times are not tested for those materials which receive a poor degradation rating; only breakthrough time is measured for those chemicals (especially corrosives) which are known to be direct skin hazards. The data also reflects the testing of pure substances and not mixtures.

In addition to the manufacturer's chemical resistance data, the best general reference for selection of CPC is *Guidelines For The Selection Of Chemical Protective Clothing*, ACGIH (1985). This reference compiles degradation and permeation test data from manufacturers, vendors, and independent laboratories with recommendations for over 300 chemicals. Table 3 illustrates information presented in this particular reference. Additional information is also available on computer databases.

Specific chemicals are rated against a variety of protective materials. The ratings (RR, rr, NN, nn) are based on two criteria; breakthrough times and vendor chemical resistance data. Each rating represents a combination of performance, number of sources confirming that performance, and consistency of the data. The number and size of the letters indicate this.

The available test data and recommendations for all CPC is extremely limited in scope and use. The user must consider these restrictions when selecting CPC and use the guidelines in the way they were intended to be used.

**TABLE 2**  
**PERMEATION/DEGRADATION RESISTANCE FOR EDMONT GLOVES**

	Nitrile NBR			Neoprene			PVC		
	Degradation Rating	Permeation: Breakthrough	Permeation Rate	Degradation Rating	Permeation: Breakthrough	Permeation Rate	Degradation Rating	Permeation: Breakthrough	Permeation Rate
Acetone	NR	-	-	B	5 min.	F	NR	3 hr.	-
Cellosolve acetate	F	1.5 hr.	G	G	1.25 hr.	VG	NR	-	-
Dimethyl sulfoxide (DMSO)	E	<4 hr.	VG	E	ND	E	NR	-	-
Hydrofluoric acid, 48%	E	2 hr.	-	E	1 hr.	-	G	40 min.	-
Propyl acetate	F	20 min.	G	P	-	-	NR	-	-
Toluene	F	10 min.	F	NR	-	-	NR	-	-
1,1,1-Trichloroethane	F	1.5 hr.	P	NR	-	-	NR	-	-

**KEY TO PERMEATION RATE**

Simply stated, drops per hour through a glove (eyedropper-size drop).

ND	-	None detected during 6-hour test (Equivalent to Excellent)
E	-	Excellent; permeation rate of less than 0.09 $\mu\text{g}/\text{cm}^2/\text{min}$ .
VG	-	Very Good; permeation rate of less than 9 $\mu\text{g}/\text{cm}^2/\text{min}$ .
G	-	Good; permeation rate of less than 90 $\mu\text{g}/\text{cm}^2/\text{min}$ .
F	-	Fair; permeation rate of less than 900 $\mu\text{g}/\text{cm}^2/\text{min}$ .
P	-	Poor; permeation rate of less than 9000 $\mu\text{g}/\text{cm}^2/\text{min}$ .
NR	-	Not recommended; permeation rate greater than 9000 $\mu\text{g}/\text{cm}^2/\text{min}$ .

NONE
0 to 1/2 drop
1 to 5 drops
6 to 50 drops
51 to 500 drops
501 to 5000 drops
> 5001 drops

*Note:* The current revision to the ASTM standard permeation test calls for permeation to be reported in micrograms of chemical permeated per square centimeter of garment exposed per minute of exposure, " $\mu\text{g}/\text{cm}^2/\text{min}$ ."

**TABLE 3**  
**GUIDELINES FOR THE SELECTION OF CHEMICAL PROTECTIVE CLOTHING (ACGIH)**

	Butyl	CPE	Viton/Neoprene	Natural Rubber	Neoprene	Nitrile & PVC	Nitrile	PE	PV Alcohol	PVC	Viton	Butyl/Neoprene	OTHER MATERIALS
<b>Inorganic Salts</b>													
<i>Inorganic Salts (34)</i>													
Ammonium fluoride													Neop + Nat Rub
Ammonium fluoride, 30-70%				rr	rr		rr			rr			
Ammonium sulfate	r			R	R	r	r			R			Polyurethane (R)
Arsenic trichloride			n									n	
Bromine trifluoride			n									n	
Calcium chloride	r			R	R	r	r			R			Polyurethane (r)
Calcium hypochlorite	r			R	R	r	r			R			Polyurethane (r)
Copper chloride				n	r		r			r			Polyurethane (r)
Copper sulfate				n	R		r			R			Polyurethane (r)
Cupric chloride	r			n	R	r				R			Polyurethane (r)
Cupric sulfate	r			n	R	r	r			R			Polyurethane (r)
Ferric chloride	r			r	R	r				R			Polyurethane (r)

*Note:* For explanation of recommendation codes (e.g. r, rr, R, n, etc.) refer to Arthur D. Little, Inc.

## **Classification of Chemical Protective Clothing**

- **Style:**

**Fully Encapsulating Suit (FES).** Fully encapsulating CPC is a one-piece garment that completely encloses the wearer. Boots, gloves, and facepiece are an integral part of the suit, but may be removed. If removable they are connected to the suit by devices that provide a vapor or gas proof seal. These are gas tight suits and must be periodically pressure tested to insure integrity.

Respiratory protection and breathing air are provided to the wearer by a positive-pressure, self-contained breathing apparatus (SCBA) worn under the suit or by an air-line respirator that maintains a positive-pressure inside the suit. Fully encapsulating suits are primarily for protecting the wearer against toxic vapors, gases, mists, or particulates in air. Concomitantly, they protect against splashes of liquids. The protection they provide against a specific chemical depends upon the material from which they are constructed.

**Nonencapsulating Suit.** Nonencapsulating CPC (frequently called splash suits) does not have a facepiece as an integral part of the suit. A positive pressure SCBA or air-line respirator is worn outside the suit, or an air-purifying respirator is used. Splash suits are of two types: a one-piece "coverall" or a two-piece "pants and coat." Either type may include a hood and other accessories.

Nonencapsulating suits are not designed to provide maximum protection against vapors, gases, or other airborne substances but they do provide protection against splashes. In effect, splash suits can be made (by taping wrist, ankle and neck joints) to totally enclose the wearer such that no part of the body is exposed but they still are not considered to be gas tight. They may be an acceptable substitute for a fully encapsulating suit if the concentration of airborne contamination is low and the material is not extremely toxic to the skin.

- **Protective Material:**

**Elastomers.** Polymeric (plastic-like) materials, after being stretched, return to about their original shape. Most protective materials are elastomers. These include: polyvinyl chloride, neoprene, polyethylene, nitrile, polyvinyl alcohol, viton, Teflon®, butyl rubber and others. Elastomers may be supported (layered on to cloth-like material) or unsupported.

**Nonelastomers.** Materials that do not have the quality of stretchability. Nonelastomers include tyvek, tyvek-coated garments, and other materials.

- **Single-Use Suits:**

A third classification is single use or disposable garment. This classification is relative and based on cost, ease of decontamination and quality of construction. Disposable CPC is commonly considered to be less than \$25.00 per garment. In

situations where decontamination is a problem, more expensive clothing may be considered disposable.

## **Protective Materials**

There are a wide variety of protective materials. The following is a list of the more common materials used in CPC segregated as elastomers or nonelastomers. The elastomers are not listed in any particular priority. The classes of chemicals rated as "good for" or "poor for" represent test data for both permeation breakthrough and permeation rate. They are general recommendations; there are many exceptions within each chemicals class. Sources consulted for this information included *Guidelines for the Selection of Chemical Protective Clothing* (ACGIH Volume 1, 1985) and manufacturer's literature.

- **Elastomers**

**Natural Rubber:** (Polyisoprene)

Good for: alcohols, dilute acids and bases, flexibility  
Poor for: organic chemicals, aging (affected by ozone)

**Polyvinyl Alcohol:** (PVA)

Good for: almost all organics, ozone resistance  
Poor for: esters, ethers, acids and bases, water and water solutions flexibility

**Chlorinated Polyethylene:** (Cloropel, CPE)

Good for: aliphatic hydrocarbons, acids and bases, alcohols, phenols, abrasion and ozone  
Poor for: amines, esters, ketones, halogenated hydrocarbons, cold temperature (becomes rigid)

**Nitrile Rubber:** (Acrylonitrile rubber, Buna-N, NBR, hycar, paracril, krynac)

Good for: phenols, PCBs, oils and fuels, alcohols, amines, bases, peroxides, abrasion and cut resistance, flexibility  
Poor for: aromatic & halogenated hydrocarbons, amides, ketones, esters, cold temperature

*Note:* The higher the acrylonitrile concentration, the better the chemical resistance; but also increases stiffness.

**Polyvinyl Chloride:** (PVC)

Good for: acids and bases, some organics, amines, peroxides  
Poor for: most organic compounds, cut and heat resistance, decontamination

**Neoprene:** (Chloroprene)

Good for: bases and dilute acids, peroxides, fuels and oils, aliphatic hydrocarbons, alcohols, glycols, phenols, abrasion and cut resistance  
Poor for: halogenated hydrocarbons, aromatic hydrocarbons, ketones, concentrated acids

**Butyl Rubber:**

Good for: bases and many organics heat and ozone resistance decontamination  
Poor for: aliphatic and aromatic hydrocarbons, gasoline, halogenated hydrocarbons, abrasion resistance

**Viton:**

Good for: aliphatic and aromatic hydrocarbons, halogenated hydrocarbons, acids, decontamination, physical properties  
Poor for: aldehydes, ketones, esters (oxygenated solvents), amines

**Teflon®:**

Teflon® has become available for chemical protective suits. Limited permeation test data is published on Teflon®. Teflon®, similar to viton, is thought to afford excellent chemical resistance against most chemicals.

**Polyurethane:**

Good for: bases, aliphatic hydrocarbons, alcohols, abrasion resistance, flexibility  
- especially at cold temperatures  
Poor for: halogenated hydrocarbons

**Blends/Layers:**

CPC Manufacturers have developed a technique of layering materials to improve chemical resistance. Essentially one suit is designed with multiple layers. Some examples of layered fully encapsulating suits are viton/butyl (Trelleborg), viton/neoprene (MSA Vautex and Draeger), and butyl/neoprene (MSA Betex).

- **Nonelastomers**

**Tyvek:** (nonwoven polyethylene fibers)

Good for: dry particulate and dust protection decontamination (disposable)  
lightweight  
Poor for: chemical resistance (penetration/degradation) durability

Recommendations: Used against toxic particulates but provides no chemical protection; worn over other CPC to prevent gross



contamination of nondisposable items and under suits to replace cotton.

**Polyethylene:** (coated tyvek)

**Good for:** acids and bases, alcohols, phenols, aldehydes, decontamination (disposable), lightweight

**Poor for:** halogenated hydrocarbons, aliphatic and aromatic hydrocarbons  
physical properties (durability) penetration (stitched seams)

**Recommendations:** Provides limited chemical protection against concentrated liquids and vapors. Useful against low concentrations and those activities which do not create a high risk of splash; also worn over CPC to prevent gross contamination of nondisposables.

**Saranex:** (laminated tyvek)

**Good for:** acids and bases, amines, some organics, PCBs, decontamination (disposable), lightweight, durable

**Poor for:** halogenated hydrocarbons, aromatic hydrocarbons, stitched seams (penetration may occur)

**Recommendations:** Provides greater chemical resistance and overall protection compared to polyethylene coated tyvek; used to prevent contamination of nondisposable clothing.

**Personal Cooling Devices**

Wearing chemical-resistant clothing and respirators increases the risk of heat stress. They cause additional strain on the body by adding weight, increasing breathing resistance, and restricting movement. They can also reduce the body's natural cooling mechanisms. The body releases heat by convecting heat to cooler air, radiating heat to cooler surfaces in the surroundings, and evaporating moisture from the skin. Chemical-resistant clothing interferes with these processes. This can lead to heat illness, heat fatigue, heat rash, heat cramps, heat syncope (fainting), heat exhaustion, or even heat stroke. Methods used to prevent heat illness include frequent rest breaks, reduced work loads, increased consumption of fluids, acclimatization, and working during the cooler times of the day. Another method that is available is the use of personal cooling devices to remove heat from the user's body.

There are many different types of personal cooling devices. When selecting a unit, one main consideration is whether it is compatible with the other protective equipment worn. Mobility, weight and duration of use must also be considered. Worker acceptance is also an important consideration. Whatever device is used, it must be remembered that the device reduces but doesn't eliminate the heat stress.

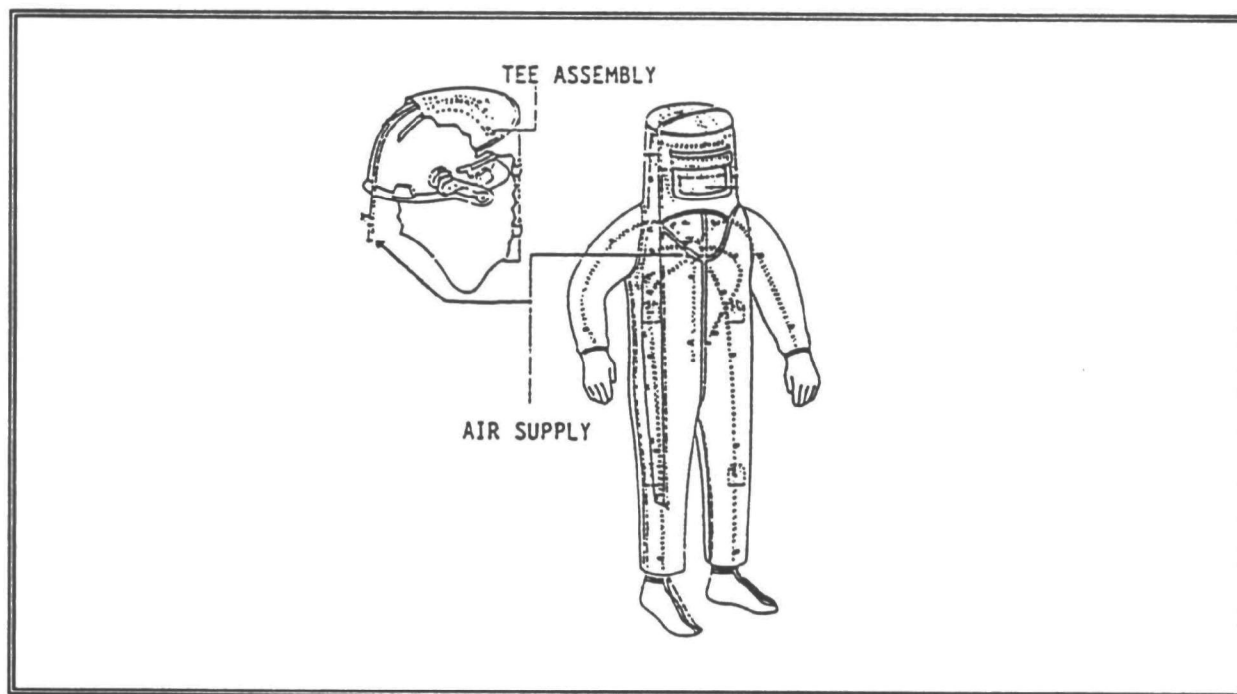
Cooling devices are divided into two types: those that use a coolant source external to the wearer (an umbilical system) or self-contained systems that are not connected to an outside source.

- **External Coolant Systems**

Devices using an external cooling source need a connection between the wearer and the coolant source. The coolant can be compressed air or a liquid.

**Compressed Air Systems**

Compressed air systems use cool, dry air to aid in cooling the body. Generally the air is distributed to the ankles, wrists, and head by an arrangement of air tubes worn on the body or attached to the protective clothing (**Figure 1**). Some systems can be found in the form of a hood or vest. Many manufacturers of fully encapsulating suits have air distribution systems built into their suits.



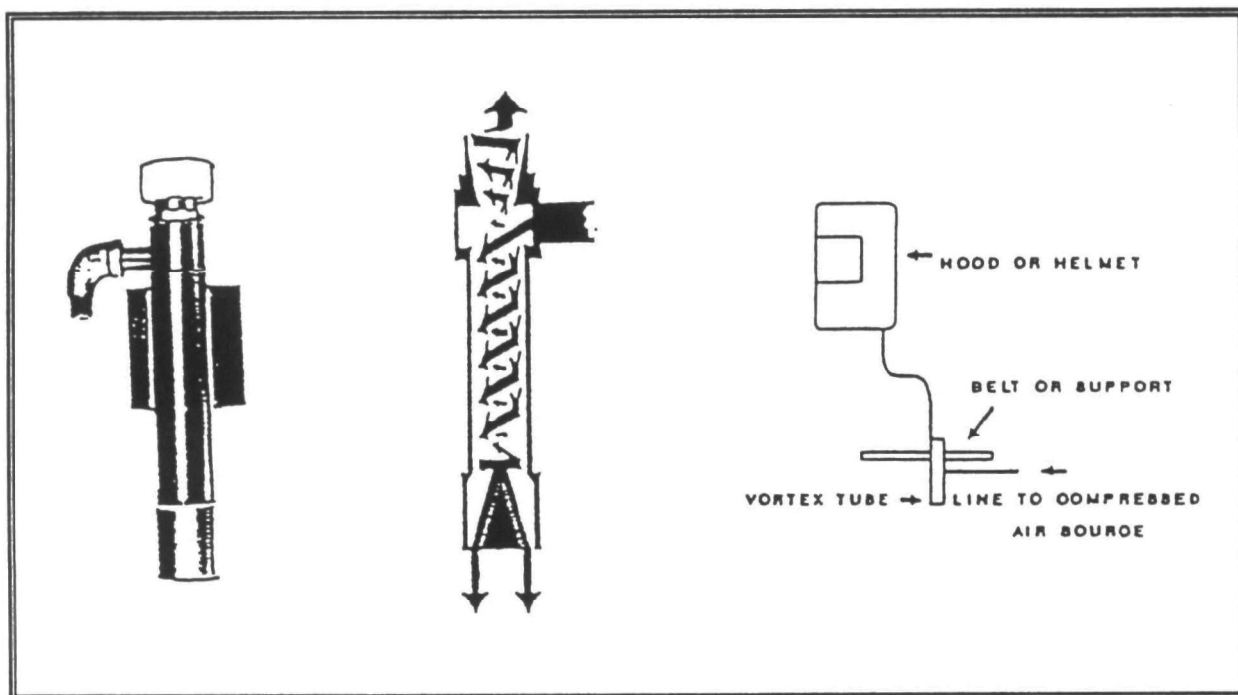
**FIGURE 1**  
**FULLY ENCAPSULATING SUIT WITH AIR DISTRIBUTION SYSTEM**

*Used with permission of Mine Safety Appliances, Pittsburgh, PA.*

The air is delivered to the units from a compressor or a large compressed air container (like a cascade system). The air acts as an insulator from external heat and increases evaporation of sweat because of the constant flow of dry air. If additional cooling is needed, a vortex cooler to chill the air can be connected into the airline at the user's end. The vortex cooler (**Figure 2**) takes compressed air, increases its velocity, directs it into an outer "hot" tube, and forms a vortex. The air spirals down

the tube and a fraction escapes through a valve in the end. The remaining air forms a second vortex which passes through the center of the outer vortex—flowing in the opposite direction—and exits from the "cold" tube. The outer vortex takes heat from the inner vortex. How much heat is transferred is determined by how much air the valve releases; more hot air out, more cold air to user. The vortex cooler is attached to a belt or other support. It must be worn on the outside of any protective clothing so that the heat can be vented.

It is important to remember that NIOSH does not have a specific testing and certification schedule for supplied air suits. Thus, the suits should not be used for respiratory protection. Some suits and hoods have a NIOSH/MSHA respiratory approval under the SCBA or airline testing schedules. If a vortex tube is used with a unit for respirator protection, then the respirator must be tested and approved with the vortex tube.



**FIGURE 2**  
**VORTEX TUBE; SCHEMATIC OF VORTEX TUBE;**  
**VORTEX TUBE CONNECTED TO AIR-SUPPLIED HOOD**

*Used with permission of Fyrepel Products, Inc., Newark, OH.*

Compressed air systems have two advantages. They are able to cool the whole body and they allow the wearer to work as long as desired. However, they have several disadvantages. They restrict mobility because of the airline umbilical. Since the system is continuous flow, they use a lot of air - especially if using a vortex cooler. One unit with a vortex cooler uses 25 cubic feet of air per minute to deliver 15 cubic feet of usable air to the wearer. A normal airline respirator uses 6-8 cubic feet per

minute. Also, the hot air from the vortex tube—as hot as 162°F—can add heat to the environment or to the outside surface of the protective clothing.

### **Liquid-Cooled Devices**

There is only one device in this category. Water is circulated through tubing in a garment resembling long johns. It can use an external water supply - which can be chilled - or a portable chilling unit for recirculated water.

This unit has the same advantages and disadvantages of the air-supplied systems. It has additional disadvantages. There is additional weight due to the water in the system. At the present, fully encapsulating suits do not have liquid line connections. One advantage is that the cooling system can be located away from the user and thus not add heat to the user's immediate area.

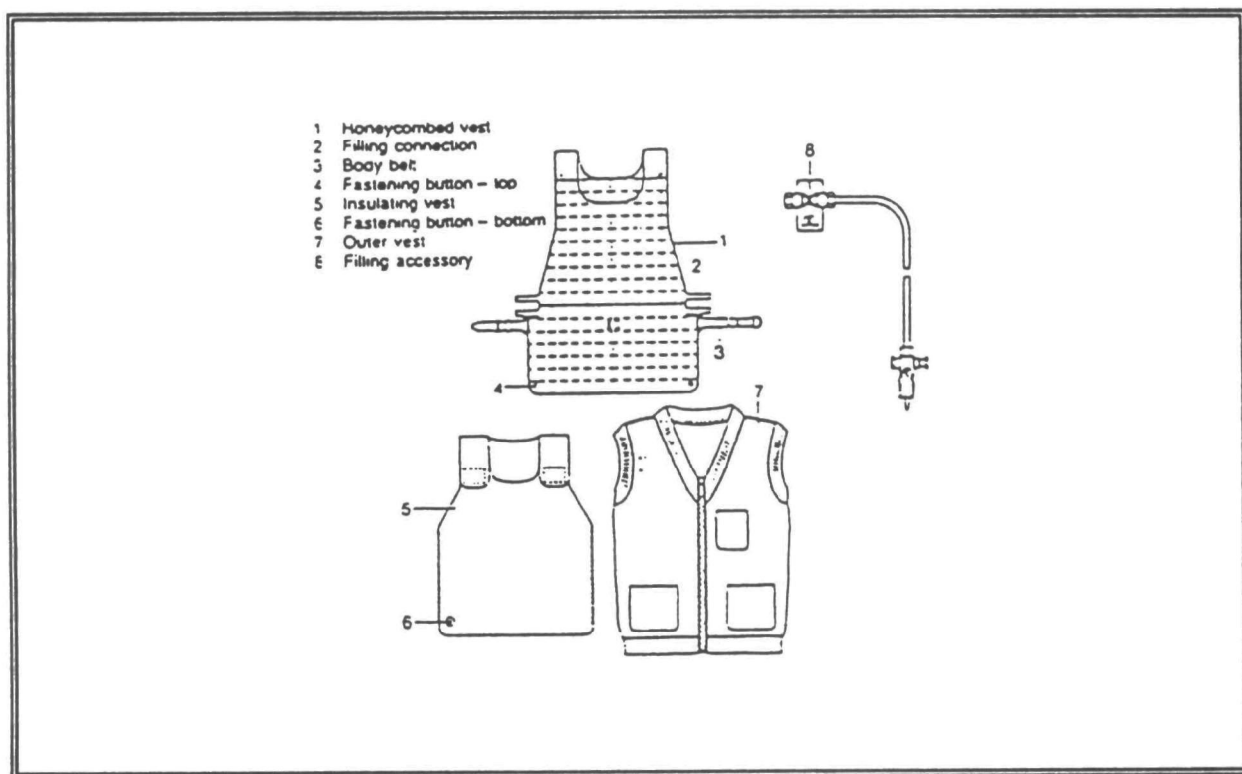
- **Self-Contained Systems**

Self-contained systems have all of the heat-exchanging elements as part of the wearer's ensemble. Thus, they are not hooked to an outside coolant source. These systems are usually of two types: those that use ice to cool the wearer and those that circulate a liquid cooled by a heat-exchange system.

### **Ice Vests/Jackets**

These systems use ice in a vest or jacket or in removable packets. The size and number of packets vary from manufacturer to manufacturer. Some systems come with an inner vest to prevent direct contact with the skin. Some have an outer vest to reduce external heat effects on the ice (Figure 3).

These systems have several advantages. They are simple to use, have no moving parts, and do not restrict mobility. They can be worn under protective clothing or an SCBA. They also have disadvantages. They are usually limited to a maximum of 1 hour of cooling. If more time is needed, extra packets are needed. If the unit has no removable packets, the whole vest has to be refrozen. After the ice melts, the wearer is carrying extra weight with no cooling benefit. They weigh from 12 to 15 pounds. If there is no inner insulation, they may be too cold.



**FIGURE 3**  
**WATER-FILLED ICE VEST**  
 (Entire jacket is frozen prior to use)

*Used with permission of National Draeger, Pittsburgh, PA.*

### Circulating Systems

Circulating systems use a water or a water/alcohol mixture circulated through the vest to cool the wearer. The liquid is cooled by ice or other frozen liquid contained in a pouch or container carried by the wearer (Figure 4). In some cases, the melting ice becomes part of the circulating system. There are a couple of experimental models that use dry ice to cool the circulating liquid.

The circulating systems have some of the same advantages and disadvantages as the ice vests. They have the additional disadvantage of using an electric circulator. This requires battery pack to power the circulator. Thus, more weight is added. Also, while the units have waterproof and sparkproof connections, none have received an inherent safety rating. Their main advantage is that the cooling rate can be controlled by controlling the flow of the liquid through the vest. They can be worn under protective clothing and an SCBA. There is one model that is incorporated into a fully encapsulating suit. The ice can be replenished without removing the suit.



**FIGURE 4**  
**COOL VEST® MODEL 19**

(The back of the unit has a battery-operated pump  
and pouch containing ice and circulating water)

*Used with permission of ILC Dover, Frederica, DE.*

## **SITE ENTRY AND RECONNAISSANCE**

The primary objective when responding to a hazardous material incident is the prevention, or reduction, of detrimental effects to public health or environment. To accomplish this it is necessary to:

- Identify the substance involved.
- Evaluate its behavior when released and its effects on public health and the environment.
- Initiate actions to prevent or modify its effects.

A high priority, from start to finish of an incident, is obtaining the necessary information to evaluate its impact. This is called incident characterization and is the process of identifying the substance involved and evaluating actual, or potential, impact on public health or the environment.

Characterization is relatively straightforward in incidents where the substance involved is known or easily identified, the pathways of dispersion are clearly defined, and the effect or potential impact is demonstrated. For example, the effects of a large discharge of vinyl chloride on fish in a small stream is relatively easy to evaluate. However, an incident such as an abandoned waste site containing 60,000 55-gallon drums is more complex because there generally is not enough initial information to determine the hazards and to evaluate their impact.

Evaluating a hazardous substance incident is generally a two-phase process: (1) an initial characterization and (2) a more comprehensive characterization.

### **Preliminary Assessment**

At site responses where the hazards are largely unknown and where there is no need to go on-site immediately, conduct an off-site reconnaissance by: (1) making visual observations; (2) monitoring atmospheric hazards near the site; and (3) collecting off-site samples that may indicate on-site conditions or migration from the incident.

An off-site reconnaissance and information gathering should also include:

- Collections of information not available from, or needed to verify or supplement, the preliminary assessment.
- General layout and map of the site.
- Monitoring ambient air with direct-reading instruments for: oxygen deficiency; combustible gases; radiation; organic vapors, gases, and particulates; inorganic vapors, gases, and particulates; and specific materials if known.
- Placards, labels, markings on containers or transportation vehicles.

- Configuration of containers, tank cars, and trailers.
- Types and number of containers, buildings, and impoundments.
- Biological indicators - dead vegetation, animals, insects, and fish.
- Unusual odors or conditions.
- Visual observation of vapors, clouds, or suspicious substances.
- Off-site samples (surface water, drinking water, site run-off, groundwater, soil, air).
- Interviews with inhabitants, observers, or witnesses.

### **Initial Characterization**

The **initial characterization** is based on information that is readily available or that can be quickly obtained. This information is used to determine: (1) what hazards exist and (2) whether immediate protective measures are necessary. During this initial phase, a number of key decisions must be made as follows:

- Imminent or potential risk to public health and to the environment.
- Immediate need for protective actions to prevent or reduce the impact.
- Protection of the health and safety of response personnel.

Once immediate control measures are implemented, actions can start to restore the area to environmentally acceptable conditions. If there is no emergency, time can be spent to: (1) evaluate hazards; (2) design cleanup plans; and (3) establish safety requirements for response personnel. Also, information to characterize the hazards can be obtained from intelligence (records, placards, eye witnesses, etc.), direct-reading instruments, and sampling. Various combinations of these information gathering techniques can be used depending on the nature of the incident and the time available.

The outline that follows lists the types data necessary to evaluate the impact of a hazardous materials incident. Not every incident requires all items to be obtained. However, the list does provide a guide that can be adapted to meet site-specific conditions.

**Data Gathering and Preliminary Assessment.** Upon notification or discovery of an incident, obtain the following information:

- Brief description.
- Exact location.
- Date and time of occurrence.
- Hazardous materials involved and their physical/chemical properties.
- Present status of incident.



- Potential pathways of dispersion.
- Habitation - population at risk.
- Environmentally sensitive areas - endangered species, delicate ecosystems.
- Economically sensitive areas - industrial, agricultural.
- Accessibility by air and roads.
- Waterways.
- Current weather and forecast.
- Terrain - include topographic map.
- Geology and hydrology - include appropriate maps.
- Aerial photographs.
- Communications.
- Any other related background information.

Information about an incident, especially abandoned waste sites, may also be available from:

- Other federal agencies.
- State and local health or environmental agencies.
- Company records.
- Court records.
- Water departments, sewage districts.
- State and local authorities.

### **On-Site Survey**

A more thorough evaluation of hazards generally requires personnel to enter the defined site. Before going on-site, an entry plan is developed to: (1) address what will be initially accomplished and (2) give the procedures to protect the health and safety of response personnel. On-site inspection and information gathering includes:

- Monitoring ambient air with direct-reading instruments for: oxygen deficiency, combustible gases, radiation, organic vapors and gases, inorganic vapors and gases, particulates, and specific materials if known.
- Types of containers, impoundments, and their storage systems: numbers, types, and quantities of material.
- Condition of storage systems (such as state of repair or deterioration).
- Leaks or discharges from containers, tanks, ponds, vehicles, etc.
- Potential pathways of dispersion: air, surface water, groundwater, land surface, biological routes.
- Placards, labels, markings, identification tags, or indicators of material.
- Container configuration, shape of tank cars or trailers.

- Standing water or liquids.
- Condition of soil.
- Wells, storage containers, drainage ditches, or streams and ponds.

### **Comprehensive Characterization**

The second phase, **comprehensive characterization** (which may not be needed in all responses), is a more methodical investigation to enhance, refine, and enlarge the information base obtained during the preliminary inspection. This phase provides more complete information to characterize the hazards associated with an incident. As a continuously operating program, the second phase also reflects environmental changes resulting from response activities.

Available information and information obtained through initial site entries may be sufficient to thoroughly identify and assess the human and environmental effects of an incident. If not, an environmental surveillance program needs to be implemented. Much of the same type of information as collected during the preliminary inspection is needed. However, it may be much more extensive. Instead of one or two groundwater samples being collected, an extensive groundwater survey may be needed over a long period of time. Results from the preliminary inspection provide a screening mechanism for a more complete environmental surveillance program to determine the extent of contamination. Also, since mitigation and remedial measures may cause changes in the original conditions, a continual surveillance program must be maintained to identify any changes.

Evaluating the hazards associated with an incident involves various degrees of complexity. The release of a single, known chemical compound may represent a relatively simple problem. It becomes progressively more difficult to determine harmful effects as the number of compounds increase. Evaluation of the imminent, or potential hazards, associated with an abandoned waste site, storage tanks, or lagoons holding vast amounts of known, or unknown, chemical substances is far more complex than a single release of an identifiable substance.

The major responsibility of response personnel is the protection of public health and the environment. The effective accomplishment of this goal is dependent upon a thorough characterization of the chemical compounds involved, their dispersion pathways, concentrations in the environment, and deleterious effects. A base of information is developed over the lifetime of the incident to assess the harmful effects and ensure that effective actions are taken to mitigate the release.

## **RADIATION**

There are three primary categories of radiation that might be encountered in a field survey: (1) alpha, (2) beta, and (3) gamma. Each of these has unique properties that must be considered in selecting an instrument for use. Alpha particles are simply energetic helium ions (i.e., atoms that have lost their electrons). Because of their large size (compared to other forms of radiation) and high charge, they will not penetrate through much matter. They will penetrate through more material than alphas, but generally can be stopped by a thin piece of metal. Gamma radiation is simply high energy light and is the most penetrating of the radiation types. Very high energy gammas can penetrate through several centimeters of lead.

There are hazards associated with exposure of humans to radiation, but if the exposure is limited to low levels, that hazard is not very serious. In fact, humans are exposed to natural background radiation every day. Naturally occurring radioactive materials can be found in the soil, building materials, certain foods, and even the human body. The unit used to quantify the radiation dose received by an individual is the roentgen equivalent man (rem). The average dose, due to natural background radiation and natural radioactive materials in the environment, to an individual in the United States is about 0.2 rem/year.

The actual health risk from low-levels of radiation is quite small. There is no direct evidence that low doses of radiation can injure the health of humans. All of the estimates of the health risks associated with radiation have been extrapolated from studies of people who have received doses equivalent to hundreds of rem. It has been assumed that very low levels of radiation would affect the body in the same way as these very high doses, only with proportionately less damage. As radiation passes through matter, it may interact and lose energy. The damage done by radiation as it interacts with the body results from the way it affects molecules essential to the normal functioning of human cells. One of four things may happen when radiation strikes a cell: (1) the radiation may pass through the cell without doing any damage, (2) the cell may be damaged but repairs itself, (3) the cell may be damaged so that it not only fails to repair itself, but reproduces in damaged form over a period of years, or (4) the cell may be killed. The death of a single cell may not be harmful because the body can readily replace most cells, but problems will occur if so many cells are killed that the body cannot properly function. Incompletely or imperfectly repaired cells can lead to delayed health effects such as cancer, genetic mutations, or birth defects. Again, it is important to recognize that the risks from radiation are small. For example, the statistical risk of a cancer death from 7 mrem of radiation is equivalent to that associated with smoking a single cigarette.

Radiation cannot be detected by any of the human senses. We cannot taste, smell, feel, see or hear it. Because of this, we must rely upon instruments that respond to an interaction between the radiation and the instrument itself. Radiation is nothing more than energetic particles or photons.

As the radiation passes through matter, it interacts with the material's electrons to lose some of the energy. This energy results in either excitation or ionization of atoms. Depending upon the type of detector, either the excitation or the ionization is sensed, quantified, and the instrument produces a response that is proportional to the total amount of radiation that is present in the area being monitored or surveyed.

Portable survey instruments are calibrated to read out in either counts per minute (CPM), in direct units or radiation intensity, such as milli-Roentgen/hour (mR/hr) or micro-Roentgen/hour ( $\mu$ R/hr). Instruments reading out in mR/hr and  $\mu$ R/hr are used to measure extended radiation fields such as that experienced in the vicinity of radioactive materials' storage or disposal sites. Instruments that read out in CPM are usually used to monitor for low-level surface contamination, particularly on hard, nonporous surfaces.

One of the difficulties in measuring radiation is that there is always some background level of radiation present. This background will vary with location; some regions of the country will have higher background than others, brick buildings will have higher backgrounds than wooden buildings, etc. Because of this variation, when any survey instrument is used, a determination of local background must be made in an area that is not believed to contain any radioactive materials. Any reading significantly above the background (two to three times background) is indicative of the presence of radioactive materials. Background levels throughout the United States will typically range between 5 and 100  $\mu$ R/hr. The United States Environmental Protection Agency limits the radiation exposure to workers to 1 mR/hr above background. This action level is specified in the EPA's *Standard Operating Safety Guides*.

The detectors used in most portable survey instruments are gas-filled or scintillation devices. The gas-filled detectors measure the amount of ionization in the gas that is caused by radiation entering the detectors. This is accomplished by establishing a voltage potential across a volume of gas. When the gas is ionized, the current that flows between the electrodes producing the potential can be measured. The amount of current is directly proportional to the amount of radiation that enters the detector. Scintillation detectors depend upon light that is produced in a crystal plastic, of certain compounds, when the material's atoms are excited by interactions with radiation. The amount of light produced is measured and converted to an easily monitored electrical signal by a photomultiplier tube. There are gas-filled and scintillation detectors designed to detect all three of the radiation types of interest in field surveys.

The most obvious difference in detectors used for different radiation types is the manner in which radiation can enter the sensitive volume of the detector. Many gamma survey instruments will not appear to have a detector, but only an electronics box. This is because the gammas can easily penetrate the metal electronics enclosure and the detector is placed inside where it is protected from damage. The Ludlum Model 19 Micro R meter is an example of such a detector. Alpha and beta detectors must have thin entrance windows so that these particles can enter the sensitive volume. Some gas filled detectors are designed with a thick metal shield so they can discriminate between betas and gammas; with the shield open, the detector is sensitive to both betas and gammas; with it closed, it will detect only gammas, since the shield absorbs the betas before they can interact with the detector.

A good survey meter should be portable, rugged, sensitive, simple in construction, and reliable. Portability implies lightness and compactness with a suitable handle or strap for carrying. Ruggedness requires that an instrument be capable of withstanding mild shock without damage. Sensitivity demands an instrument which will respond to the type of energy level of the radiation being measured. Rarely does one find an instrument capable of measuring all types and energies of radiation that are encountered in practice. Simplicity in construction necessitates convenient arrangement of components and simple circuitry comprised of parts which may be replaced easily. Reliability is that attribute which implies ability to duplicate response under similar circumstances.

## **Ludlum Model 19 Micro R Meter**

The Ludlum Model 19 Micro R Meter is designed to monitor low-level gamma radiation. The instrument utilizes an internally mounted sodium iodide scintillator crystal. The meter face has two scales, one in black representing 0-50  $\mu\text{R/hr}$  and one in red representing 0-25  $\mu\text{R/hr}$ . The meter range is controlled with a six position switch: OFF, 5000, 500, 250, 50 and 25. The full scale reading of the meter is equal to the switch setting; the red scale corresponds to the 25 and 250 position and the black scale to the other three positions. As an example, if the switch is in the 500 position and the meter pointer is aligned with the "30" scale marking, the radiation field is 300  $\mu\text{R/hr}$ .

The Ludlum Model 19 is equipped with five additional switches or buttons. One button, labeled L, lights the meter face while depressed. This allows accurate readings in poor lighting conditions. The BAT button tests the battery condition. If the batteries are good, the meter pointer will deflect to the "batt OK" portion of the scale. The audio switch controls the audible signal; in the ON position, a "beeping" signal accompanies each radiation event that is detected. The switch marked with the F and S controls the meter response; the S (slow) position is used for most applications, although in conditions where the radiation level is changing rapidly, the F (fast) position will provide a better representation of the radiation level. The remaining button resets the detector operating high voltage should a transient pulse cause it to be disabled.

## **Detector Probes**

Detector probes will fall into two major categories: gas-filled detectors and scintillation detectors. These have been briefly discussed in the introduction section. This section will describe a few of the most commonly used probes.

The Geiger-Mueller (GM) pancake probe is very common and is most valuable for monitoring for surface activity on equipment, benchtops, soil surface and personnel. The probe may be used to monitor alpha, beta or gamma radiation. The sensitive volume of the detector is covered with a thin mica window of about 1.75 inch diameter. This window allows detection of alphas and low energy betas. The fragile window is protected by a metal screen, and care must be taken to avoid puncturing it.

End-window GM probes may also be used for alpha, beta, and gamma monitoring. These tubes are generally cylindrical, about 6-8 inches long and have mica entrance windows about 1 inch in diameter. The window often does not have a protective screen and is easily punctured. Because of its configuration, this tube is not as convenient as a pancake probe for surface monitoring. Also, because of the smaller entrance window, it is less efficient for detecting alphas and betas.

Thin-walled GM probes are used for beta and gamma detection. The tube is constructed within steel walls through which beta rays can pass. The tube is housed in a protective cage fitted with a movable steel shield. With the shield in place, betas are absorbed and only gammas can be detected. When the shield is moved away from the cage opening, the detector is sensitive to both betas and gammas.

Scintillation probes are available for alphas, betas, and gammas. They differ in the type of scintillator used and the detector housing. Alpha detectors are made of thin activated zinc sulfide crystals. The beta detectors generally use thin scintillation plastic crystals. Gamma probes use thick crystals of activated sodium iodide. Beta and alpha probes have entrance windows of thin aluminized mylar. This window protects the detector from light which would be sensed by the photomultiplier as if it were a high radiation field. Care must be taken not to puncture the window.

The alpha probes often have large surface areas (50-100 cm<sup>2</sup>) to allow efficient detection of low levels of alpha contamination. The gamma detectors are usually housed in an aluminum shell. This shell is not easy to puncture and is quite rugged, although dropping or banging it against a hard object may break the crystal or the photomultiplier.

### **Personnel Dosimeters**

The amount of radiation dose received by an individual working in a radiation field is measured by the use of personnel dosimeters. Two types that are frequently used are the direct-reading dosimeter and the thermoluminescent dosimeter (TLD).

The direct-reading dosimeter provides an immediate indication of the gamma radiation dose the wearer has received. By checking his dosimeter periodically, the wearer can get an up-to-the-minute estimate of the total gamma dose he/she has received. Only gamma radiation is measured. There is no way that beta radiation can penetrate the walls of the dosimeter to cause ionization.

Inside the detection chamber of the dosimeter is a stationary metal electrode with a movable quartz fiber attached to it. The dosimeter is charged so that both the electrode and the fiber are positively charged. Because both are positively charged, they repel each other, and the movable fiber moves as far away from the electrode as it can. When gamma radiation causes ionization in the detection chamber, the negative ions move to the positively charged electrode or fiber. This action reduces the positive charge and allows the fiber to move a little closer to the stationary electrode. The movement of the fiber, then, is a measure of the amount of gamma radiation absorbed by the detector.

In direct-reading pocket dosimeters, a scale is placed so that the hairline on the scale is the movable fiber. As the fiber moves, the scale indicates the total amount of gamma radiation absorbed by the dosimeter. A magnifying glass inside the dosimeter enables the scale to be read. This provides an immediate estimate of an individual's total gamma exposure.

Anyone who is instructed to wear a direct-reading dosimeter should make sure that it is properly charged. When a dosimeter is properly charged, there is sufficient potential between the electrode and the fiber that the fiber is significantly displaced and the hairline on the scale reads near zero. In general, a dosimeter is considered adequately charged if it reads below 10 mR.

If a dosimeter is not properly charged, a charger must be used to charge it before it can be worn. The dosimeter is pushed into the charger, and the charger control is turned until the dosimeter is zeroed. The dosimeter must be checked again after it is taken out of the charger. Sometimes the hairline shifts when the dosimeter is removed from the charger, and the dosimeter will have to be readjusted so that the hairline will end up at or near zero.

Because the direct-reading dosimeter measures the whole-body gamma radiation dose, it should be worn on the trunk of the body. When using a dosimeter, care must be taken not to bang or drop it. Rough treatment may cause the electrode to discharge completely, sending the hairline all the way upscale.

Thermoluminescent dosimeters (TLDs) are often used for beta and gamma whole-body measurements. Inside the TLD is a very small quantity of crystalline material called a detector chip that is used to measure beta and gamma exposure. A typical detector chip is approximately 1/8 inch across and 1/32 inch thick.

To understand how a detector chip measures radiation, we first need to go through a short review of electron energy levels. As we know, electrons in a solid material prefer to be in their ground energy state. This is especially true for a crystalline material. If radiation imparts enough energy to one of these electrons, the electron will jump up to a higher, instable energy level. However, since the electron prefers to be in the ground state, it will drop to the ground state and emit the extra energy in the form of heat, x-rays, or light.

In TLD material, there is an in-between state called a metastable state, which acts as an electron trap. When radiation strikes the ground state electron, the electron jumps up and is trapped in the metastable state. It remains there until it gets enough energy to move it up to the unstable state. This energy is supplied when the TLD chip is heated to a high enough temperature. Then the electron will drop back down to the ground state and, because the TLD chip is a luminescent material, it will release its extra energy in the form of light. The total quantity of light emitted by electrons returning to the ground state is proportional to the number of electrons that were trapped in the metastable state. The number of electrons trapped in the metastable state is proportional to the amount of beta and gamma radiation that interacts with the material. This means the amount of light emitted when the TLD is heated is proportional to the total amount of beta and gamma radiation interacting with the material.

In the photomultiplier tube, electrons are produced in the photocathode, multiplied across the dynodes, and finally collected on the anode. This then produces a pulse in the circuit that is proportional to the total amount of beta and gamma radiation absorbed by the TLD material.

There are several reasons for using TLDs instead of film badges. One reason is size - TLD chips are so small that they can be taped to the fingers to measure exposure to the extremities without interfering with work. A second reason is sensitivity. The TLD is generally more sensitive than a film badge, more accurate in the low mR range, and able to provide a better overall indication of the total beta/gamma dose received. A third reason is that the TLD chip can be reused after it is read.

As with the direct-reading dosimeter, TLD is normally worn on the trunk of the body to give the best indication of whole-body dose. There are times, however, when these devices might be worn on other parts of the body. For example, a TLD might be moved to an arm or a leg if these portions of the body might receive more radiation than the trunk area. An additional device such as a finger ring might also be used to measure an extremity dose. A finger ring contains a TLD chip to measure absorbed dose from beta and gamma radiation.

# **DECONTAMINATION**

There are a number of ways that hazardous waste site workers and emergency responders may become contaminated such as:

- Contact with gases, mists, vapors or particulates in the air.
- Splash from materials while sampling or working.
- Walking, sitting, touching, or handling contaminated liquids, soils, or equipment.

Protective clothing and respirators help prevent the worker from coming in contact with contaminants, while proper work practices help to reduce the contact and spread of contaminants. Care must be taken to prevent the transfer of contaminants to clean areas and to prevent exposing unprotected personnel. In order to prevent such events, contamination reduction and decontamination procedures must be developed and implemented as part of the health and safety plan before any activity begins. These procedures should include: the number of decontamination stations, equipment needed, methods to minimize overall contamination, and disposal methods.

Decontamination has four primary goals:

- To protect workers from hazardous substances that may contaminate and eventually permeate the protective clothing, respiratory equipment, tools, and vehicles used on-site.
- To protect all site personnel by reducing/minimizing the transfer of contaminants to clean areas.
- To prevent the mixing/contact of incompatible substances.
- To protect the community from the migration of contaminants off-site.

## **Initial Planning**

Some considerations must be given when developing a decontamination plan:

- Stress work practices that minimize contact with contaminants (e.g., do not work in puddles, do not set equipment down in obvious contamination).
- Use remote sampling, handling, and container opening techniques.
- Protect monitoring and sampling instruments by bagging (making openings in the bags for sample ports, probes, sensors, etc.)
- Wear disposable outer garments and use disposable equipment where appropriate.



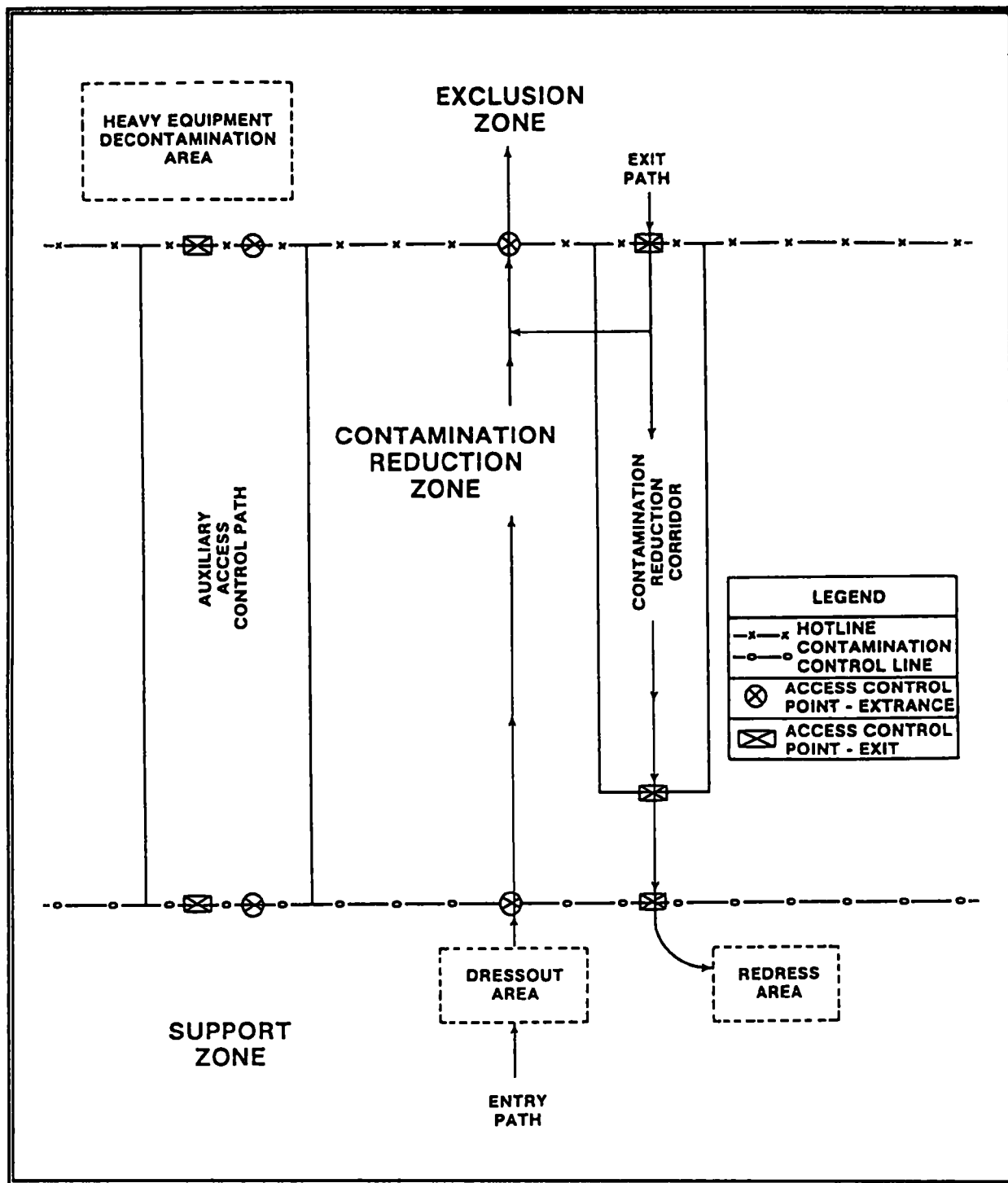
- Cover equipment and tools with strippable coating which can be removed during decontamination.
- Encase the source of contaminants (e.g., plastic or overpacks).
- Use protective liner when setting equipment on the ground.

### **Zone Layout**

An area within the **Contamination Reduction Zone**, or CRZ, (**Figure 1**) is designated as the **Contamination Reduction Corridor**, or CRC. The CRC controls access into and out of the **Exclusion Zone** and confines personnel decontamination activities to a limited area. The size of the corridor depends on the number of stations in the decontamination procedure, the overall dimensions of work control zones, and the amount of space available. A corridor of 75 × 15 feet should be adequate for full decontamination. Whenever possible, it should be a straight path.

The CRC boundaries should be conspicuously marked with entry and exit restricted. The far end is the **hotline**, the boundary between the **Exclusion Zone** and the **Contamination Reduction Zone**. Personnel exiting the **Exclusion Zone** must go through the CRC. Anyone in the CRC should be wearing the level of protection designated for the decontamination crew. Another corridor may be required for the entrance and exit of heavy equipment needing decontamination. Within the CRC, distinct areas are set aside for the decontamination of personnel, portable field equipment, removed clothing, etc.,. These areas should be marked and restricted to those personnel wearing the appropriate level of protection. All activities within the corridor are confined to decontamination.

Protective clothing, respirators, monitoring equipment, sampling supplies, and other equipment are all maintained outside the CRC. Personnel don their protective equipment away from the CRC and enter the **Exclusion Zone** through a separate access control point at the hotline.



**FIGURE 1**  
**CONTAMINATION REDUCTION ZONE LAYOUT**

Source: *Standard Operating Safety Guides*. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Emergency Response Division, Environmental Response Team (July 1988).

## **Decontamination Worker Protection**

Generally, decontamination workers will either don the same level of protection that is worn by workers in the Exclusion Zone or downgrade one level of protection. In any case, the level of protection for decontamination workers is relative to the site in question and the worker's position in the decontamination line.

The level of protection worn by decontamination workers is determined by:

- Expected or visible contamination on workers.
- Type(s) of contaminant(s) and associated respiratory and skin hazards.
- Total vapor/gas concentrations in the CRC.
- Particulates and specific inorganic or organic vapors in the CRC.
- Results of swipe tests.
- The presence (or suspected presence) of highly toxic or skin-destructive materials.

## **Effectiveness of Decontamination**

There is no method of determining immediately how effective decontamination is in removing contaminants. Discolorations, stains, corrosion, and residues on objects may indicate that contaminants have not been removed. However, observable effects only indicate surface contamination and not permeation (absorption) into clothing. Many contaminants are not easily observed.

One method for determining the effectiveness of surface decontamination is **swipe testing**. Cloth or paper patches (swipes) are wiped over predetermined surfaces of the suspect contaminated clothing and later analyzed in a laboratory. Both the inner and outer surfaces of protective clothing should be swipe tested. Positive results for both sets of swipes would indicate that surface contamination has not been removed and substances have penetrated or permeated the garment. Swipe tests can also be performed on skin or inside clothing. Another way to test the effectiveness of decontamination procedures is to analyze for contaminants left in the cleaning solutions. Elevated levels of contaminants in the final rinse solution may suggest that additional cleaning and rinsing are needed. As noted, laboratory analysis is required for the aforementioned test methods. As can be seen, lab testing provides after-the-fact information. However, along with visual observations, results of these tests can help in ascertaining the effectiveness of decontamination. In addition, the decision-making chart can aid in evaluating the health and safety aspects of decontamination methods (Figure 2).

## **Decontamination Solutions**

Protective equipment, sampling tools, and other equipment are usually decontaminated by scrubbing with detergent water using a soft-bristle brush, followed by rinsing with copious amounts of water.

While this process may not be fully effective in removing some contaminants (in some cases, the contaminants may react with water), it is a relatively safe option compared to the use of other decontamination solutions. The contaminant must be identified before a decontamination chemical

is used, and reactions of such a chemical with unidentified substances or mixtures and personal protective equipment could be especially troublesome. A decontamination solution must always be selected in consultation with an experienced chemist and an industrial hygienist.

Although it is recommended that water be used for decontamination as much as possible, **Table 1** provides a general guide toward developing decontamination solutions.

### **Disposal of Contaminated Materials**

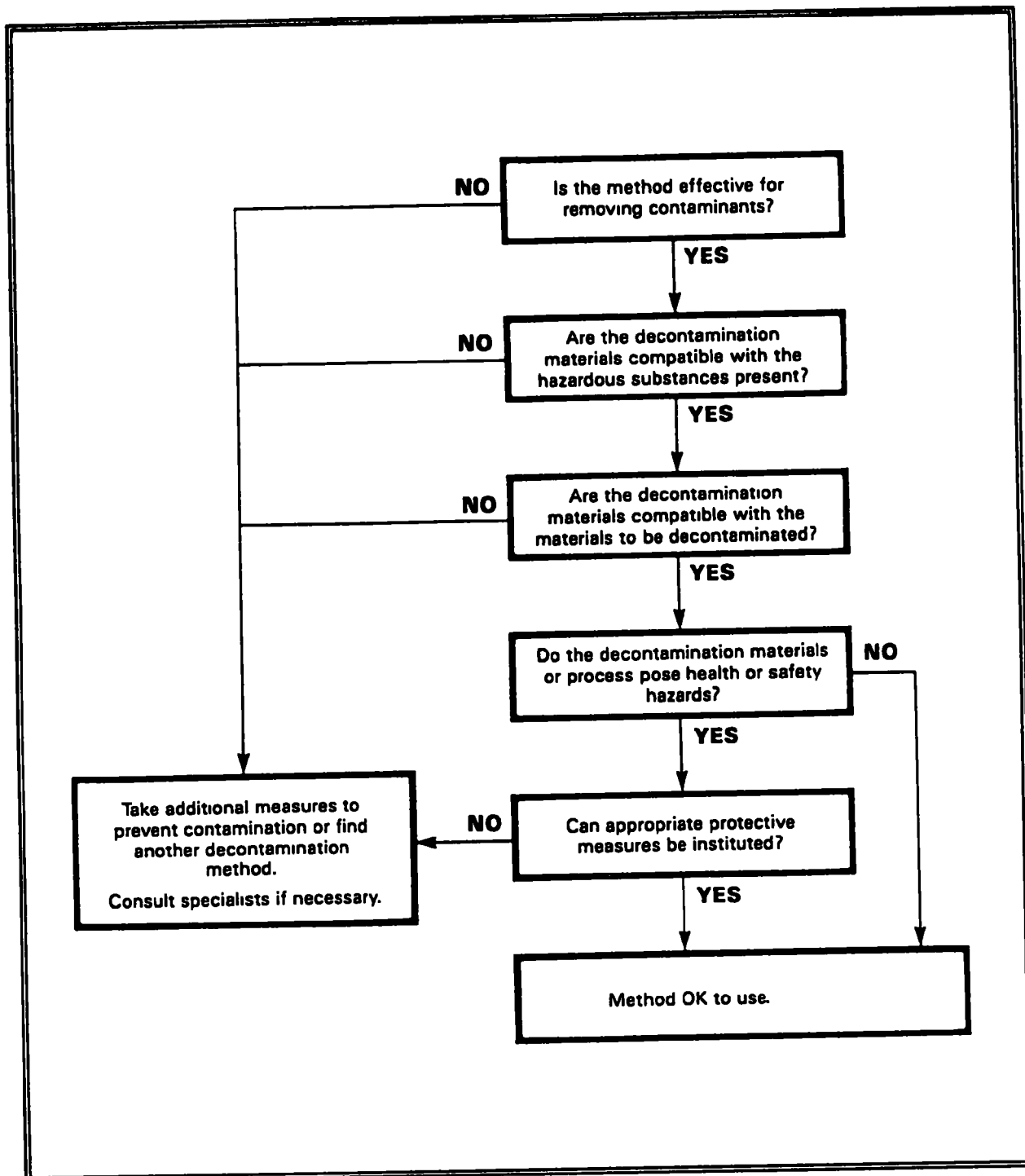
All materials and equipment used for decontamination must be disposed of properly. Clothing, tools, buckets, brushes, and all other equipment that are contaminated must be secured in drums or other containers and labeled. Clothing not completely contaminated on the site should be secured in plastic bags pending further decontamination and/or disposal.

Contaminated wash and rinse solutions can be kept temporarily in a step-in container (for example, a child's wading pool) or in a plastic-lined trench about 4 inches deep. Such solutions are ultimately transferred to labeled drums and disposed of with other substances on the site. Generally, hazardous waste or industrial haulers are called upon to handle the ultimate disposal of decontamination equipment and drums.

**Figures 3–5**, describe basic decontamination procedures for workers wearing levels A, B, or C protection. Bear in mind that these decontamination lines are designated by theory for a worse-case situation. Field modifications will and can occur as necessary.

### **Medical Emergency Decontamination**

When outlining decontamination procedures in the health and safety plan, provisions must be made for decontaminating personnel with medical problems and injuries. There is the possibility that decontamination may aggravate a health problem or cause more serious problems. For example, life-saving care should be instituted immediately without considering decontamination. The outside garments can be removed (depending on the weather) if this does not cause delays, interfere with treatment, or aggravate the problem. Respiratory masks and backpack assemblies must always be removed. Fully encapsulating suits or chemical-resistant clothing can be cut away. If the outer contaminated garments cannot be safely removed, the individual should be wrapped in plastic, rubber, or blankets to help prevent contaminating medical personnel and/or the inside of ambulances. Outside garments are then removed at the medical facility. Whenever possible, response personnel should accompany contaminated victims to the medical facility to advise on matters involving decontamination. No attempt should be made to wash or rinse the victim unless it is known that the victim has been contaminated with an extremely toxic or corrosive material that could also cause severe injury or loss of life. For minor medical problems or injuries, the normal decontamination procedures should be followed.



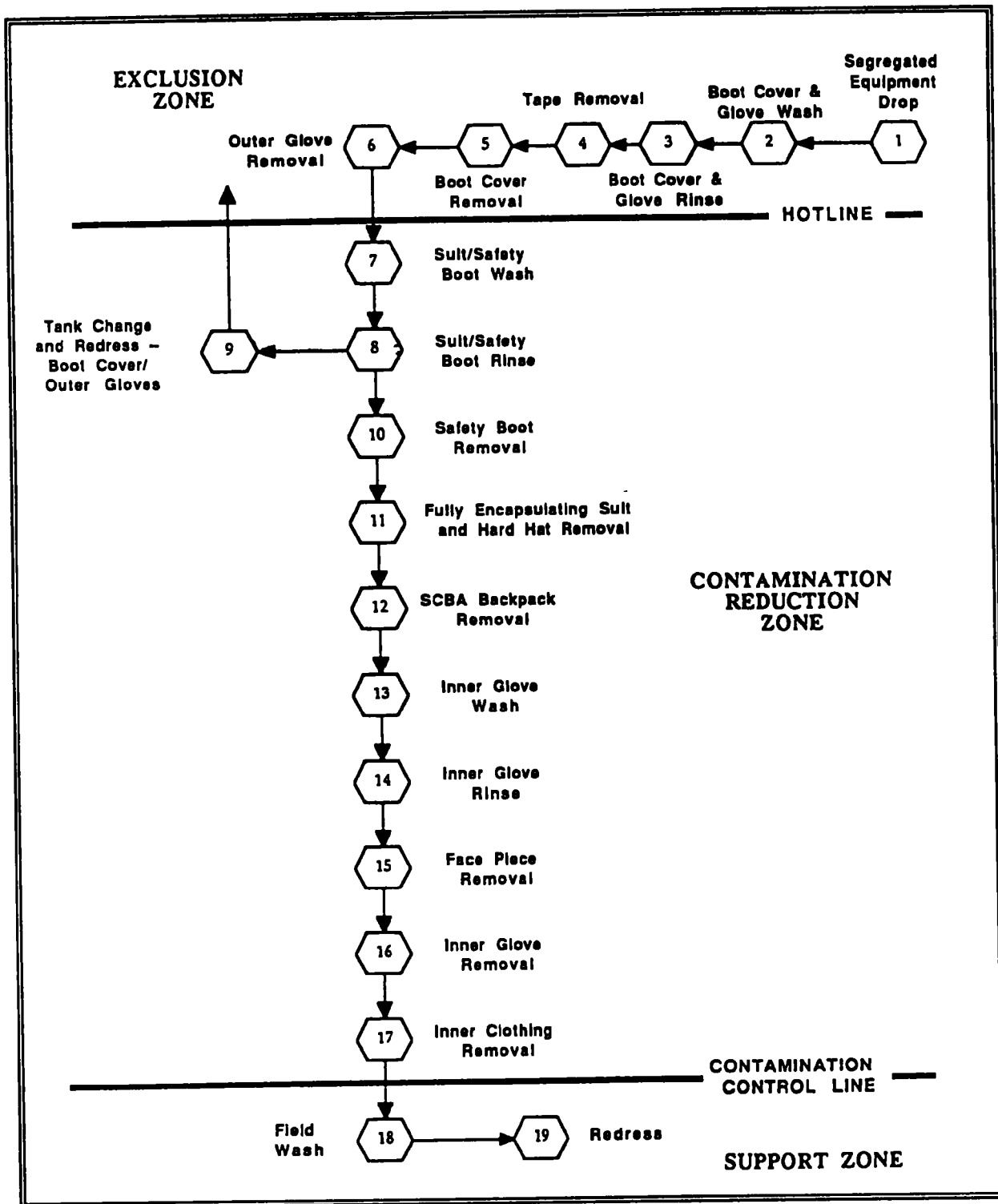
**FIGURE 2**  
**DECISION AID FOR EVALUATING HEALTH AND SAFETY**  
**ASPECTS OF DECONTAMINATION METHODS**

*Source: NIOSH/OSHA/USCG/EPA Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities (1985).*

<b>TABLE 1</b> <b>GENERAL GUIDE TO SOLUBILITY OF CONTAMINANTS</b> <b>IN FOUR SOLVENT TYPES</b>	
<b>Solvent</b>	<b>Soluble Contaminants</b>
<b>Water</b>	Low-chain hydrocarbons
	Inorganic compounds
	Salts
	Some organic acids & other polar compounds
<b>Dilute Acids</b>	Basic (caustic) compounds
	Amines
	Hydrazines
<b>Dilute Bases</b>	Acidic compounds
Detergent	Phenols
Soap	Thiols
	Some nitro and sulfonic compounds
<b>Organic Solvents<sup>a</sup></b>	Nonpolar compounds (e.g., some organic compounds)
Alcohols	
Ethers	
Ketones	
Aromatics	
Straight-chain alkanes (e.g., hexane)	
Common petroleum products (e.g., fuel oil, kerosene)	

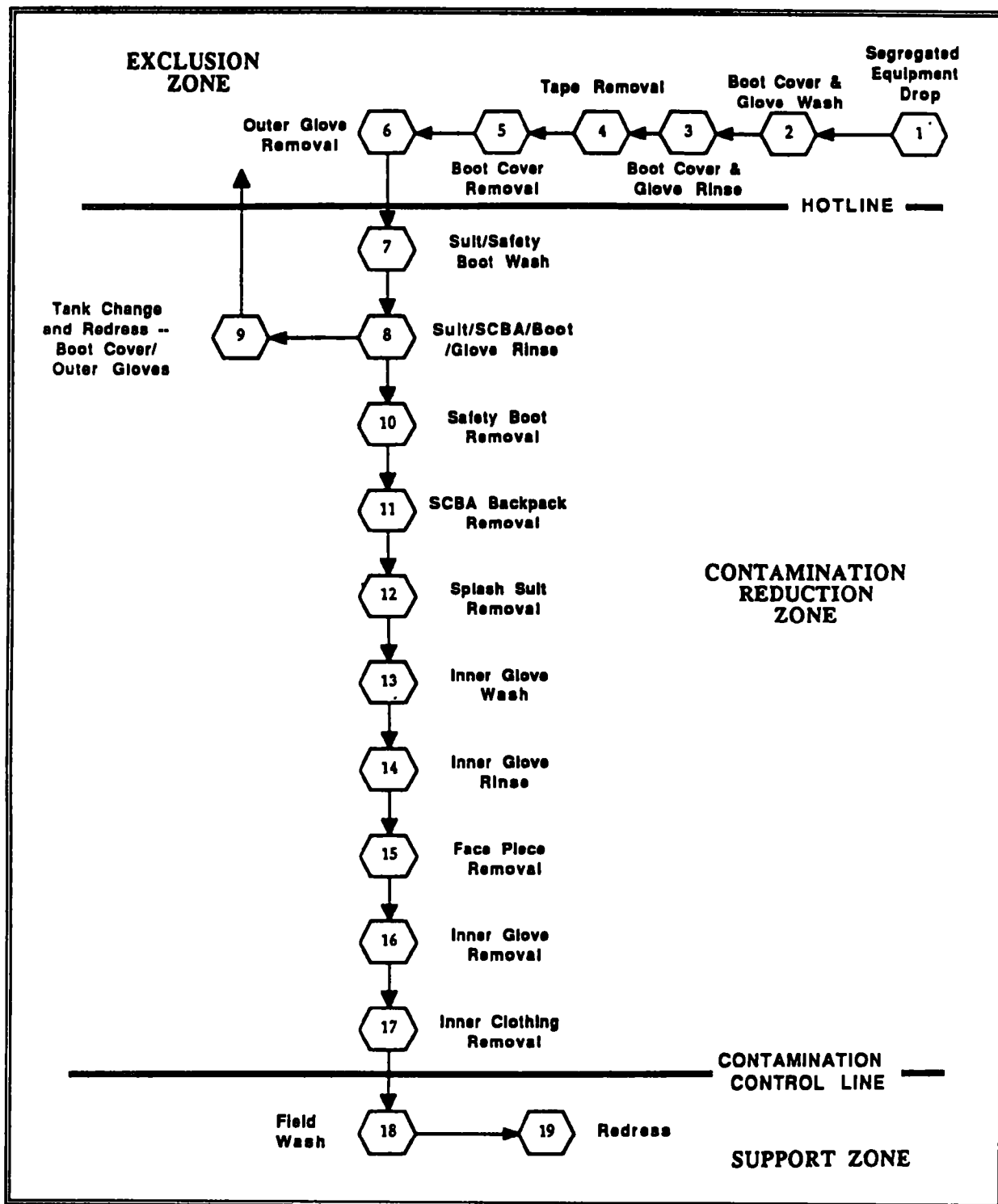
<sup>a</sup> **WARNING:** Some organic solvents can permeate and/or degrade the protective clothing.

*Source: NIOSH/OSHA/USCG/EPA Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities (1985).*



**FIGURE 3  
DECONTAMINATION LAYOUT: LEVEL A PROTECTION**

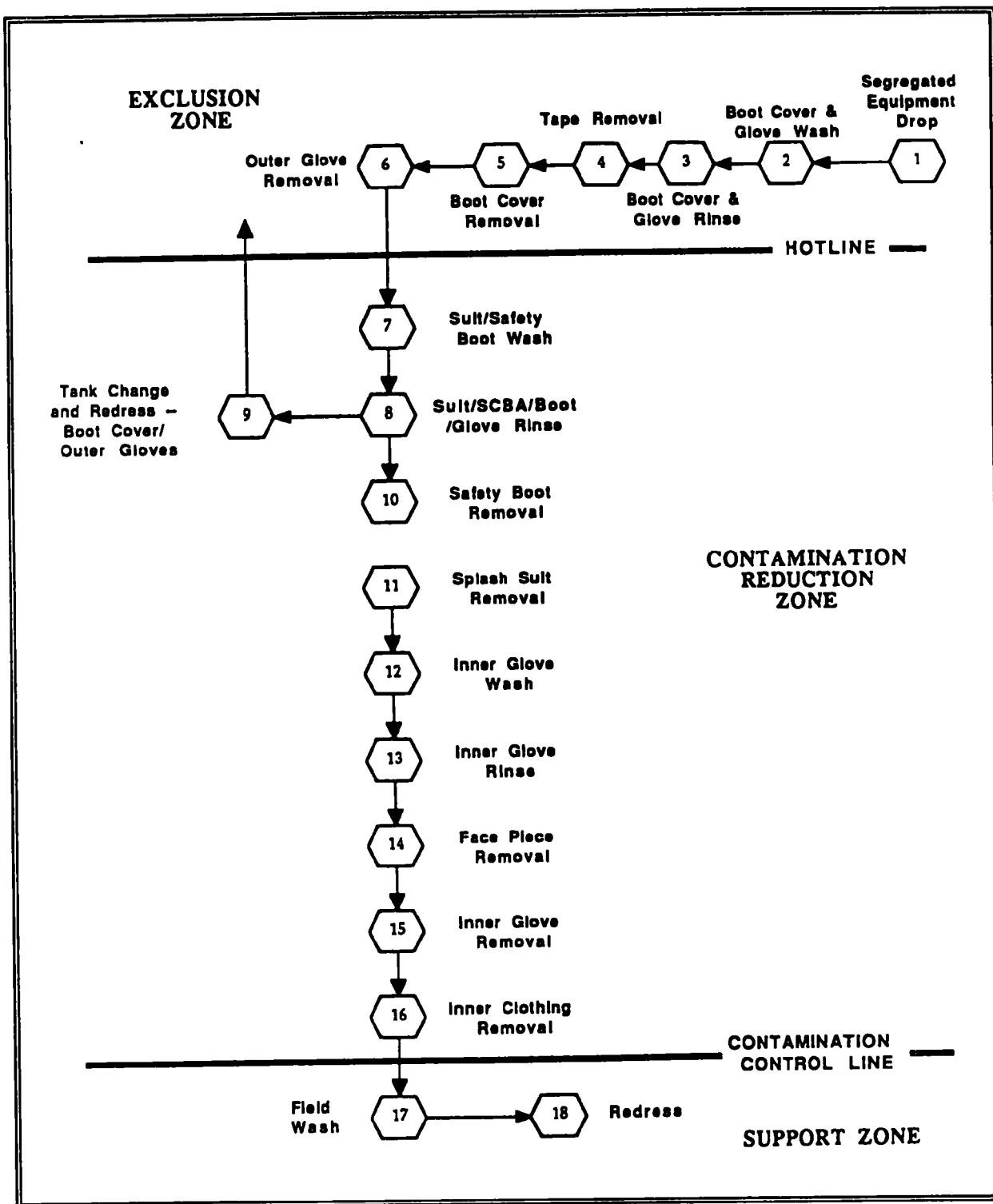
Source: *Standard Operating Safety Guides*. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Emergency Response Division, Environmental Response Team (June 1992).



**FIGURE 4  
DECONTAMINATION LAYOUT: LEVEL B PROTECTION**

*Source: Standard Operating Safety Guides. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Emergency Response Division, Environmental Response Team (June 1992).*





**FIGURE 5**  
**DECONTAMINATION LAYOUT: LEVEL C PROTECTION**

*Source: Standard Operating Safety Guides. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Emergency Response Division, Environmental Response Team (June 1992).*

## **RESPONSE ORGANIZATION**

The number of people needed to respond to an incident involving the release or potential release of hazardous substances can vary greatly. To successfully accomplish the primary response goal, of protecting public health and the environment, requires the coordinated, cooperative effort of these people.

Every incident is unique. The hazardous materials involved, their impact on public health and the environment, and the activities required to remedy the event are incident specific. Each incident tends to establish its own operational and organizational requirements. However, common to all incidents are planning, organizational considerations, personnel, and the implementation of operations.

### **Hazardous Materials Contingency Plans**

Many of the problems encountered by responders can be reduced if a hazardous materials contingency plan exists. When an incident (involving chemicals or other kinds of man-made or natural disasters) occurs, local government reacts. An organization, comprised of all who are available, will naturally evolve. Its capability, however, to efficiently manage the situation may be severely restricted. Expertise, equipment, and funds needed to prevent or reduce the impact of the event may not be readily available. Necessary actions to ameliorate the situation may be delayed.

A more effective response occurs when a contingency plan exists. In general, contingency plans anticipate the myriad of problems faced by responders and through the planning process solves them. A response organization is established, resources are identified, and prior arrangements made to obtain assistance. A good plan minimizes the delays frequently encountered in a no-plan response, thus permitting more prompt remedial actions. It also reduces the risk to the health of both the responders and public by establishing, in advance, procedures for protecting their safety.

A contingency plan can lessen many of the problems encountered in a response. However, even a good plan cannot anticipate and address all the circumstances created by a release of chemicals. Even with a plan, modifications may be needed in the response organization to accommodate unforeseen situations. A well-written plan acknowledges that adaptations are necessary and provides the framework for doing so without impeding the progress of implementation.

Without a plan the ability to effectively manage the incident is diminished. Time is wasted attempting to define the problem, get organized, locate resources, and implement response activities. These organizational difficulties can cause delays in the response actions, thus creating additional problems that prompt action would have avoided. For hazardous materials contingency plans to be effective they must be: well-written, agreed upon by all involved, current, flexible, reviewed and modified and tested.

## **Organization**

The responders needed for an incident may range from a few to hundreds. They represent many government agencies and private industries. Functions and responsibilities of each responders group differ. These diverse elements must be organized into a cohesive unit capable of managing and directing response activities toward a successful conclusion (Figure 1).

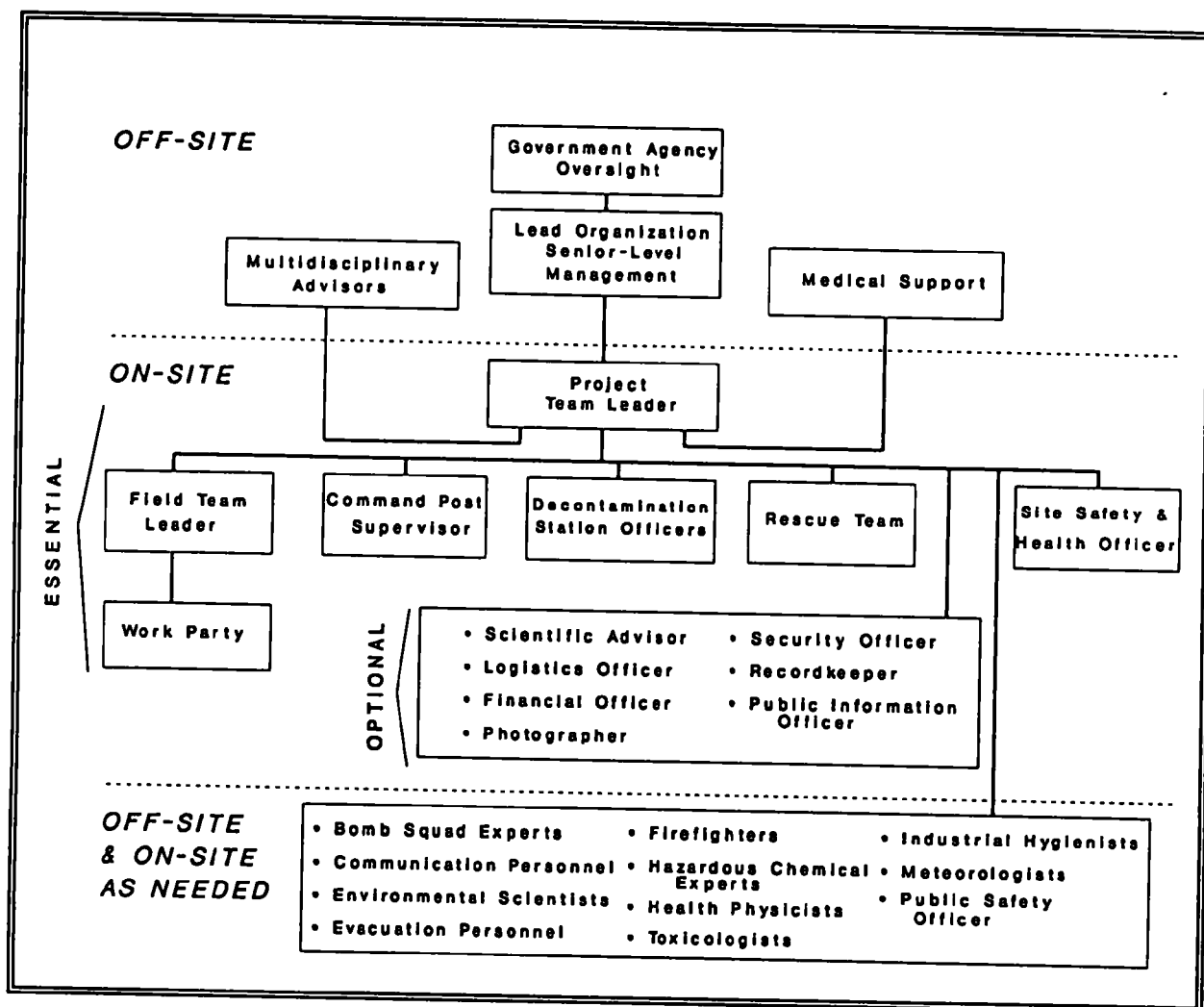
Relatively few well-trained response teams exist. Most response teams are associated with metropolitan fire services or with industry, but are small and may have limited capability or responsibility. In an incident of any magnitude, where more personnel and resources are needed, a team is assembled from the various responding government agencies or private contractors. An organization is then established according to an existing contingency plan. Without a plan, an ad hoc organization is created to manage that specific incident.

The contingency plan or ad hoc organization established, to function effectively must:

- Designate a leader
- Determine objectives
- Establish authority
- Develop policies and procedures
- Assign responsibilities
- Plan and direct operations
- Establish internal communications
- Manage resources (money, equipment, and personnel)
- Establish external communications

In any incident involving more than a few responders, it is generally necessary to develop an organizational chart. This chart depicts the organization's structure. It links personnel and functions, defines lines of responsibility, and establishes internal communication channels. To a large degree, the form and complexity of the organizational chart depends on the magnitude of the incident, the activities needed, the number of people and agencies involved, and the project leader's mode of operation. The key requirements are:

- Establish a chain-of-command
- Assign responsibilities and functions
- Develop personnel requirements
- Establish internal communications



**FIGURE 1  
EXAMPLE OF A POSSIBLE RESPONSE ORGANIZATION  
FLOWCHART**

### Personnel

To manage and direct the various operations, personnel or responding agencies must be assigned the responsibility for certain activities. The positions, functions, and responsibilities that follow represent personnel requirements for a major response effort. They should be tailored to fit a particular chemical incident. A person must not be assigned responsibility for more than one function.

The **Project Leader/On-Scene Coordinator/Incident Manager** (required under 29 CFR 1910.120) has clearly defined authority and responsibility to manage and direct all response personnel and operations while ensuring protection of the health and safety of site personnel and the public.

The **Safety Officer** (required under 29 CFR 1910.120) advises the project leader on all matters related to the health and safety of those involved in site operations. This individual establishes and

directs the safety program and coordinates these activities with the scientific advisor. The Safety Officer can halt operations if unsafe conditions exist.

The **Scientific Advisor** directs, coordinates, and prioritizes scientific studies, sample collection, field monitoring, analysis of samples, and the interpretation of results. The science advisor may also recommend remedial plans and/or actions and may provide technical guidance to the project leader in those areas.

The **Field Team Leader** directs activities related to cleanup contractors and others involved in emergency and long term restoration measures.

The **Public Information Officer (PIO)** disseminates information to news media and the public concerning site activities. This individual establishes internal communications to keep all team members informed. All media questions are referred to the PIO.

The **Security Officer** manages general site security and controls site access. The security officer provides a liaison with local law enforcement and fire departments.

The **Recordkeeper** documents and maintains the official records of site activities. The recordkeeper assures that the written record is sufficiently clear, detailed and accurate for presentations in courts of law.

The **Field/Operations Officer** directs the activities of team leaders. This individual coordinates these operations with the scientific advisor and safety officer.

The **Team Leaders** manage specific assigned tasks such as: entry team(s), decontamination, sampling teams, monitoring, equipment, photography, and communications.

The **Financial Officer** provides financial and contractual support.

The **Logistics Officer** provides necessary equipment and other resources.

The **Medical Officer** provides medical support and acts as liaison with the medical community.

### **Implementing Response Operations**

The release or potential release of hazardous materials requires operations (or activities) that will eventually restore the situation to normal, or as near as possible to pre-incident conditions. Although each incident establishes its own operational requirements, there is a general sequence of events for all responses. Planning and implementing a response involves, as a minimum, the following:

- **Organize:** Select key personnel. Establish an organization. Assign responsibilities. Modify operations as needed. Institute emergency actions.
- **Evaluate situation:** Based on available information, make preliminary hazard evaluation.

- **Develop plan of action:** Develop preliminary operations plan for gathering and disseminating information; taking immediate counter measures; and implementing emergency and remedial actions. Reevaluate the situation as supplemental information becomes available.
  - Make preliminary off-site survey. Collect additional data to evaluate situation (monitor using direct-reading instruments, sample, make visual observations). Establish emergency actions to protect public health and environment. Identify requirements for on-site reconnaissance. Determine level of protection, if necessary, for off-site personnel. Establish boundaries for contaminated areas.
  - Make initial on-site reconnaissance. Collect data (monitor, sample, make visual observations) to determine or verify hazardous conditions and make an overall assessment of the incident. Modify initial entry safety procedures as more data is obtained. Determine levels of protection for initial entry team(s) and subsequent operations. Plan and implement site control and decontamination procedures.
- **Modify original plan of action:** Modify or adapt original plan based on additional information obtained during initial entries. Revise immediate emergency measures. Plan long-term actions including:
  - Additional monitoring and sampling
  - Resource requirements
  - Site safety plan
  - Cleanup and restoration measures
  - Legal implications and litigation
  - Site activity documentation
- **Complete planned cleanup and restoration**

### **Personnel and Site Reconnaissance**

The greatest risk to the safety of responders occurs close to the release. The health and safety of those responders is of paramount importance. Therefore, projected on-site operations must be carefully thought out, well-planned, and properly executed. To accomplish this, a site reconnaissance must be completed prior to entering the hazardous substance release area. During this reconnaissance, it is necessary to collect as much information as possible in the time available, on the types and degrees of hazards, as well as risks that may exist. This information can be obtained from shipping manifests, transportation placards, existing records, container labels, sampling results, monitoring data, or off-site studies.

**The Project Leader, after review of intelligence gained from site reconnaissance, makes decisions on the matters that follow:**

- **Off-site measurements needed**
- **The need to go on-site**
- **Equipment available versus equipment needed**
- **Type of data needed to evaluate hazards such as: organic vapors/gases, inorganic vapors/gases, particulates, oxygen concentration, radiation,**
- **Samples needed for laboratory analysis**
- **Levels of protection needed by entry team(s)**
- **Number and size of entry team(s) needed**
- **Briefing/Debriefing of response team**
- **Site control procedures which include: designation of work zones, access control, and physical barriers**
- **Decontamination procedures required**
- **Medical backup resources available versus needed**
- **Emergency actions/countermeasures to be taken**
- **Priority for collecting data and samples**

**To effectively prevent or reduce the impact of a hazardous materials incident on people or the environment, the personnel responding must be organized into a structured operating unit - a response organization. For the response organization to be effective it must be developed in advance, be tested, and be an integral part of a Hazardous Materials Contingency Plan. To a large degree, the success of the response is dependent upon how well the response personnel are organized. The more organized, the more rapidly the organization can begin to function. A response organization, once established (whether specified in a contingency plan or as an "ad hoc" incident specific-group) must be flexible enough to adapt to the ever changing conditions created as the incident progresses.**

## **EXAMPLE LIST OF RESPONSE EQUIPMENT**

### **Communication Equipment**

Hand-held radios

### **Protective Clothing**

Fully encapsulating suit  
Chemical-resistant splash suit  
Chemical-resistant safety boots  
Work gloves  
Rain suit  
Windbreaker  
Medium-weight jacket  
Coveralls (work)  
Coveralls (Nomex)  
Uniform pants and shirt  
Socks (regular)  
Socks (heavy)  
Underclothes  
Earplugs  
Clipboard  
Hardhat (w/faceshield)  
Hardhat for cold weather  
Safety goggles  
Safety glasses

### **Field Equipment**

Combustible gas indicator  
HNU photoionizer  
Organic vapor analyzer (OVA)  
Oxygen meters  
Colorimetric indicator pump/tubes  
Specific gas detectors  
Radiation detector  
Metal detector  
Pressure-demand SCBAs  
Extra air cylinders  
Full-face APR (w/canisters)  
Photographic equipment  
Film badges  
Dosimeters  
Organic vapor badges  
Hand tool kit (Schedule A)  
First Aid kit (Schedule B)  
Reference materials (Schedule C)  
Field support kit (Schedule D)  
Soil sample set (Schedule E)  
Water sample set (Schedule F)  
Air sample set (Schedule G)  
Emergency oxygen inhaler  
Portable wash unit  
Fire extinguisher  
Portable eyewash

## **SCHEDULE A: HAND TOOL KIT**

Wood mallet	Rubber mallet	Ballpeen hammer
Claw hammer	Hand hammer (nonsparking)	Hacksaw
Lumberjack knife	Duckbill snip	Rod and bolt cutter
Cutting pliers	Lineman's pliers	Slipjoint pliers
Plier wrench	Pipe wrench	Screwdrivers
Stapler/staples	Pressure gauge	Measure tape
Reel tape	Electrical tape	Strapping tape
Duct tape		



### **SCHEDULE B: FIRST AID KIT**

First Aid Guide	Scissors	Aspirin
Forceps	Pain aid	Tweezers
Cold tablets	Cotton swabs	Lozenges
Alcohol swabs	Antiseptic swabs	Antacid
Antiseptic spray	Burn spray	Syrup of ipecac
Spray-on bandage	Vaseline	Eye drops
Antibiotic ointment	Eye/skin neutralizer	Insect repellent
Eye wash	Sting relief	Adhesive tape
Chigger/tick remover	Cohesive tape	Poison ivy treatment
Snake bite kit	Band-Aids	Ammonia inhalants
Blood clotter	Finger tip bandages	Tourniquet
Knuckle bandages	Ice packs	Elastic strip bandages
Triangle bandages	Salt tablets	Gauze bandages
Finger splint	Blanket	Stretcher

### **SCHEDULE C: REFERENCE MATERIALS**

NFPA Guide on Hazardous Materials  
CHRIS Condensed Guide to Chemical Hazards  
Dangerous Properties of Industrial Materials (Sax)  
NIOSH Pocket Guide to Chemical Hazards  
TLVs for Chemical Substances & Physical Agents in the Work Environment

### **SCHEDULE D: FIELD SUPPORT KIT**

Binoculars (2, 7 × 35-mm-wide angle)	Rangefinder (2)
Spotting scope	Stereoscopes
Compass (2)	Hand level (2)
Hand calculator (2)	Cassette recorder

### **SCHEDULE E: SOIL SAMPLING SET**

Soil auger	Auger extensions
Power head (electric)	Soil sample tubes
Replacement tips for tube samplers	Wet, heavy duty tips
Scoops for bottom sediments	Labels
Stainless steel pipe section	Logbooks for soil profiles
Electrical resistivity apparatus	Stainless steel spoons
Post hole digger	Pick-ax
Shovel	Stainless steel pans

### **SCHEDULE F: WATER SAMPLING SET**

Weighted bottle sampler  
Glass and polyethylene containers  
Suction devices (hand pumps)  
Cased thermometers/thermistors  
Dissolved oxygen meter

Pond sampler  
Scoops and dippers  
Water level indicator  
Teflon® bailer  
Conductivity meter

### **SCHEDULE G: AIR SAMPLING SET**

Colorimetric indicator tubes  
Impinger tubes  
Particulate samplers  
Wind speed indicator  
Barometric pressure indicator

Hi-vol sampler  
Carbon adsorption tubes  
Wind direction indicator  
Temperature indicator



## **APPENDIX A**

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### **1910.120—Hazardous Waste Operations and Emergency Response**

## STANDARDS AND INTERPRETATIONS

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## 1910.120—HAZARDOUS WASTE OPERATIONS AND EMERGENCY RESPONSE

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### (a) Scope, application, and definitions.

(1) **Scope.** This section covers the following operations, unless the employer can demonstrate that the operation does not involve employee exposure or the reasonable possibility for employee exposure to safety or health hazards:

(i) Clean-up operations required by a governmental body, whether Federal, state, local or other involving hazardous substances that are conducted at uncontrolled hazardous waste sites (including, but not limited to, the EPA's National Priority Site List (NPL), state priority site lists, sites recommended for the EPA NPL, and initial investigations of government identified sites which are conducted before the presence or absence of hazardous substances has been ascertained);

(ii) Corrective actions involving cleanup operations at sites covered by the Resource Conservation and Recovery Act of 1976 (RCRA) as amended (42 U.S.C. 6901 *et seq.*);

(iii) Voluntary clean-up operations at sites recognized by Federal, state, local or other governmental bodies as uncontrolled hazardous waste sites;

(iv) Operations involving hazardous wastes that are conducted at treatment, storage, and disposal (TSD) facilities regulated by 40 CFR Parts 264 and 265 pursuant to RCRA; or by agencies under agreement with U.S.E.P.A. to implement RCRA regulations; and

(v) Emergency response operations for releases of, or substantial threats of releases of, hazardous substances without regard to the location of the hazard.

### (2) Application.

(i) All requirements of Part 1910 and Part 1926 of Title 29 of the Code of Federal Regulations apply pursuant to their terms to hazardous waste and emergency response operations whether covered by this section or

not. If there is a conflict or overlap, the provision more protective of employee safety and health shall apply without regard to 29 CFR 1910.5(c)(1).

(ii) Hazardous substance clean-up operations within the scope of paragraphs (a)(1)(i) through (a)(1)(iii) of this section must comply with all paragraphs of this section except paragraphs (p) and (q).

(iii) Operations within the scope of paragraph (a)(1)(iv) of this section must comply only with the requirements of paragraph (p) of this section.

**Exceptions:** For large quantity generators of hazardous waste who store those wastes less than 90 days and for small quantity generators of hazardous wastes, who have emergency response teams that respond to releases of, or substantial threats of releases of, hazardous substances, for their RCRA workplaces only paragraph (p)(8) of this section is applicable. Such generators of hazardous wastes who do not have emergency response teams that respond to releases of, or substantial threats of releases of, hazardous substances are exempt from the requirements of this section.

(iv) Emergency response operations for releases of, or substantial threats of releases of, hazardous substances which are not covered by paragraphs (a)(1)(i) through (a)(1)(iv) of this section must only comply with the requirements of paragraph (q) of this section.

(3) **Definitions.** "Buddy system" means a system of organizing employees into work groups in such a manner that each employee of the work group is designated to be observed by at least one other employee in the work group. The purpose of the buddy system is to provide rapid assistance to employees in the event of an emergency.

"Clean-up operation" means an operation where hazardous substances are removed, con-

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tained, incinerated, neutralized, stabilized, cleared-up, or in any other manner processed or handled with the ultimate goal of making the site safer for people or the environment.

"Decontamination" means the removal of hazardous substances from employees and their equipment to the extent necessary to preclude the occurrence of foreseeable adverse health affects.

"Emergency response" or "responding to emergencies" means a response effort by employees from outside the immediate release area or by other designated responders (i.e., mutual-aid groups, local fire departments, etc.) to an occurrence which results or is likely to result, in an uncontrolled release of a hazardous substance. Responses to incidental releases of hazardous substances where the substance can be absorbed, neutralized, or otherwise controlled at the time of release by employees in the immediate release area, or by maintenance personnel are not considered to be emergency responses within the scope of this standard. Responses to releases of hazardous substances where there is no potential safety or health hazard (i.e., fire, explosion, or chemical exposure) are not considered to be emergency responses.

"Facility" means (A) any building, structure, installation, equipment, pipe or pipeline (including any pipe into a sewer or publicly owned treatment works), well, pit, pond, lagoon, impoundment, ditch, storage container, motor vehicle, rolling stock, or aircraft, or (B) any site or area where a hazardous substance has been deposited, stored, disposed of, or placed, or otherwise come to be located; but does not include any consumer product in consumer use or any water-borne vessel.

(3) "Hazardous materials response (HAZMAT) team" means an organized group of employees, designated by the employer, who are expected to perform work to handle and control actual or potential leaks or spills of hazardous substances requiring possible close approach to the substance. The team members perform responses to releases or potential releases of hazardous substances for the purpose of control or stabilization of the incident. A HAZMAT team is not a fire brigade nor is a typical fire brigade a HAZMAT team. A HAZMAT team, however, may be a separate component of a fire brigade or fire department.

"Hazardous substance" means any substance designated or listed under paragraphs (A) through (D) of this definition, exposure to which results or may result in adverse affects on the health or safety of employees:

(a) Any substance defined under section 101(14) of CERCLA;

(b) Any biological agent and other disease-causing agent as defined in section 101(33) of CERCLA;

(c) Any substance listed by the U.S. Department of Transportation as hazardous materials under 49 CFR 172.101 and appendices; and

(d) Hazardous waste as herein defined.

"Hazardous waste" means

(a) A waste or combination of wastes as defined in 40 CFR 261.3, or

(b) Those substances defined as hazardous wastes in 49 CFR 171.8.

"Hazardous waste operation" means any operation conducted within the scope of this standard.

"Hazardous waste site" or "Site" means any facility or location within the scope of this standard at which hazardous waste operations take place.

"Health hazard" means a chemical, mixture of chemicals or a pathogen for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed employees. The term "health hazard" includes chemicals which are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents which act on the hematopoietic system, and agents which damage the lungs, skin, eyes, or mucous membranes. It also includes stress due to temperature extremes. Further definition of the terms used above can be found in Appendix A to 29 CFR 1910.1200.

"IDLH" or "Immediately dangerous to life or health" means an atmospheric concentration of any toxic, corrosive or asphyxiant substance that poses an immediate threat to life or would cause irrever-

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sible or delayed adverse health effects or would interfere with an individual's ability to escape from a dangerous atmosphere.

"Oxygen deficiency" means that concentration of oxygen by volume below which atmosphere supplying respiratory protection must be provided. It exists in atmospheres where the percentage of oxygen by volume is less than 19.5 percent oxygen.

"Permissible exposure limit" means the exposure, inhalation or dermal permissible exposure limit specified in 29 CFR Part 1910, Subparts G and Z.

"Published exposure level" means the exposure limits published in "NIOSH Recommendations for Occupational Health Standards" dated 1986 incorporated by reference, or 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.

"Post emergency response" means that portion of an emergency response performed after the immediate threat of a release has been stabilized or eliminated and clean-up of the site has begun. If post emergency response is performed by an employer's own employees who were part of the initial emergency response, it is considered to be part of the initial response and not post emergency response. However, if a group of an employer's own employees, separate from the group providing initial response, performs the clean-up operation, then the separate group of employees would be considered to be performing post-emergency response and subject to paragraph (g)(11) of this section.

"Qualified person" means a person with specific training, knowledge and experience in the area for which the person has the responsibility and the authority to control.

"Site safety and health supervisor (or official)" means the individual located on a hazardous waste site who is responsible to the employer and has the authority and knowledge necessary to implement the site safety and health plan and verify compliance with applicable safety and health requirements.

"Small quantity generator" means a generator of hazardous wastes who in any calendar month generates no more than 1,000 kilograms (2,205 pounds) of hazardous waste in that month.

"Uncontrolled hazardous waste site" means an area where an accumulation of hazardous waste creates a threat to the health and safety of individuals or the environment or both. Some sites are found on public lands, such as those created by former municipal, county or state landfills where illegal or poorly managed waste disposal has taken place. Other sites are found on private property, often belonging to generators or former generators of hazardous waste. Examples of such sites include, but are not limited to, surface impoundments, landfills, dumps, and tank or drum farms. Normal operations at TSD sites are not covered by this definition.

**(b) Safety and health program.**

**Note to (b):** Safety and health programs developed and implemented to meet other Federal, state, or local regulations are considered acceptable in meeting this requirement if they cover or are modified to cover the topics required in this paragraph. An additional or separate safety and health program is not required by this paragraph.

**(1) General.**

(i) Employers shall develop and implement a written safety and health program for their employees involved in hazardous waste operations. The program shall be designed to identify, evaluate, and control safety and health hazards, and provide for emergency response for hazardous waste operations.

(ii) The written safety and health program shall incorporate the following:

(a) An organizational structure:

(b) A comprehensive workplan:

(c) A site-specific safety and health plan which need not repeat the employer's standard operating procedures required in paragraph (b)(1)(ii)(F) of this section:

(d) The safety and health training program:

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(e) The medical surveillance program;

(f) The employer's standard operating procedures for safety and health; and

(g) Any necessary interface between general program and site specific activities.

(iii) **Site excavation.** Site excavations created during initial site preparation or during hazardous waste operations shall be shored or sloped as appropriate to prevent accidental collapse in accordance with Subpart P of 29 CFR Part 1926.

(iv) **Contractors and sub-contractors.** An employer who retains contractor or sub-contractor services for work in hazardous waste operations shall inform those contractors, sub-contractors, or their representatives of the site emergency response procedures and any potential fire, explosion, health, safety or other hazards of the hazardous waste operation that have been identified by the employer, including those identified in the employer's information program.

(v) **Program availability.** The written safety and health program shall be made available to any contractor or subcontractor or their representative who will be involved with the hazardous waste operation; to employees; to employee designated representatives; to OSHA personnel, and to personnel of other Federal, state, or local agencies with regulatory authority over the site.

**(2) Organizational structure part of the site program.**

(i) The organizational structure part of the program shall establish the specific chain of command and specify the overall responsibilities of supervisors and employees. It shall include, at a minimum, the following elements:

(a) A general supervisor who has the responsibility and authority to direct all hazardous waste operations.

(b) A site safety and health supervisor who has the responsibility and authority to develop and implement the site safety and health plan and verify compliance.

(c) All other personnel needed for hazardous waste site operations and emergency response and their general functions and responsibilities.

(d) The lines of authority, responsibility, and communication.

(ii) The organizational structure shall be reviewed and updated as necessary to reflect the current status of waste site operations.

**(3) Comprehensive workplan part of the site program.** The comprehensive workplan part of the program shall address the tasks and objectives of the site operations and the logistics and resources required to reach those tasks and objectives.

(i) The comprehensive workplan shall address anticipated clean-up activities as well as normal operating procedures which need not repeat the employer's procedures available elsewhere.

(ii) The comprehensive workplan shall define work tasks and objectives and identify the methods for accomplishing those tasks and objectives.

(iii) The comprehensive workplan shall establish personnel requirements for implementing the plan.

(iv) The comprehensive workplan shall provide for the implementation of the training required in paragraph (e) of this section.

(v) The comprehensive workplan shall provide for the implementation of the required informational programs required in paragraph (i) of this section.

(vi) The comprehensive workplan shall provide for the implementation of the medical surveillance program described in paragraph (f) of this section.

**(4) Site-specific safety and health plan part of the program.**

(i) **General.** The site safety and health plan, which must be kept on site, shall address the safety and health hazards of each phase of site operation and include the requirements and procedures for employee protection.



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(ii) **Elements.** The site safety and health plan, as a minimum, shall address the following:

(a) A safety and health risk or hazard analysis for each site task and operation found in the workplan.

(b) Employee training assignments to assure compliance with paragraph (e) of this section.

(c) Personal protective equipment to be used by employees for each of the site tasks and operations being conducted as required by the personal protective equipment program in paragraph (g)(5) of this section.

(d) Medical surveillance requirements in accordance with the program in paragraph (f) of this section.

(e) 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.

(f) Site control measures in accordance with the site control program required in paragraph (d) of this section.

(g) Decontamination procedures in accordance with paragraph (k) of this section.

(h) An emergency response plan meeting the requirements of paragraph (l) of this section for safe and effective responses to emergencies, including the necessary PPE and other equipment.

(i) Confined space entry procedures.

(j) A spill containment program meeting the requirements of paragraph (j) of this section.

(iii) **Pre-entry briefing.** The site specific safety and health plan shall provide for pre-entry briefings to be held prior to initiating any site activity, and at such other times as necessary to ensure that employees are apprised of the site safety and health plan and that this plan is being followed. The information and data obtained from site characterization and analysis work required in paragraph (c) of this

section shall be used to prepare and update the site safety and health plan.

(iv) **Effectiveness of site safety and health plan.** Inspections shall be conducted by the site safety and health supervisor or, in the absence of that individual, another individual who is knowledgeable in occupational safety and health, acting on behalf of the employer as necessary to determine the effectiveness of the site safety and health plan. Any deficiencies in the effectiveness of the site safety and health plan shall be corrected by the employer.

(c) **Site characterization and analysis.**

(1) **General.** Hazardous waste sites shall be evaluated in accordance with this paragraph to identify specific site hazards and to determine the appropriate safety and health control procedures needed to protect employees from the identified hazards.

(2) **Preliminary evaluation.** A preliminary evaluation of a site's characteristics shall be performed prior to site entry by a qualified person in order to aid in the selection of appropriate employee protection methods prior to site entry. Immediately after initial site entry, a more detailed evaluation of the site's specific characteristics shall be performed by a qualified person in order to further identify existing site hazards and to further aid in the selection of the appropriate engineering controls and personal protective equipment for the tasks to be performed.

(3) **Hazard identification.** All suspected conditions that may pose inhalation or skin absorption hazards that are immediately dangerous to life or health (IDLH), or other conditions that may cause death or serious harm, shall be identified during the preliminary survey and evaluated during the detailed survey. Examples of such hazards include, but are not limited to, confined space entry, potentially explosive or flammable situations, visible vapor clouds, or areas where biological indicators such as dead animals or vegetation are located.

(4) **Required information.** The following information to the extent available shall be obtained by the employer prior to allowing employees to enter a site:

(i) Location and approximate size of the site.

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(ii) Description of the response activity and/or the job task to be performed.

(iii) Duration of the planned employee activity.

(iv) Site topography and accessibility by air and roads.

(v) Safety and health hazards expected at the site.

(vi) Pathways for hazardous substance dispersion.

(vii) Present status and capabilities of emergency response teams that would provide assistance to hazardous waste clean-up site employees at the time of an emergency.

(viii) Hazardous substances and health hazards involved or expected at the site, and their chemical and physical properties.

**(5) Personal protective equipment.** Personal protective equipment (PPE) shall be provided and used during initial site entry in accordance with the following requirements:

(i) Based upon the results of the preliminary site evaluation, an ensemble of PPE shall be selected and used during initial site entry which will provide protection to a level of exposure below permissible exposure limits and published exposure levels for known or suspected hazardous substances and health hazards, and which will provide protection against other known and suspected hazards identified during the preliminary site evaluation. If there is no permissible exposure limit or published exposure level, the employer may use other published studies and information as a guide to appropriate personal protective equipment.

(ii) If positive-pressure self-contained breathing apparatus is not used as part of the entry ensemble, and if respiratory protection is warranted by the potential hazards identified during the preliminary site evaluation, an escape self-contained breathing apparatus of at least five minute's duration shall be carried by employees during initial site entry.

(iii) If the preliminary site evaluation does not produce sufficient information to identify the

hazards or suspected hazards of the site, an ensemble providing protection equivalent to Level B PPE shall be provided as minimum protection, and direct reading instruments shall be used as appropriate for identifying IDLH conditions. (See Appendix B for a description of Level B hazards and the recommendations for Level B protective equipment.)

(iv) Once the hazards of the site have been identified, the appropriate PPE shall be selected and used in accordance with paragraph (g) of this section.

**(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 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 ionizing radiation.

(ii) Monitoring the air with appropriate direct reading test equipment (i.e., combustible gas meters, 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.

**(7) Risk identification.** Once the presence and concentrations of specific hazardous substances and health hazards have been established, the risks associated with these substances shall be identified. Employees who will be working on the site shall be informed of any risks that have been identified. In situations covered by the Hazard Communication Standard, 29 CFR 1910.1200, training required by that standard need not be duplicated.

**Note to (c)(7).**—Risks to consider include, but are not limited to:

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(a) Exposures exceeding the permissible exposure limits and published exposure levels.

(b) IDLH concentrations.

(c) Potential skin absorption and irritation sources.

(d) Potential eye irritation sources.

(e) Explosion sensitivity and flammability ranges.

(f) Oxygen deficiency.

(8) **Employee notification.** Any information concerning the chemical, physical, and toxicologic properties of each substance known or expected to be present on site that is available to the employer and relevant to the duties an employee is expected to perform shall be made available to the affected employees prior to the commencement of their work activities. The employer may utilize information developed for the hazard communication standard for this purpose.

**(d) Site control.**

(1) **General.** Appropriate site control procedures shall be implemented to control employee exposure to hazardous substances before clean-up work begins.

(2) **Site control program.** A site control program for protecting employees which is part of the employer's site safety and health program required in paragraph (b) of this section shall be developed during the planning stages of a hazardous waste clean-up operation and modified as necessary as new information becomes available.

(3) **Elements of the site control program.** The site control program shall, as a minimum, include: A site map; site work zones; the use of a "buddy system"; site communications including alerting means for emergencies; the standard operating procedures or safe work practices; and, identification of the nearest medical assistance. Where these requirements are covered elsewhere they need not be repeated.

**(e) Training.**

**(1) General.**

(i) All employees working on site (such as but

not limited to equipment operators, general laborers and others) exposed to hazardous substances, health hazards, or safety hazards and their supervisors and management responsible for the site shall receive training meeting the requirements of this paragraph before they are permitted to engage in hazardous waste operations that could expose them to hazardous substances, safety, or health hazards, and they shall receive review training as specified in this paragraph.

(ii) Employees shall not be permitted to participate in or supervise field activities until they have been trained to a level required by their job function and responsibility.

(2) **Elements to be covered.** The training shall thoroughly cover the following:

(i) Names of personnel and alternates responsible for site safety and health;

(ii) Safety, health and other hazards present on the site;

(iii) Use of personal protective equipment;

(iv) Work practices by which the employee can minimize risks from hazards;

(v) Safe use of engineering controls and equipment on the site;

(vi) Medical surveillance requirements, including recognition of symptoms and signs which might indicate overexposure to hazards; and

(vii) The contents of paragraphs (g) through (j) of the site safety and health plan set forth in paragraph (b)(4)(ii) of this section.

**(3) Initial training.**

(i) General site workers (such as equipment operators, general laborers and supervisory personnel) engaged in hazardous substance removal or other activities which expose or potentially expose workers to hazardous substances and health hazards shall receive a minimum of 40 hours of instruction off the site, and a minimum of three days actual field experience under the direct supervision of a trained, experienced supervisor.

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(ii) Workers on site only occasionally for a specific limited task (such as, but not limited to, ground water monitoring, land surveying, or geo-physical surveying) and who are unlikely to be exposed over permissible exposure limits and published exposure limits shall receive a minimum of 24 hours of instruction off the site, and the minimum of one day actual field experience under the direct supervision of a trained, experienced supervisor.

(iii) Workers regularly on site who work in areas which have been monitored and fully characterized indicating that exposures are under permissible exposure limits and published exposure limits where respirators are not necessary, and the characterization indicates that there are no health hazards or the possibility of an emergency developing, shall receive a minimum of 24 hours of instruction off the site and the minimum of one day actual field experience under the direct supervision of a trained, experienced supervisor.

(iv) Workers with 24 hours of training who are covered by paragraphs (a)(3)(ii) and (a)(3)(iii) of this section, and who become general site workers or who are required to wear respirators, shall have the additional 16 hours and two days of training necessary to total the training specified in paragraph (e)(3)(i).

**(4) Management and supervisor training.** On-site management and supervisors directly responsible for, or who supervise employees engaged in, hazardous waste operations shall receive 40 hours initial training, and three days of supervised field experience (the training may be reduced to 24 hours and one day if the only area of their responsibility is employees covered by paragraphs (e)(3)(ii) and (e)(3)(iii) and at least eight additional hours of specialized training at the time of job assignment on such topics as, but not limited to, the employer's safety and health program and the associated employee training program, personal protective equipment program, spill containment program, and health hazard monitoring procedure and techniques.

**(5) Qualifications for trainers.** Trainers shall be qualified to instruct employees about the subject matter that is being presented in training. Such

trainers shall have satisfactorily completed a training program for teaching the subjects they are expected to teach, or they shall have the academic credentials and instructional experience necessary for teaching the subjects. Instructors shall demonstrate competent instructional skills and knowledge of the applicable subject matter.

**(6) Training certification.** Employees and supervisors that have received and successfully completed the training and field experience specified in paragraphs (e)(1) through (e)(4) of this section shall be certified by their instructor or the head instructor and trained supervisor as having successfully completed the necessary training. A written certificate shall be given to each person so certified. Any person who has not been so certified or who does not meet the requirements of paragraph (e)(9) of this section shall be prohibited from engaging in hazardous waste operations.

**(7) Emergency response.** Employees who are engaged in responding to hazardous emergency situations at hazardous waste clean-up sites that may expose them to hazardous substances shall be trained in how to respond to such expected emergencies.

**(8) Refresher training.** Employees specified in paragraph (e)(1) of this section, and managers and supervisors specified in paragraph (e)(4) of this section, shall receive eight hours of refresher training annually on the items specified in paragraph (e)(2) and/or (e)(4) of this section, any critique of incidents that have occurred in the past year that can serve as training examples of related work, and other relevant topics.

**(9) Equivalent training.** Employers who can show by documentation or certification that an employee's work experience and/or training has resulted in training equivalent to that training required in paragraphs (e)(1) through (e)(4) of this section shall not be required to provide the initial training requirements of those paragraphs to such employees. However, certified employees new to a site shall receive appropriate, site specific training before site entry and have appropriate supervised field experience at the new site. Equivalent training includes any

## STANDARDS AND INTERPRETATIONS

academic training or the training that existing employees might have already received from actual hazardous waste site work experience.

**(f) Medical surveillance.**

(1) **General.** Employers engaged in operations specified in paragraphs (a)(1)(i) through (a)(1)(iv) of this section and not covered by (a)(2)(iii) exceptions and employers of employees specified in paragraph (g)(9) shall institute a medical surveillance program in accordance with this paragraph.

(2) **Employees covered.** The medical surveillance program shall be instituted by the employer for the following employees:

(i) All employees who are or may be exposed to hazardous substances or health hazards at or above the permissible exposure limits or, if there is no permissible exposure limit, above the published exposure levels for these substances, without regard to the use of respirators, for 30 days or more a year;

(ii) All employees who wear a respirator for 30 days or more a year or as required by § 1910.134;

(iii) All employees who are injured due to overexposure from an emergency incident involving hazardous substances or health hazards; or

(iv) Members of HAZMAT teams.

**(3) Frequency of medical examinations and consultations.**

Medical examinations and consultations shall be made available by the employer to each employee covered under paragraph (f)(2) of this section on the following schedules:

(i) For employees covered under paragraphs (f)(2)(i), (f)(2)(ii), and (f)(2)(iv):

(a) Prior to assignment;

(b) At least once every twelve months for each employee covered unless the attending physician believes a longer interval (not greater than biennially) is appropriate;

(c) At termination of employment or reas-

signment to an area where the employee would not be covered if the employee has not had an examination within the last six months;

(d) As soon as possible upon notification by an employee that the employee has developed signs or symptoms indicating possible overexposure to hazardous substances or health hazards, or that the employee has been injured or exposed above the permissible exposure limits or published exposure levels in an emergency situation;

(e) At more frequent times, if the examining physician determines that an increased frequency of examination is medically necessary.

(ii) For employees covered under paragraph (f)(2)(iii) and for all employees including those of employers covered by paragraph (a)(1)(v) who may have been injured, received a health impairment, developed signs or symptoms which may have resulted from exposure to hazardous substances resulting from an emergency incident, or exposed during an emergency incident to hazardous substances at concentrations above the permissible exposure limits or the published exposure levels without the necessary personal protective equipment being used:

(a) As soon as possible following the emergency incident or development of signs or symptoms;

(b) At additional times, if the examining physician determines that follow-up examinations or consultations are medically necessary.

**(4) Content of medical examinations and consultations.**

(i) Medical examinations required by paragraph (f)(3) of this section shall include a medical and work history (or updated history if one is in the employee's file) with special emphasis on symptoms related to the handling of hazardous substances and health hazards, and to fitness for duty including the ability to wear any required PPE under conditions (i.e., temperature extremes) that may be expected at the work site.

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(ii) The content of medical examinations or consultations made available to employees pursuant to paragraph (f) shall be determined by the attending physician. The guidelines in the *Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities* (See Appendix D, Reference #10) should be consulted.

**(5) Examination by a physician and costs.** All medical examinations and procedures shall be performed by or under the supervision of a licensed physician, preferably one knowledgeable in occupational medicine, and shall be provided without cost to the employee, without loss of pay, and at a reasonable time and place.

**(6) Information provided to the physician.** The employer shall provide one copy of this standard and its appendices to the attending physician, and in addition the following for each employee:

(i) A description of the employee's duties as they relate to the employee's exposures.

(ii) The employee's exposure levels or anticipated exposure levels.

(iii) A description of any personal protective equipment used or to be used.

(iv) Information from previous medical examinations of the employee which is not readily available to the examining physician.

(v) Information required by §1910.134.

**(7) Physician's written opinion.**

(i) The employer shall obtain and furnish the employee with a copy of a written opinion from the attending physician containing the following:

(a) The physician's opinion as to whether the employee has any detected medical conditions which would place the employee at increased risk of material impairment of the employee's health from work in hazardous waste operations or emergency response, or from respirator use.

(b) The physician's recommended limitations upon the employee's assigned work.

(c) The results of the medical examination and tests if requested by the employee.

(d) A statement that the employee has been informed by the physician of the results of the medical examination and any medical conditions which require further examination or treatment.

(ii) The written opinion obtained by the employer shall not reveal specific findings or diagnoses unrelated to occupational exposures.

**(8) Recordkeeping.**

(i) An accurate record of the medical surveillance required by paragraph (f) of this section shall be retained. This record shall be retained for the period specified and meet the criteria of 29 CFR 1910.20.

(ii) The record required in paragraph (f)(8)(i) of this section shall include at least the following information:

(a) The name and social security number of the employee;

(b) Physician's written opinions, recommended limitations, and results of examinations and tests;

(c) Any employee medical complaints related to exposure to hazardous substances;

(d) A copy of the information provided to the examining physician by the employer, with the exception of the standard and its appendices.

**(g) Engineering controls, work practices, and personal protective equipment for employee protection.**

Engineering controls, work practices, personal protective equipment, or a combination of these shall be implemented in accordance with this paragraph to protect employees from exposure to hazardous substances and safety and health hazards.

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**(1) Engineering controls, work practices and PPE for substances regulated in Subparts G and Z.**

(i) 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.

**Note to (g)(1)(i):** Engineering controls which may be feasible include the use of pressurized cabs or control booths on equipment, and/or the use of remotely operated material handling equipment. Work practices which may be feasible are removing all non-essential employees from potential exposure during opening of drums, wetting down dusty operations and locating employees upwind of possible hazards.

(ii) Whenever engineering controls and work practices are not feasible, PPE shall be used to reduce and maintain employee exposures to or below the permissible exposure limits or dose limits for substances regulated by 29 CFR Part 1910, Subpart Z.

(iii) The employer shall not implement a schedule of employee rotation as a means of compliance with permissible exposure limits or dose limits except when there is no other feasible way of complying with the airborne or dermal dose limits for ionizing radiation.

(iv) The provisions of 29 CFR, Subpart G, shall be followed.

**(2) Engineering controls, work practices, and PPE for substances not regulated in Subparts G and Z.** An appropriate combination of engineering controls, work practices and personal protective equipment shall be used to reduce and maintain employee exposure to or below published exposure levels for hazardous substances and health hazards not regulated by 29 CFR Part 1910, Subparts G and Z. The employer may use the published literature and MSDS as a guide in making the employer's determination as to what level of protection the employer believes is appropriate for hazardous substances and health hazards for which there is no permissible exposure limit or published exposure limit.

**(3) Personal protective equipment selection.**

(i) Personal protective equipment (PPE) shall be selected and used which will protect employees from the hazards and potential hazards they are likely to encounter as identified during the site characterization and analysis.

(ii) Personal protective equipment selection shall be based on an evaluation of the performance characteristics of the PPE relative to the requirements and limitations of the site, the task-specific conditions and duration, and the hazards and potential hazards identified at the site.

(iii) Positive pressure self-contained breathing apparatus, or positive pressure air-line respirators equipped with an escape air supply, shall be used when chemical exposure levels present will create a substantial possibility of immediate death, immediate serious illness or injury, or impair the ability to escape.

(iv) Totally-encapsulating chemical protective suits (protection equivalent to Level A protection as recommended in Appendix B) shall be used in conditions where skin absorption of a hazardous substance may result in a substantial possibility of immediate death, immediate serious illness or injury, or impair the ability to escape.

(v) The level of protection provided by PPE selection shall be increased when additional information on site conditions indicates that increased protection is necessary to reduce employee exposures below permissible exposure limits and published exposure levels for hazardous substances and health hazards. (See Appendix B for guidance on selecting PPE ensembles.)

**Note to (g)(3):** The level of employee protection provided may be decreased when additional information or site conditions show that decreased protection will not result in hazardous exposures to employees.

(vi) Personal protective equipment shall be selected and used to meet the requirements of 29 CFR Part 1910, Subpart I, and additional requirements specified in this section.

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**(4) Totally-encapsulating chemical protective suits.**

(i) Totally-encapsulating suits shall protect employees from the particular hazards which are identified during site characterization and analysis.

(ii) Totally-encapsulating suits shall be capable of maintaining positive air pressure. (See Appendix A for a test method which may be used to evaluate this requirement.)

(iii) Totally-encapsulating suits shall be capable of preventing inward test gas leakage of more than 0.5 percent. (See Appendix A for a test method which may be used to evaluate this requirement.)

**(5) Personal protective equipment (PPE) program.** A written personal protective equipment program, which is part of the employer's safety and health program required in paragraph (b) of this section or required in paragraph (p)(1) of this section and which is also a part of the site-specific safety and health plan shall be established. The PPE program shall address the elements listed below. When elements, such as donning and doffing procedures, are provided by the manufacturer of a piece of equipment and are attached to the plan, they need not be rewritten into the plan as long as they adequately address the procedure or element.

- (i) PPE selection based upon site hazards.
- (ii) PPE use and limitations of the equipment,
- (iii) Work mission duration,
- (iv) PPE maintenance and storage,
- (v) PPE decontamination and disposal,
- (vi) PPE training and proper fitting,
- (vii) PPE donning and doffing procedures,
- (viii) PPE inspection procedures prior to, during, and after use,
- (ix) Evaluation of the effectiveness of the PPE program, and
- (x) Limitations during temperature extremes, heat stress, and other appropriate medical considerations.

**(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.

**(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.

**(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).

**(4) Monitoring of high-risk employees.** After the actual clean-up phase of any hazardous waste



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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 chemicals 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.

**(i) Informational programs.**

Employers shall develop and implement a program, which is part of the employer's safety and health program required in paragraph (b) of this section, to inform employees, contractors, and subcontractors (or their representative) actually engaged in hazardous waste operations of the nature, level and degree of exposure likely as a result of participation in such hazardous waste operations. Employees, contractors and subcontractors working outside of the operations part of a site are not covered by this standard.

**(j) Handling drums and containers.****(1) General.**

(i) Hazardous substances and contaminated soils, liquids, and other residues shall be handled, transported, labeled, and disposed of in accordance with this paragraph.

(ii) Drums and containers used during the clean-up shall meet the appropriate DOT, OSHA, and EPA regulations for the wastes that they contain.

(iii) When practical, drums and containers shall be inspected and their integrity shall be assured prior to being moved. Drums or containers that cannot be inspected before being moved because of storage conditions (i.e., buried beneath the earth, stacked behind other

drums, stacked several tiers high in a pile, etc.) shall be moved to an accessible location and inspected prior to further handling.

(iv) Unlabeled drums and containers shall be considered to contain hazardous substances and handled accordingly until the contents are positively identified and labeled.

(v) Site operations shall be organized to minimize the amount of drum or container movement.

(vi) Prior to movement of drums or containers, all employees exposed to the transfer operation shall be warned of the potential hazards associated with the contents of the drums or containers.

(vii) U.S. Department of Transportation specified salvage drums or containers and suitable quantities of proper absorbent shall be kept available and used in areas where spills, leaks, or ruptures may occur.

(viii) Where major spills may occur, a spill containment program, which is part of the employer's safety and health program required in paragraph (b) of this section, shall be implemented to contain and isolate the entire volume of the hazardous substance being transferred.

(ix) Drums and containers that cannot be moved without rupture, leakage, or spillage shall be emptied into a sound container using a device classified for the material being transferred.

(x) A ground-penetrating system or other type of detection system or device shall be used to estimate the location and depth of buried drums or containers.

(xi) Soil or covering material shall be removed with caution to prevent drum or container rupture.

(xii) Fire extinguishing equipment meeting the requirements of 29 CFR Part 1910, Subpart L, shall be on hand and ready for use to control incipient fires.

**(2) Opening drums and containers.** The following procedures shall be followed in areas where drums or containers are being opened:

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- (i) Where an airline respirator system is used, connections to the source of air supply shall be protected from contamination and the entire system shall be protected from physical damage.
  - (ii) Employees not actually involved in opening drums or containers shall be kept a safe distance from the drums or containers being opened.
  - (iii) If employees must work near or adjacent to drums or containers being opened, a suitable shield that does not interfere with the work operation shall be placed between the employee and the drums or containers being opened to protect the employee in case of accidental explosion.
  - (iv) Controls for drum or container opening equipment, monitoring equipment, and fire suppression equipment shall be located behind the explosion-resistant barrier.
  - (v) When there is a reasonable possibility of flammable atmospheres being present, material handling equipment and hand tools shall be of the type to prevent sources of ignition.
  - (vi) Drums and containers shall be opened in such a manner that excess interior pressure will be safely relieved. If pressure can not be relieved from a remote location, appropriate shielding shall be placed between the employee and the drums or containers to reduce the risk of employee injury.
  - (vii) Employees shall not stand upon or work from drums or containers.
- (3) Material handling equipment.** Material handling equipment used to transfer drums and containers shall be selected, positioned and operated to minimize sources of ignition related to the equipment from igniting vapors released from ruptured drums or containers.
- (4) Radioactive wastes.** Drums and containers containing radioactive wastes shall not be handled until such time as their hazard to employees is properly assessed.
- (5) Shock sensitive wastes.** As a minimum, the following special precautions shall be taken when drums and containers containing or suspected of containing shock-sensitive wastes are handled:
- (i) All non-essential employees shall be evacuated from the area of transfer.
  - (ii) Material handling equipment shall be provided with explosive containment devices or protective shields to protect equipment operators from exploding containers.
  - (iii) An employee alarm system capable of being perceived above surrounding light and noise conditions shall be used to signal the commencement and completion of explosive waste handling activities.
  - (iv) Continuous communications (i.e., portable radios, hand signals, telephones, as appropriate) shall be maintained between the employee-in-charge of the immediate handling area and both the site safety and health supervisor and the command post until such time as the handling operation is completed. Communication equipment or methods that could cause shock sensitive materials to explode shall not be used.
  - (v) Drums and containers under pressure, as evidenced by bulging or swelling, shall not be moved until such time as the cause for excess pressure is determined and appropriate containment procedures have been implemented to protect employees from explosive relief of the drum.
  - (vi) Drums and containers containing packaged laboratory wastes shall be considered to contain shock-sensitive or explosive materials until they have been characterized.
- Caution:** Shipping of shock sensitive wastes may be prohibited under U.S. Department of Transportation regulations. Employers and their shippers should refer to 49 CFR 173.21 and 173.50.
- (6) Laboratory waste packs.** In addition to the requirements of paragraph (j)(5) of this section, the following precautions shall be taken, as a minimum, in handling laboratory waste packs (lab packs):
- (i) Lab packs shall be opened only when necessary and then only by an individual knowledgeable in the inspection, classification, and segregation of the containers within the pack according to the hazards of the wastes.
  - (ii) If crystalline material is noted on any con-

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tainer, the contents shall be handled as a shock-sensitive waste until the contents are identified.

**(7) Sampling of drum and container contents.** Sampling of containers and drums shall be done in accordance with a sampling procedure which is part of the site safety and health plan developed for and available to employees and others at the specific worksite.

**(8) Shipping and transport.**

(i) Drums and containers shall be identified and classified prior to packaging for shipment.

(ii) Drum or container staging areas shall be kept to the minimum number necessary to identify and classify materials safely and prepare them for transport.

(iii) Staging areas shall be provided with adequate access and egress routes.

(iv) Bulking of hazardous wastes shall be permitted only after a thorough characterization of the materials has been completed.

**(9) Tank and vault procedures.**

(i) Tanks and vaults containing hazardous substances shall be handled in a manner similar to that for drums and containers, taking into consideration the size of the tank or vault.

(ii) Appropriate tank or vault entry procedures as described in the employer's safety and health plan shall be followed whenever employees must enter a tank or vault.

**(k) Decontamination.**

**(1) General.** Procedures for all phases of decontamination shall be developed and implemented in accordance with this paragraph.

**(2) Decontamination procedures.**

(i) A decontamination procedure shall be developed, communicated to employees and implemented before any employees or equipment may enter areas on site where potential for exposure to hazardous substances exists.

(ii) Standard operating procedures shall be developed to minimize employee contact with hazardous substances or with equipment that has contacted hazardous substances.

(iii) All employees leaving a contaminated area shall be appropriately decontaminated; all contaminated clothing and equipment leaving a contaminated area shall be appropriately disposed of or decontaminated.

(iv) Decontamination procedures shall be monitored by the site safety and health supervisor to determine their effectiveness. When such procedures are found to be ineffective, appropriate steps shall be taken to correct any deficiencies.

**(3) Location.** Decontamination shall be performed in geographical areas that will minimize the exposure of uncontaminated employees or equipment to contaminated employees or equipment.

**(4) Equipment and solvents.** All equipment and solvents used for decontamination shall be decontaminated or disposed of properly.

**(5) Personal protective clothing and equipment.**

(i) Protective clothing and equipment shall be decontaminated, cleaned, laundered, maintained or replaced as needed to maintain their effectiveness.

(ii) Employees whose non-impermeable clothing becomes wetted with hazardous substances shall immediately remove that clothing and proceed to shower. The clothing shall be disposed of or decontaminated before it is removed from the work zone.

**(6) Unauthorized employees.** Unauthorized employees shall not remove protective clothing or equipment from change rooms.

**(7) Commercial laundries or cleaning establishments.** Commercial laundries or cleaning establishments that decontaminate protective clothing or equipment shall be informed of the potentially harmful effects of exposures to hazardous substances.

**(8) Showers and change rooms.** Where the decontamination procedure indicates a need for regular showers and change rooms outside of a

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contaminated area, they shall be provided and meet the requirements of 29 CFR 1910.141. If temperature conditions prevent the effective use of water, then other effective means for cleansing shall be provided and used.

**(l) Emergency response by employees at uncontrolled hazardous waste sites.**

**(1) Emergency response plan.**

(i) An emergency response plan shall be developed and implemented by all employers within the scope of this section to handle anticipated emergencies prior to the commencement of hazardous waste operations. The plan shall be in writing and available for inspection and copying by employees, their representatives, OSHA personnel and other governmental agencies with relevant responsibilities.

(ii) Employers who will evacuate their employees from the workplace when an emergency occurs, and who do not permit any of their employees to assist in handling the emergency, are exempt from the requirements of this paragraph if they provide an emergency action plan complying with section 1910.38(a) of this part.

**(2) Elements of an emergency response plan.** The employer shall develop an emergency response plan for emergencies which shall address, as a minimum the following:

- (i) Pre-emergency planning.
- (ii) Personnel roles, lines of authority, and communication.
- (iii) Emergency recognition and prevention.
- (iv) Safe distances and places of refuge.
- (v) Site security and control.
- (vi) Evacuation routes and procedures.
- (vii) Decontamination procedures which are not covered by the site safety and health plan.
- (viii) Emergency medical treatment and first aid.

(ix) Emergency alerting and response procedures.

(x) Critique of response and follow-up.

(xi) PPE and emergency equipment.

**(3) Procedures for handling emergency incidents.**

(i) In addition to the elements for the emergency response plan required in paragraph (1)(2) of this section, the following elements shall be included for emergency response plans:

(a) Site topography, layout, and prevailing weather conditions.

(b) Procedures for reporting incidents to local, state, and federal governmental agencies.

(ii) The emergency response plan shall be a separate section of the Site Safety and Health Plan.

(iii) The emergency response plan shall be compatible and integrated with the disaster, fire and/or emergency response plans of local, state, and federal agencies.

(iv) The emergency response plan shall be rehearsed regularly as part of the overall training program for site operations.

(v) The site emergency response plan shall be reviewed periodically and, as necessary, be amended to keep it current with new or changing site conditions or information.

(vi) An employee alarm system shall be installed in accordance with 29 CFR 1910.165 to notify employees of an emergency situation; to stop work activities if necessary; to lower background noise in order to speed communication; and to begin emergency procedures.

(vii) Based upon the information available at time of the emergency, the employer shall evaluate the incident and the site response capabilities and proceed with the appropriate steps to implement the site emergency response plan.

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**(m) Illumination.**

Areas accessible to employees shall be lighted to not less than the minimum illumination intensities listed in the following Table H-120.1 while any work is in progress:

**TABLE H-120.1—MINIMUM ILLUMINATION INTENSITIES IN FOOT-CANDLES**

Foot-candles	Area or operations
5 . . . . .	General site areas.
3 . . . . .	Excavation and waste areas, accessways, active storage areas, loading platforms, refueling, and field maintenance areas.
5 . . . . .	Indoors: Warehouses, corridors, hallways, and exitways.
5 . . . . .	Tunnels, shafts, and general underground work areas. (Exception: Minimum of 10 foot-candles is required at tunnel and shaft heading during drilling mucking, and scaling. Mine Safety and Health Administration approved cap lights shall be acceptable for use in the tunnel heading).
10 . . . . .	General shops (e.g., mechanical and electrical equipment rooms, active storerooms, barracks or living quarters, locker or dressing rooms, dining areas, and indoor toilets and workrooms.)
30 . . . . .	First aid stations, infirmaries, and offices.

**(n) Sanitation at temporary workplaces.****(1) Potable water.**

(i) An adequate supply of potable water shall be provided on the site.

(ii) Portable containers used to dispense drinking water shall be capable of being tightly closed, and equipped with a tap. Water shall not be dipped from containers.

(iii) Any container used to distribute drinking water shall be clearly marked as to the nature of its contents and not used for any other purpose.

(iv) Where single service cups (to be used but once) are supplied, both a sanitary container for the unused cups and a receptacle for disposing of the used cups shall be provided.

**(2) Nonpotable water.**

(i) Outlets for nonpotable water, such as water for firefighting purposes, shall be identified to indicate clearly that the water is unsafe and is not to be used for drinking, washing, or cooking purposes.

(ii) There shall be no cross-connection, open or potential, between a system furnishing potable water and a system furnishing nonpotable water.

**(3) Toilet facilities.**

(i) Toilets shall be provided for employees according to the following Table H-120.2.

**TABLE H-120.2—TOILET FACILITIES**

Number of employees	Minimum number of facilities
20 or fewer . . . . .	One.
More than 20, fewer than 200.	One toilet seat and one urinal per 40 employees.
More than 200 . . . . .	One toilet seat and one urinal per 50 employees.

(ii) Under temporary field conditions, provisions shall be made to assure that at least one toilet facility is available.

(iii) Hazardous waste sites not provided with a sanitary sewer shall be provided with the following toilet facilities unless prohibited by local codes:

(a) Chemical toilets;

(b) Recirculating toilets;

(c) Combustion toilets; or

(d) Flush toilets.

(iv) The requirements of this paragraph for sanitation facilities shall not apply to mobile crews having transportation readily available to nearby toilet facilities.

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(v) Doors entering toilet facilities shall be provided with entrance locks controlled from inside the facility.

(4) **Food handling.** All food service facilities and operations for employees shall meet the applicable laws, ordinances, and regulations of the jurisdictions in which they are located.

(5) **Temporary sleeping quarters.** When temporary sleeping quarters are provided, they shall be heated, ventilated, and lighted.

(6) **Washing facilities.** The employer shall provide adequate washing facilities for employees engaged in operations where hazardous substances may be harmful to employees. Such facilities shall be in near proximity to the worksite: in areas where exposures are below permissible exposure limits and published exposure levels and which are under the controls of the employer; and shall be so equipped as to enable employees to remove hazardous substances from themselves.

(7) **Showers and change rooms.** When hazardous waste clean-up or removal operations commence on a site and the duration of the work will require six months or greater time to complete, the employer shall provide showers and change rooms for all employees exposed to hazardous substances and health hazards involved in hazardous waste clean-up or removal operations.

(i) Showers shall be provided and shall be provided and shall meet the requirements of 29 CFR 1910.141(d)(3).

(ii) Change rooms shall be provided and shall meet the requirements of 29 CFR 1910.141(e). Change rooms shall consist of two separate change areas separated by the shower area required in paragraph (n)(7)(i) of this section. One change area, with an exit leading off the worksite, shall provide employees with a clean area where they can remove, store, and put on street clothing. The second area, with an exit to the worksite, shall provide employees with an area where they can put on, remove and store work clothing and personal protective equipment.

(iii) Showers and change rooms shall be located in areas where exposures are below the permissible exposure limits and published exposure levels. If this cannot be accom-

plished, then a ventilation system shall be provided that will supply air that is below the permissible exposure limits and published exposure levels.

(iv) Employers shall assure that employees shower at the end of their work shift and when leaving the hazardous waste site.

**(o) New technology programs.**

(1) The employer shall develop and implement procedures for the introduction of effective new technologies and equipment developed for the improved protection of employees working with hazardous waste clean-up operations, and the same shall be implemented as part of the site safety and health program to assure that employee protection is being maintained.

(2) New technologies, equipment or control measures available to the industry, such as the use of foams, absorbents, adsorbents, neutralizers, or other means to suppress the level of air contaminants while excavating the site or for spill control, shall be evaluated by employers or their representatives. Such an evaluation shall be done to determine the effectiveness of the new methods, materials, or equipment before implementing their use on a large scale for enhancing employee protection. Information and data from manufacturers or suppliers may be used as part of the employer's evaluation effort. Such evaluations shall be made available to OSHA upon request.

**(p) Certain Operations Conducted Under the Resource Conservation and Recovery Act of 1976 (RCRA).**

Employers conducting operations at treatment, storage, and disposal (TSD) facilities specified in paragraph (a)(1)(iv) of this section not exempted by paragraph (a)(2)(iii) of this section shall provide and implement the programs specified in this paragraph.

(1) **Safety and health program.** The employer shall develop and implement a written safety and health program for employees involved in hazardous waste operations that shall be available for inspection by employees, their representatives and OSHA personnel. The program shall be designed to identify, evaluate and control safety and health hazards in their facilities

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for the purpose of employee protection, to provide for emergency response meeting the requirements of paragraph (p)(8) of this section and to address as appropriate site analysis, engineering controls, maximum exposure limits, hazardous waste handling procedures and uses of new technologies.

**(2) Hazard communication program.** The employer shall implement a hazard communication program meeting the requirements of 29 CFR 1910.1200 as part of the employer's safety and program.

**Note to 1910.120.**—The exemption for hazardous waste provided in §1910.1200 is applicable to this section.

**(3) Medical surveillance program.** The employer shall develop and implement a medical surveillance program meeting the requirements of paragraph (f) of this section.

**(4) Decontamination program.** The employer shall develop and implement a decontamination procedure meeting the requirements of paragraph (k) of this section.

**(5) New technology program.** The employer shall develop and implement procedures meeting the requirements of paragraph (o) of this section for introducing new and innovative equipment into the workplace.

**(6) Material handling program.** Where employees will be handling drums or containers, the employer shall develop and implement procedures meeting the requirements of paragraphs (j)(1)(ii) through (viii) and (xi) of this section, as well as (j)(3) and (j)(8) of this section prior to starting such work.

**(7) Training program.**

**(i) New employees.** The employer shall develop and implement a training program, which is part of the employer's safety and health program, for employees involved with hazardous waste operations to enable employees to perform their assigned duties and functions in a safe and healthful manner so as not to endanger themselves or other employees. The initial training shall be for 24 hours and refresher training shall be for eight hours annually. Employees who have received

the initial training required by this paragraph shall be given a written certificate attesting that they have successfully completed the necessary training.

**(ii) Current employees.** Employers who can show by an employee's previous work experience and/or training that the employee has had training equivalent to the initial training required by this paragraph, shall be considered as meeting the initial training requirements of this paragraph as to that employee. Equivalent training includes the training that existing employees might have already received from actual site work experience. Current employees shall receive eight hours of refresher training annually.

**(iii) Trainers.** Trainers who teach initial training shall have satisfactorily completed a training course for teaching the subjects they are expected to teach or they shall have the academic credentials and instruction experience necessary to demonstrate a good command of the subject matter of the courses and competent instructional skills.

**(8) Emergency response program.**

**(i) Emergency response plan.** An emergency response plan shall be developed and implemented by all employers. Such plans need not duplicate any of the subjects fully addressed in the employer's contingency planning required by permits, such as those issued by the U.S. Environmental Protection Agency, provided that the contingency plan is made part of the emergency response plan shall be a written portion of the employers safety and health program required in paragraph (p)(1) of this section. Employers who will evacuate their employees from the worksite location when an emergency occurs and who do not permit any of their employees to assist in handling the emergency are exempt from the requirements of paragraph (p)(8) if they provide an emergency action plan complying with §1910.38(a) of this part.

**(ii) Elements of an emergency response plan.** The employer shall develop an emergency response plan for emergencies which shall address, as a minimum, the following areas to the extent that they are not addressed in any specific program required in this paragraph:

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- (a) Pre-emergency planning and coordination with outside parties.
- (b) Personnel roles, lines of authority, and communication.
- (c) Emergency recognition and prevention.
- (d) Safe distances and places of refuge.
- (e) Site security and control.
- (f) Evacuation routes and procedures.
- (g) Decontamination procedures.
- (h) Emergency medical treatment and first aid.
- (i) Emergency alerting and response procedures.
- (j) Critique of response and follow-up.
- (k) PPE and emergency equipment.

**(iii) Training.**

(a) Training for emergency response employees shall be completed before they are called upon to perform in real emergencies. Such training shall include the elements of the emergency response plan, standard operating procedures the employer has established for the job, the personal protective equipment to be worn and procedures for handling emergency incidents.

**Exception #1:** An employer need not train all employees to the degree specified if the employer divides the work force in a manner such that a sufficient number of employees who have responsibility to control emergencies have the training specified, and all other employees, who may first respond to an emergency incident, have sufficient awareness training to recognize that an emergency response situation exists and that they are instructed in that case to summon the fully trained employees and not attempt control activities for which they are not trained.

**Exception #2:** An employer need not train all employees to the degree specified if arrangements have been made in advance for an outside fully-trained emergency response team to

respond in a reasonable period and all employees, who may come to the incident first, have sufficient awareness training to recognize that an emergency response situation exists and they have been instructed to call the designated outside fully-trained emergency response team for assistance.

(b) Employee members of TSD facility emergency response organizations shall be trained to a level of competence in the recognition of health and safety hazards to protect themselves and other employees. This would include training in the methods used to minimize the risk from safety and health hazards; in the safe use of control equipment; in the selection and use of appropriate personal protective equipment; in the safe operating procedures to be used at the incident scene; in the techniques of coordination with other employees to minimize risks; in the appropriate response to over exposure from health hazards or injury to themselves and other employees; and in the recognition of subsequent symptoms which may result from over exposures.

(c) The employer shall certify that each covered employee has attended and successfully completed the training required in paragraph (p)(8)(iii) of this section, or shall certify the employee's competency at least yearly. The method used to demonstrate competency for certification of training shall be recorded and maintained by the employer.

**(iv) Procedures for handling emergency incidents.**

(a) In addition to the elements for the emergency response plan required in paragraph (p)(8)(ii) of this section, the following elements shall be included for emergency response plans to the extent that they do not repeat any information already contained in the emergency response plan:

(1) Site topography, layout, and prevailing weather conditions.

(2) Procedures for reporting incidents to local, state, and federal governmental agencies.

(b) The emergency response plan shall be compatible and integrated with the disas-



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ter, fire and/or emergency response plans of local, state, and federal agencies.

(c) The emergency response plan shall be rehearsed regularly as part of the overall training program for site operations.

(d) The site emergency response plan shall be reviewed periodically and, as necessary, be amended to keep it current with new or changing site conditions or information.

(e) An employee alarm system shall be installed in accordance with 29 CFR 1910.165 to notify employees of an emergency situation; to stop work activities if necessary; to lower background noise in order to speed communication; and to begin emergency procedures.

(f) Based upon the information available at time of the emergency, the employer shall evaluate the incident and the site response capabilities and proceed with the appropriate steps to implement the site emergency response plan.

**(q) Emergency response to hazardous substance releases.**

This paragraph covers employers whose employees are engaged in emergency response no matter where it occurs except that it does not cover employees engaged in operations specified in paragraphs (a)(1)(i) through (a)(1)(iv) of this section. Those emergency response organizations who have developed and implemented programs equivalent to this paragraph for handling releases of hazardous substances pursuant to section 303 of the Superfund Amendments and Reauthorization Act of 1986 (Emergency Planning and Community Right-to-Know Act of 1986, 42 U.S.C. 11003) shall be deemed to have met the requirements of this paragraph.

(1) **Emergency response plan.** An emergency response plan shall be developed and implemented to handle anticipated emergencies prior to the commencement of emergency response operations. The plan shall be in writing and available for inspection and copying by employees, their representatives and OSHA personnel. Employers who will evacuate their employees from the workplace when an emergency occurs, and who do not permit any of their employees to assist in handling the

emergency, are exempt from the requirements of this paragraph if they provide an emergency action plan in accordance with §1910.38(a) of this part.

(2) **Elements of an emergency response plan.** The employer shall develop an emergency response plan for emergencies which shall address, as a minimum, the following to the extent that they are not addressed elsewhere:

(i) Pre-emergency planning and coordination with outside parties.

(ii) Personnel roles, lines of authority, training, and communication.

(iii) Emergency recognition and prevention.

(iv) Safe distances and places of refuse.

(v) Site security and control.

(vi) Evacuation routes and procedures.

(vii) Decontamination.

(viii) Emergency medical treatment and first aid.

(ix) Emergency alerting and response procedures.

(x) Critique of response and follow-up.

(xi) PPE and Emergency equipment.

(xii) Emergency response organizations may use the local emergency response plan or the state emergency response plan or both, as part of their emergency response plan to avoid duplication. Those items of the emergency response plan that are being properly addressed by the SARA Title III plans may be substituted into their emergency plan or otherwise kept together for the employer and employee's use.

**(3) Procedures for handling emergency response.**

(i) The senior emergency response official responding to an emergency shall become the individual in charge of a site-specific Incident Command System (ICS). All emergency responders and their communications shall be coordinated and controlled through the individual in charge of the ICS assisted by the senior official present for each employer.

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**Note to (q)(3)(i).**—The “senior official” at an emergency response is the most senior official on the site who has the responsibility for controlling the operations at the site. Initially it is the senior officer on the first-due piece of responding emergency apparatus to arrive on the incident scene. As more senior officers arrive (i.e., battalion chief, fire chief, state law enforcement official, site coordinator, etc.) the position is passed up the line of authority which has been previously established.

(ii) The individual in charge of the ICS 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 substance handling procedures, and use of any new technologies.

(iii) Based on the hazardous substances and/or conditions present, the individual in charge of the ICS shall implement appropriate emergency operations, and assure that the personal protective equipment worn is appropriate for the hazards to be encountered. However, personal protective equipment shall meet, at a minimum, the criteria contained in 29 CFR 1910.156(e) when worn while performing fire fighting operations beyond the incipient stage for any incident or site.

(iv) Employees engaged in emergency response and exposed to hazardous substances presenting an inhalation hazard or potential inhalation hazard shall wear positive pressure self-contained breathing apparatus while engaged in emergency response, until such time that the individual in charge of the ICS determines through the use of air monitoring that a decreased level of respiratory protection will not result in hazardous exposures to employees.

(v) The individual in charge of the ICS shall limit the number of emergency response personnel at the emergency site, in those areas of potential or actual exposure to incident or site hazards, to those who are actively performing emergency operations. However, operations in hazardous areas shall be performed using the buddy system in groups of two or more.

(vi) Back-up personnel shall stand by with equipment ready to provide assistance or res-

cue. Advance first aid support personnel, as a minimum, shall also stand by with medical equipment and transportation capability.

(vii) The individual in charge of the ICS shall designate a safety official, who is knowledgeable in the operations being implemented at the emergency response site, with specific responsibility to identify and evaluate hazards and to provide direction with respect to the safety of operations for the emergency at hand.

(viii) When activities are judged by the safety official to be an IDLH condition and/or to involve an imminent danger condition, the safety official shall have the authority to alter, suspend, or terminate those activities. The safety official shall immediately inform the individual in charge of the ICS of any actions needed to be taken to correct these hazards at an emergency scene.

(ix) After emergency operations have terminated, the individual in charge of the ICS shall implement appropriate decontamination procedures.

(x) When deemed necessary for meeting the tasks at hand, approved self-contained compressed air breathing apparatus may be used with approved cylinders from other approved self-contained compressed air breathing apparatus provided that such cylinders are of the same capacity and pressure rating. All compressed air cylinders used with self-contained breathing apparatus shall meet U.S. Department of Transportation and National Institute for Occupational Safety and Health criteria.

**(4) Skilled support personnel.** Personnel, not necessarily an employer's own employees, who are skilled in the operation of certain equipment, such as mechanized earth moving or digging equipment or crane and hoisting equipment, and who are needed temporarily to perform immediate emergency support work that cannot reasonably be performed in a timely fashion by an employer's own employees, and who will be or may be exposed to the hazards at an emergency response scene, are not required to meet the training required in this paragraph for the employer's regular employees. However, these personnel shall be given an initial briefing at the site prior to their participation in any emergency response. The initial briefing shall

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include instruction in the wearing of appropriate personal protective equipment, what chemical hazards are involved, and what duties are to be performed. All other appropriate safety and health precautions provided to the employer's own employees shall be used to assure the safety and health of these personnel.

**(5) Specialist employees.** Employees who, in the course of their regular job duties, work with and are trained in the hazards of specific hazardous substances, and who will be called upon to provide technical advice or assistance at a hazardous substance release incident to the individual in charge, shall receive training or demonstrate competency in the area of their specialization annually.

**(6) Training.** Training shall be based on the duties and function to be performed by each responder of an emergency response organization. The skill and knowledge levels required for all new responders, those hired after the effective date of this standard, shall be conveyed to them through training before they are permitted to take part in actual emergency operations on an incident. Employees who participate, or are expected to participate, in emergency response, shall be given training in accordance with the following paragraphs:

**(i) First responder awareness level.** First responders at the awareness level are individuals who are likely to witness or discover a hazardous substance release and who have been trained to initiate an emergency response sequence by notifying the proper authorities of the release. They would take no further action beyond notifying the authorities of the release. First responders at the awareness level shall have sufficient training to have had sufficient experience to objectively demonstrate competency in the following areas.

**(a)** An understanding of what hazardous materials are, and the risks associated with them in an incident.

**(b)** An understanding of the potential outcomes associated with an emergency created when hazardous materials are present.

**(c)** The ability to recognize the presence of hazardous materials in an emergency.

**(d)** The ability to identify the hazardous materials, if possible.

**(e)** An understanding of the role of the first responder awareness individual in the employer's emergency response plan including the site security and control and the U.S. Department of Transportation's Emergency Response Guidebook.

**(f)** The ability to realize the need for additional resources, and to make appropriate notifications to the communication center.

**(ii) First responder operations level.** First responders at the operations level are individuals who respond to releases or potential releases of hazardous substances as part of the initial response to the site for the purpose of protecting nearby persons, property, or the environment from the effects of the release. They are trained to respond in a defensive fashion without actually trying to stop the release. Their function is to contain the release from a safe distance, keep it from spreading, and prevent exposures. First responders at the operational level shall have received at least eight hours of training or have had sufficient experience to objectively demonstrate competency in the following areas in addition to those listed for the awareness level and the employer shall so certify:

**(a)** Knowledge of the basic hazard and risk assessment techniques.

**(b)** Know how to select and use proper personal protective equipment provided to the first responder operational level.

**(c)** An understanding of basic hazardous materials terms.

**(d)** Know how to perform basic control, containment and/or confinement operations within the capabilities of the resources and personal protective equipment available with their unit.

**(e)** Know how to implement basic decontamination procedures.

**(f)** An understanding of the relevant standard operating procedures and termination procedures.

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**(iii) Hazardous materials technician.** Hazardous materials technicians are individuals who respond to releases or potential releases for the purpose of stopping the release. They assume a more aggressive role than a first responder at the operations level in that they will approach the point of release in order to plug, patch or otherwise stop the release of a hazardous substance. Hazardous materials technicians shall have received at least 24 hours of training equal to the first responder operations level and in addition have competency in the following areas and the employer shall so certify:

- (a) Know how to implement the employer's emergency response plan.
- (b) Know the classification, identification and verification of known and unknown materials by using field survey instruments and equipment.
- (c) Be able to function within an assigned role in the Incident Command System.
- (d) Know how to select and use proper specialized chemical personal protective equipment provided to the hazardous materials technician.
- (e) Understand hazard and risk assessment techniques.
- (f) Be able to perform advance control, containment, and/or confinement operations within the capabilities of the resources and personal protective equipment available with the unit.
- (g) Understand and implement decontamination procedures.
- (h) Understand termination procedures.
- (i) Understand basic chemical and toxicological terminology and behavior.

**(iv) Hazardous materials specialist.** Hazardous materials specialists are individuals who respond with and provide support to hazardous materials technicians. Their duties parallel those of the hazardous materials technician, however, those duties require a more directed or specific knowledge of the various substances they may be called upon to con-

tain. The hazardous materials specialist would also act as the site liaison with Federal, state, local and other government authorities in regards to site activities. Hazardous materials specialists shall have received at least 24 hours of training equal to the technician level and in addition have competency in the following areas and the employer shall so certify:

- (a) Know how to implement the local emergency response plan.
- (b) Understand classification, identification and verification of known and unknown materials by using advanced survey instruments and equipment.
- (c) Know of the state emergency response plan.
- (d) Be able to select and use proper specialized chemical personal protective equipment provided to the hazardous materials specialist.
- (e) Understand in-depth hazard and risk techniques.
- (f) Be able to perform specialized control, containment, and/or confinement operations within the capabilities of the resources and personal protective equipment available.
- (g) Be able to determine and implement decontamination procedures.
- (h) Have the ability to develop a site safety and control plan.
- (i) Understand chemical, radiological and toxicological terminology and behavior.

**(v) On scene incident commander.** Incident commanders, who will assume control of the incident scene beyond the first responder awareness level, shall receive at least 24 hours of training equal to the first responder operations level and in addition have competency in the following areas and the employer shall so certify:

- (a) Know and be able to implement the employer's incident command system.
- (b) Know how to implement the employer's emergency response plan.

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(c) Know and understand the hazards and risks associated with employees working in chemical protective clothing.

(d) Know how to implement the local emergency response plan.

(e) Know of the state emergency response plan and of the Federal Regional Response Team.

(f) Know and understand the importance of decontamination procedures.

**(7) Trainers.** Trainers who teach any of the above training subjects shall have satisfactorily completed a training course for teaching the subjects they are expected to teach, such as the courses offered by the U.S. Fire Academy, or they shall have the training and/or academic credentials and instructional experience necessary to demonstrate competent instructional skills and a good command of the subject matter of the courses they are to teach.

**(8) Refresher training.**

(i) Those employees who are trained in accordance with paragraph (q)(6) of this section shall receive annual refresher training of sufficient content and duration to maintain their competencies, or shall demonstrate competency in those areas at least yearly.

(ii) A statement shall be made of the training or competency, and if a statement of competency is made, the employer shall keep a record of the methodology used to demonstrate competency.

**(9) Medical surveillance and consultation.**

(i) Members of an organized and designated HAZMAT team and hazardous materials specialists shall receive a baseline physical examination and be provided with medical surveillance as required in paragraph (f) of this section.

(ii) Any emergency response employees who exhibits signs or symptoms which may have resulted from exposure to hazardous substances during the course of an emergency incident, either immediately or subsequently, shall be provided with medical consultation as required in paragraph (f)(3)(ii) of this section.

**(10) Chemical protective clothing.** Chemical protective clothing and equipment to be used by organized and designated HAZMAT team members, or to be used by hazardous materials specialists, shall meet the requirements of paragraphs (g)(3) through (5) of this section.

**(11) Post-emergency response operations.** Upon completion of the emergency response, if it is determined that it is necessary to remove hazardous substances, health hazards, and materials contaminated with them (such as contaminated soil or other elements of the natural environment) from the site of the incident, the employer conducting the clean-up shall comply with one of the following:

(i) Meet all of the requirements of paragraphs (b) through (o) of this section; or

(ii) Where the clean-up is done on plant property using plant or workplace employees, such employees shall have completed the training requirements of the following: 29 CFR 1910.38(a); 1910.134; 1910.1200, and other appropriate safety and health training made necessary by the tasks that they are expected to be performed such as personal protective equipment and decontamination procedures. All equipment to be used in the performance of the clean-up work shall be in serviceable condition and shall have been inspected prior to use.

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**APPENDICES TO 1910.120—HAZARDOUS WASTE OPERATIONS AND EMERGENCY RESPONSE**

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**Note:** The following appendices serve as non-mandatory guidelines to assist employees and employers in complying with the appropriate requirements of this section. However paragraph 1910.120(g) makes mandatory in certain circumstances the use of Level A and Level B PPE protection.

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**Appendix A—Personal Protective Equipment Test Methods**

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This appendix sets forth the nonmandatory examples of tests which may be used to evaluate compliance with § 1910.120 (g)(4)(ii) and (iii). Other tests and other challenge agents may be used to evaluate compliance.

**A. Totally-encapsulating chemical protective suit pressure test.**

**1.0—Scope**

**1.1** This practice measures the ability of a gas tight totally-

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encapsulating chemical protective suit material, seams, and closures to maintain a fixed positive pressure. The results of this practice allow the gas tight integrity of a totally-encapsulating chemical protective suit to be evaluated.

1.2 Resistance of the suit materials to permeation, penetration, and degradation by specific hazardous substances is not determined by this test method.

## 2.0—Definition of terms

2.1 "Totally-encapsulated chemical protective suit (TECP suit)" means a full body garment which is constructed of protective clothing materials; covers the wearer's torso, head, arms, legs and respirator; may cover the wearer's hands and feet with tightly attached gloves and boots; completely encloses the wearer and respirator by itself or in combination with the wearer's gloves and boots.

2.2 "Protective clothing material" means any material or combination of materials used in an item of clothing for the purpose of isolating parts of the body from direct contact with a potentially hazardous liquid or gaseous chemicals.

2.3 "Gas tight" means, for the purpose of this test method, the limited flow of a gas under pressure from the inside of a TECP suit to atmosphere at a prescribed pressure and time interval.

## 3.0—Summary of test method

3.1 The TECP suit is visually inspected and modified for the test. The test apparatus is attached to the suit to permit inflation to the pre-test suit expansion pressure for removal of suit wrinkles and creases. The pressure is lowered to the test pressure and monitored for three minutes. If the pressure drop is excessive, the TECP suit fails the test and is removed from service. The test is repeated after leak location and repair.

## 4.0—Required Supplies

4.1 Source of compressed air.

4.2 Test apparatus for suit testing, including a pressure measurement device with a sensitivity of at least  $\frac{1}{4}$  inch water gauge.

4.3 Vent valve closure plugs or sealing tape.

4.4 Soapy water solution and soft brush.

4.5 Stop watch or appropriate timing device.

## 5.0—Safety Precautions

5.1 Care shall be taken to provide the correct pressure safety devices required for the source of compressed air used.

## 6.0—Test Procedure

6.1 Prior to each test, the tester shall perform a visual inspection of the suit. Check the suit for seam integrity by visually examining the seams and gently pulling on the seams. Ensure that all air supply lines, fittings, visor, zippers, and valves are secure and show no signs of deterioration.

6.1.1 Seal off the vent valves along with any other normal inlet or exhaust points (such as umbilical air line fittings or face piece opening) with tape or other appropriate means (caps, plugs, fixture, etc.). Care should be exercised in the sealing process not to damage any of the suit components.

6.1.2 Close all closure assemblies.

6.1.3 Prepare the suit for inflation by providing an improvised connection point on the suit for connecting an air-line. Attach the pressure test apparatus to the suit to permit suit inflation from a compressed air source equipped with a pressure indicating regulator. The leak tightness of the pressure test apparatus should be tested before and after each test by closing off the end of the tubing attached to the suit and assuring a pressure of three inches water gauge for three minutes can be maintained. If a component is removed for the test, that component shall be replaced and a second test conducted with another component removed to permit a complete test of the ensemble.

6.1.4 The pre-test expansion pressure (A) and the suit test pressure (B) shall be supplied by the suit manufacturer, but in no case shall they be less than: (A) = three inches water gauge; and (B) = two inches water gauge. The ending suit pressure (C) shall be no less than 80 percent of the test pressure (B); i.e., the pressure drop shall not exceed 20 percent of the test pressure (B).

6.1.5 Inflate the suit until the pressure inside is equal to pressure (A), the pre-test expansion suit pressure. Allow at least one minute to fill out the wrinkles in the suit. Release sufficient air to reduce the suit pressure to pressure (B), the suit test pressure. Begin timing. At the end of three minutes, record the suit pressure as pressure (C), the ending suit pressure. The difference between the suit test pressure and the ending suit test pressure (B-C) shall be defined as the suit pressure drop.

6.1.6 If the suit pressure drop is more than 20 percent of the suit test pressure (B) during the three-minute test period, the suit fails the test and shall be removed from service.

## 7.0—Retest Procedure

7.1 If the suit fails the test check for leaks by inflating the suit to pressure (A) and brushing or wiping the entire suit (including seams, closures, lens gaskets, glove-to-sleeve joints, etc.) with a mild soap and water solution. Observe the suit for the formation of soap bubbles, which is an indication of a leak. Repair all identified leaks.

7.2 Retest the TECP suit as outlined in Test procedure 6.0.

## 8.0—Report

8.1 Each TECP suit tested by this practice shall have the following information recorded:

8.1.1 Unique identification number, identifying brand name, date of purchase, material of construction, and unique fit features, e.g., special breathing apparatus.

8.1.2 The actual values for test pressures (A), (B), and (C) shall be recorded along with the specific observation times. If the ending pressure (C) is less than 80 percent of the test pres-

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sure (B), the suit shall be identified as failing the test. When possible, the specific leak location shall be identified in the test records. Retest pressure data shall be recorded as an additional test.

8.1.3 The source of the test apparatus used shall be identified and the sensitivity of the pressure gauge shall be recorded.

8.1.4 Records shall be kept for each pressure test even if repairs are being made at the test location.

**Caution**

Visually inspect all parts of the suit to be sure they are positioned correctly and secured tightly before putting the suit back into service. Special care should be taken to examine each exhaust valve to make sure it is not blocked.

Care should also be exercised to assure that the inside and outside of the suit is completely dry before it is put into storage.

**B. Totally-encapsulating chemical protective suit qualitative leak test.****1.0—Scope**

1.1 This practice semi-qualitatively tests gas tight totally-encapsulating chemical protective suit integrity by detecting inward leakage of ammonia vapor. Since no modifications are made to the suit to carry out this test, the results from this practice provide a realistic test for the integrity of the entire suit.

1.2 Resistance of the suit materials to permeation, penetration, and degradation is not determined by this test method. ASTM test methods are available to test suit materials for these characteristics and the tests are usually conducted by the manufacturers of the suits.

**2.0—Definition of terms**

2.1 "Totally-encapsulated chemical protective suit (TECP suit) means a full body garment which is constructed of protective clothing materials; covers the wearer's torso, head, arms, legs and respirator; may cover the wearer's hands and feet with tightly attached gloves and boots; completely encloses the wearer and respirator by itself or in combination with the wearer's gloves, and boots.

2.2 "Protective clothing material" means any material or combination of materials used in an item of clothing for the purpose of isolating parts of the body from direct contact with a potentially hazardous liquid or gaseous chemicals.

2.3 "Gas tight" means, for the purpose of this test method, the limited flow of a gas under pressure from the inside of a TECP suit to atmosphere at a prescribed pressure and time interval.

2.4 "Intrusion Coefficient" means a number expressing the level of protection provided by a gas tight totally-encapsulating chemical protective suit. The intrusion coefficient is calculated by dividing the test room challenge agent concentration by the

concentration of challenge agent found inside the suit. The accuracy of the intrusion coefficient is dependent on the challenge agent monitoring methods. The larger the intrusion coefficient the greater the protection provided by the TECP suit.

**3.0—Summary of recommended practice**

3.1 The volume of concentrated aqueous ammonia solution (ammonia hydroxide  $\text{NH}_4\text{OH}$ ) required to generate the test atmosphere is determined using the directions outlined in 6.1. The suit is donned by a person wearing the appropriate respiratory equipment (either a positive pressure self-contained breathing apparatus or a positive pressure supplied air respirator) and worn inside the enclosed test room. The concentrated aqueous ammonia solution is taken by the suited individual into the test room and poured into an open plastic pan. A two-minute evaporation period is observed before the test room concentration is measured, using a high range ammonia length of stain detector tube. When the ammonia vapor reaches a concentration of between 1000 and 1200 ppm, the suited individual starts a standardized exercise protocol to stress and flex the suit. After this protocol is completed, the test room concentration is measured again. The suited individual exits the test room and his stand-by person measures the ammonia concentration inside the suit using a low range ammonia length of stain detector tube or other more sensitive ammonia detector. A stand-by person is required to observe the test individual during the test procedure; aid the person in donning and doffing the TECP suit; and monitor the suit interior. The intrusion coefficient of the suit can be calculated by dividing the average test area concentration by the interior suit concentration. A colorimetric ammonia indicator strip of bromophenol blue or equivalent is placed on the inside of the suit face piece lens so that the suited individual is able to detect a color change and know if the suit has a significant leak. If a color change is observed the individual shall leave the test room immediately.

**4.0—Required supplies**

4.1 A supply of concentrated aqueous (58 percent ammonium hydroxide by weight).

4.2 A supply of bromophenol/blue indicating paper or equivalent, sensitive to 5-10 ppm ammonia or greater over a two-minute period of exposure. [pH 3.0 (yellow) to pH 4.6 (blue)]

4.3 A supply of high range (0.5-10 volume percent) and low range (5-700 ppm) detector tubes for ammonia and the corresponding sampling pump. More sensitive ammonia detectors can be substituted for the low range detector tubes to improve the sensitivity of this practice.

4.4 A shallow plastic pan (PVC) at least 12" 14" 1" and a half pint plastic container (PVC) with tightly closing lid

4.5 A graduated cylinder or other volumetric measuring device of at least 50 milliliters in volume with an accuracy of at least  $\pm 1$  milliliters.

**5.0—Safety precautions**

5.1 Concentrated aqueous ammonium hydroxide,  $\text{NH}_4\text{OH}$ , is a corrosive volatile liquid requiring eye, skin, and respiratory protection. The person conducting the test shall review the MSDS for aqueous ammonia.

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5.2 Since the established permissible exposure limit for ammonia is 50 ppm, only persons wearing a positive pressure self-contained breathing apparatus or a positive pressure supplied air respirator shall be in the chamber. Normally only the person wearing the totally-encapsulating suit will be inside the chamber. A stand-by person shall have a positive pressure self-contained breathing apparatus, or a positive pressure supplied air respirator available to enter the test area should the suited individual need assistance.

5.3 A method to monitor the suited individual must be used during this test. Visual contact is the simplest but other methods using communication devices are acceptable.

5.4 The test room shall be large enough to allow the exercise protocol to be carried out and then to be ventilated to allow for easy exhaust of the ammonia test atmosphere after the test(s) are completed.

5.5 Individuals shall be medically screened for the use of respiratory protection and checked for allergies to ammonia before participating in this test procedure.

#### 6.0—Test procedure

6.1.1 Measure the test area to the nearest foot and calculate its volume in cubic feet. Multiply the test area volume by 0.2 milliliters of concentrated aqueous ammonia solution per cubic foot of test area volume to determine the approximate volume of concentrated aqueous ammonia required to generate 1000 ppm in the test area.

6.1.2 Measure this volume from the supply of concentrated aqueous ammonia and place it into a closed plastic container.

6.1.3 Place the container, several high range ammonia detector tubes, and the pump in the clean test pan and locate it near the test area entry door so that the suited individual has easy access to these supplies.

6.2.1 In a non-contaminated atmosphere, open a pre-sealed ammonia indicator strip and fasten one end of the strip to the inside of the suit face shield lens where it can be seen by the wearer. Moisten the indicator strip with distilled water. Care shall be taken not to contaminate the detector part of the indicator paper by touching it. A small piece of masking tape or equivalent should be used to attach the indicator strip to the interior of the suit face shield.

6.2.2 If problems are encountered with this method of attachment, the indicator strip can be attached to the outside of the respirator face piece lens being used during the test.

6.3 Don the respiratory protective device normally used with the suit, and then don the TECP suit to be tested. Check to be sure all openings which are intended to be sealed (zippers, gloves, etc.) are completely sealed. DO NOT, however, plug off any venting valves.

6.4 Step into the enclosed test room such as a closet, bathroom, or test booth, equipped with an exhaust fan. No air should be exhausted from the chamber during the test because this will dilute the ammonia challenge concentrations.

6.5 Open the container with the premeasured volume of concentrated aqueous ammonia within the enclosed test room, and

pour the liquid into the empty plastic test pan. Wait two minutes to allow for adequate volatilization of the concentrated aqueous ammonia. A small mixing fan can be used near the evaporation pan to increase the evaporation rate of the ammonia solution.

6.6 After two minutes a determination of the ammonia concentration within the chamber should be made using the high range colorimetric detector tube. A concentration of 1000 ppm ammonia or greater shall be generated before the exercises are started.

6.7 To test the integrity of the suit the following four minute exercise protocol should be followed:

6.7.1 Raising the arms above the head with at least 15 raising motions completed in one minute.

6.7.2 Walking in place for one minute with at least 15 raising motions of each leg in a one-minute period.

6.7.3 Touching the toes with at least 10 complete motions of the arms from above the head to touching of the toes in a one-minute period.

6.7.4 Knee bends with at least 10 complete standing and squatting motions in a one-minute period.

6.8 If at any time during the test the colorimetric indicating paper should change colors, the test should be stopped and section 6.10 and 6.12 initiated (See ¶4.2).

6.9 After completion of the test exercise, the test area concentration should be measured again using the high range colorimetric detector tube.

6.10 Exit the test area.

6.11 The opening created by the suit zipper or other appropriate suit penetration should be used to determine the ammonia concentration in the suit with the low range length of stain detector tube or other ammonia monitor. The internal TECP suit air should be sampled far enough from the enclosed test area to prevent a false ammonia reading.

6.12 After completion of the measurement of the suit interior ammonia concentration the test is concluded and the suit is doffed and the respirator removed.

6.13 The ventilating fan for the test room should be turned on and allowed to run for enough time to remove the ammonia gas. The fan shall be vented to the outside of the building.

6.14 Any detectable ammonia in the suit interior (five ppm ammonia (NH<sub>3</sub>) or more for the length of stain detector tube) indicates that the suit has failed the test. When other ammonia detectors are used a lower level of detection is possible, and it should be specified as the pass/fail criteria.

6.15 By following this test method, an intrusion coefficient of approximately 200 or more can be measured with the suit in a completely operational condition. If the intrusion coefficient is 200 or more, then the suit is suitable for emergency response and field use.



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## 7.0—Retest procedures

7.1 If the suit fails this test, check for leaks by following the pressure test in test A above.

7.2 Retest the TECP suit as outlined in the test procedure 6.0.

## 8.0—Report

8.1 Each gas tight totally-encapsulating chemical protective suit tested by this practice shall have the following information recorded.

8.1.1 Unique identification number, identifying brand name, date of purchase, material of construction, and unique suit features; e.g., special breathing apparatus.

8.1.2 General description of test room used for test.

8.1.3 Brand name and purchase date of ammonia detector strips and color change data.

8.1.4 Brand name, sampling range, and expiration date of the length of stain ammonia detector tubes. The brand name and model of the sampling pump should also be recorded. If another type of ammonia detector is used, it should be identified along with its minimum detection limit for ammonia.

8.1.5 Actual test results shall list the two test area concentrations, their average, the interior suit concentration, and the calculated intrusion coefficient. Retest data shall be recorded as an additional test.

8.2 The evaluation of the data shall be specified as "suit passed" or "suit failed," and the date of the test. Any detectable ammonia (five ppm or greater for the length of stain detector tube) in the suit interior indicates the suit has failed this test. When other ammonia detectors are used, a lower level of detection is possible and it should be specified as the pass fail criteria.

## Caution

Visually inspect all parts of the suit to be sure they are positioned correctly and secured tightly before putting the suit back into service. Special care should be taken to examine each exhaust valve to make sure it is not blocked.

Care should also be exercised to assure that the inside and outside of the suit is completely dry before it is put into storage.

## Appendix B—General Description and Discussion of the Levels of Protection and Protective Gear

This appendix sets forth information about personal protective equipment (PPE) protection levels which may be used to assist employers in complying with the PPE requirements of this section.

As required by the standard, PPE must be selected which will protect employees from the specific hazards which they are likely to encounter during their work on-site.

Selection of the appropriate PPE is a complex process which should take into consideration a variety of factors. Key factors involved in this process are identification of the hazards, or suspected hazards; their routes of potential hazard to employees (inhalation, skin absorption, ingestion, and eye or skin contact), and the performance of the PPE materials (and seams) in providing a barrier to these hazards. The amount of protection provided by PPE is material-hazard specific. That is, protective equipment materials will protect well against some hazardous substances and poorly, or not at all, against others. In many instances, protective equipment materials cannot be found which will provide continuous protection from the particular hazardous substance. In these cases the breakthrough time of the protective material should exceed the work durations, or the exposure after breakthrough may not pose a hazardous level.

Other factors in this selection process to be considered are matching the PPE to the employee's work requirements and task-specific conditions. The durability of PPE materials, such as tear strength and seam strength, should be considered in relation to the employee's tasks. The effects of PPE in relation to heat stress and task duration are a factor in selecting and using PPE. In some cases layers of PPE may be necessary to provide sufficient protection, or to protect expensive PPE inner garments, suits or equipment.

The more that is known about the hazards at the site, the easier the job of PPE selection becomes. As more information about the hazards and conditions at the site becomes available, the site supervisor can make decisions to up-grade or down-grade the level of PPE protection to match the tasks at hand.

The following are guidelines which an employer can use to begin the selection of the appropriate PPE. As noted above, the site information may suggest the use of combinations of PPE selected from the different protection levels (i.e., A, B, C, or D) as being more suitable to the hazards of the work. It should be cautioned that the listing below does not fully address the performance of the specific PPE material in relation to the specific hazards at the job site, and that PPE selection, evaluation and re-selection is an ongoing process until sufficient information about the hazards and PPE performance is obtained.

Part A. Personal protective equipment is divided into four categories based on the degree of protection afforded. (See Part B of this appendix for further explanation of Levels A, B, C, and D hazards.)

1. Level A—To be selected when the greatest level of skin, respiratory, and eye protection is required

The following constitute Level A equipment: it may be used as appropriate;

1. Positive pressure, full face-piece self-contained breathing apparatus (SCBA), or positive pressure supplied air respirator with escape SCBA, approved by the National Institute for Occupational Safety and Health (NIOSH).

2. Totally-encapsulating chemical-protective suit.

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3. Coveralls.<sup>1</sup>4. Long underwear.<sup>1</sup>

## 5. Gloves, outer, chemical-resistant.

## 6. Gloves, inner, chemical-resistant.

## 7. Boots, chemical-resistant, steel toe and shank.

8. Hard hat (under suit).<sup>1</sup>

9. Disposable protective suit, gloves and boots (depending on suit construction, may be worn over totally-encapsulating suit).

**II. Level B**—The highest level of respiratory protection is necessary but a lesser level of skin protection is needed

The following constitute Level B equipment; it may be used as appropriate

1. Positive pressure, full-facepiece self-contained breathing apparatus (SCBA), or positive pressure supplied air respirator with escape SCBA (NIOSH approved).

2. Hooded chemical-resistant clothing (overalls and long-sleeved jacket; coveralls; one or two-piece chemical-splash suit, disposable chemical-resistant overalls).

3. Coveralls.<sup>1</sup>

## 4. Gloves, outer, chemical-resistant

## 5. Gloves, inner, chemical-resistant.

## 6. Boots, outer, chemical-resistant steel toe and shank

7. Boot-covers, outer, chemical-resistant (disposable).<sup>1</sup>8. Hard hat.<sup>1</sup>

## 9. [Reserved]

10. Face shield.<sup>1</sup>

**III. Level C**—The concentration(s) and type(s) of airborne substance(s) is known and the criteria for using air purifying respirators are met

The following constitute Level C equipment, it may be used as appropriate

1. Full-face or half-mask, air purifying respirators (NIOSH approved)

2. Hooded chemical-resistant clothing (overalls, two-piece chemical-splash suit, disposable chemical-resistant overalls)

3. Coveralls.<sup>1</sup>

## 4. Gloves, outer, chemical-resistant

## 5. Gloves, inner, chemical-resistant

6. Boots (outer), chemical-resistant steel toe and shank.<sup>1</sup>7. Boot-covers, outer, chemical-resistant (disposable).<sup>1</sup>8. Hard hat.<sup>1</sup>9. Escape mask.<sup>1</sup>10. Face shield.<sup>1</sup>

**IV. Level D**—A work uniform affording minimal protection, used for nuisance contamination only.

The following constitute Level D equipment, it may be used as appropriate:

## 1. Coveralls.

2. Gloves.<sup>1</sup>

## 3. Boots/shoes, chemical-resistant steel toe and shank.

4. Boots, outer, chemical-resistant (disposable).<sup>1</sup>

## 5. Safety glasses or chemical splash goggles\*

6. Hard hat.<sup>1</sup>7. Escape mask.<sup>1</sup>8. Face shield.<sup>1</sup>

**Part B.** The types of hazards for which levels A, B, C, and D protection are appropriate are described below:

**I. Level A**—Level A protection should be used when:

1. The hazardous substance has been identified and requires the highest level of protection for skin, eyes, and the respiratory system based on either the measured (or potential for) high concentration of atmospheric vapors, gases, or particulates; or the site operations and work functions involve a high potential for splash, immersion, or exposure to unexpected vapors, gases, or particulates of materials that are harmful to skin or capable of being absorbed through the skin.

2. Substances with a high degree of hazard to the skin are known or suspected to be present, and skin contact is possible, or

3. Operations are being conducted in confined, poorly ventilated areas, and the absence of conditions requiring Level A have not yet been determined

**II. Level B**—Level B protection should be used when

1. The type and atmospheric concentration of substances have been identified and require a high level of respiratory protection, but less skin protection.

2. The atmosphere contains less than 19.5 percent oxygen, or

3. The presence of incompletely identified vapors or gases is indicated by a direct-reading organic vapor detection instrument, but vapors and gases are not suspected of containing high levels of chemicals harmful to skin or capable of being absorbed through the skin.

<sup>1</sup>Optional, as applicable

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**Note:** This involves atmospheres with IDLH concentrations of specific substances that present severe inhalation hazards and that do not represent a severe skin hazard; or that do not meet the criteria for use of air-purifying respirators.

### III. Level C—Level C protection should be used when:

1. The atmospheric contaminants, liquid splashes, or other direct contact will not adversely affect or be absorbed through any exposed skin.

2. The types of air contaminants have been identified, concentrations measured, and an air-purifying respirator is available that can remove the contaminants; and

3. All criteria for the use of air-purifying respirators are met.

### IV. Level D—Level D protection should be used when:

1. The atmosphere contains no known hazard; and

2. Work functions preclude splashes, immersion, or the potential for unexpected inhalation of or contact with hazardous levels of any chemicals.

**Note:** As stated before, combinations of personal protective equipment other than those described for Levels A, B, C, and D protection may be more appropriate and may be used to provide the proper level of protection.

As an aid in selecting suitable chemical protective clothing, it should be noted that the National Fire Protection Association is developing standards on chemical protective clothing. These standards are currently undergoing public review prior to adoption, including

NFPA 1991—Standard on Vapor-Protective Suits for Hazardous Chemical Emergencies (EPA Level A Protective Clothing)

NFPA 1991—Standard on Liquid Splash-Protective Suits for Hazardous Chemical Emergencies (EPA Level B Protective Clothing.)

NFPA 1993—Standard on Liquid Splash-Protective Suits for Non-emergency, Non-flammable Hazardous Chemical Situations (EPA Level B Protective Clothing)

These standards would apply documentation and performance requirements to the manufacture of chemical protective suits. Chemical protective suits meeting these requirements would be labelled as compliant with the appropriate standard. When these standards are adopted by the National Fire Protection Association, it is recommended that chemical protective suits which meet these standards be used.

## Appendix C—Compliance Guidelines

1. **Occupational Safety and Health Program.** Each hazardous waste site clean-up effort will require an occupational safety and health program headed by the site coordinator or the employer's representative. The purpose of the program will be the protection of employees at the site and will be an extension of the employer's overall safety and health program. The program will need to be developed before work begins on the site and implemented as work proceeds as stated in paragraph (b). The program is to facilitate coordination and communica-

tion of safety and health issues among personnel responsible for the various activities which will take place at the site. It will provide the overall means for planning and implementing the needed safety and health training and job orientation of employees who will be working at the site. The program will provide the means for identifying and controlling worksite hazards and the means for monitoring program effectiveness. The program will need to cover the responsibilities and authority of the site coordinator or the employer's manager on the site for the safety and health of employees at the site, and the relationships with contractors or support services as to what each employer's safety and health responsibilities are for their employees on the site. Each contractor on the site needs to have its own safety and health program so structured that it will smoothly interface with the program of the site coordinator or principal contractor.

Also those employers involved with treating, storing or disposal of hazardous waste as covered in paragraph (p) must have implemented a safety and health program for their employees. This program is to include the hazard communication program required in paragraph (p)(1) and the training required in paragraphs (p)(7) and (p)(8) as parts of the employers comprehensive overall safety and health program. This program is to be in writing.

Each site or workplace safety and health program will need to include the following: (1) Policy statements of the line of authority and accountability for implementing the program, the objectives of the program and the role of the site safety and health supervisor or manager and staff; (2) means or methods for the development of procedures for identifying and controlling workplace hazards at the site; (3) means or methods for the development and communication to employees of the various plans, work rules, standard operating procedures and practices that pertain to individual employees and supervisors; (4) means for the training of supervisors and employees to develop the needed skills and knowledge to perform their work in a safe and healthful manner; (5) means to anticipate and prepare for emergency situations; and (6) means for obtaining information feedback to aid in evaluating the program and for improving the effectiveness of the program. The management and employees should be trying continually to improve the effectiveness of the program thereby enhancing the protection being afforded those working on the site.

Accidents on the site or workplace should be investigated to provide information on how such occurrences can be avoided in the future. When injuries or illnesses occur on the site or workplace, they will need to be investigated to determine what needs to be done to prevent this incident from occurring again. Such information will need to be used as feedback on the effectiveness of the program and the information turned into positive steps to prevent any reoccurrence. Receipt of employee suggestions or complaints relating to safety and health issues involved with site or workplace activities is also a feedback mechanism that can be used effectively to improve the program and may serve in part as an evaluative tool.

For the development and implementation of the program to be the most effective, professional safety and health personnel should be used. Certified Safety Professionals, Board Certified Industrial Hygienists or Registered Professional Safety Engineers are good examples of professional stature for safety and health managers who will administer the employer's program.

2. **Training.** The training programs for employees subject to the requirements of paragraph (e) of this standard should address the safety and health hazards employees should expect

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to find on hazardous waste clean-up sites; what control measures or techniques are effective for those hazards; what monitoring procedures are effective in characterizing exposure levels; what makes an effective employer's safety and health program; what a site safety and health plan should include; hands on training with personal protective equipment and clothing they may be expected to use; the contents of the OSHA standard relevant to the employee's duties and function; and, employee's responsibilities under OSHA and other regulations. Supervisors will need training in their responsibilities under the safety and health program and its subject areas such as the spill containment program, the personal protective equipment program, the medical surveillance program, the emergency response plan and other areas.

The training programs for employees subject to the requirements of paragraph (p) of this standard should address: the employers safety and health program elements impacting employees, the hazard communication program; the medical surveillance program; the hazards and the controls for such hazards that employees need to know for their job duties and functions. All require annual refresher training.

The training programs for employees covered by the requirements of paragraph (q) of this standard should address those competencies required for the various levels of response such as, the hazards associated with hazardous substances; hazard identification and awareness, notification of appropriate persons; the need for and use of personal protective equipment including respirators; the decontamination procedures to be used; preplanning activities for hazardous substance incidents including the emergency response plan; company standard operating procedures for hazardous substance emergency responses; the use of the incident command system and other subjects. Hands-on training should be stressed whenever possible. Critiques done after an incident which include an evaluation of what worked and what did not and how could the incident be better handled the next time may be counted as training time.

For hazardous materials specialists (usually members of hazardous materials teams), the training should address the care, use and/or testing of chemical protective clothing including totally encapsulating suits, the medical surveillance program, the standard operating procedures for the hazardous materials team including the use of plugging and patching equipment and other subject areas.

Officers and leaders who may be expected to be in charge at an incident should be fully knowledgeable of their company's incident command system. They should know where and how to obtain additional assistance and be familiar with the local district's emergency response plan and the state emergency response plan

Specialist employees such as technical experts, medical experts or environmental experts that work with hazardous materials in their regular jobs, who may be sent to the incident scene by the shipper, manufacturer or governmental agency to advise and assist the person in charge of the incident should have training on an annual basis. Their training should include the care and use of personal protective equipment including respirators, knowledge of the incident command system and how they are to relate to it; and those areas needed to keep them current in their respective field as it relates to safety and health involving specific hazardous substances.

Those skilled support personnel, such as employees who work for public works departments or equipment operators

who operate bulldozers, sand trucks, backhoes, etc., who may be called to the incident scene to provide emergency support assistance, should have at least a safety and health briefing before entering the area of potential or actual exposure. These skilled support personnel, who have not been a part of the emergency response plan and do not meet the training requirements, should be made aware of the hazards they face and should be provided all necessary protective clothing and equipment required for their tasks.

3. Decontamination. Decontamination procedures should be tailored to the specific hazards of the site, and may vary in complexity and number of steps, depending on the level of hazard and the employee's exposure to the hazard. Decontamination procedures and PPE decontamination methods will vary depending upon the specific substance, since one procedure or method may not work for all substances. Evaluation of decontamination methods and procedures should be performed, as necessary, to assure that employees are not exposed to hazards by re-using PPE. References in Appendix F may be used for guidance in establishing an effective decontamination program. In addition, the U.S. Coast Guard's Manual, "Policy Guidance for Response to Hazardous Chemical Releases," U.S. Department of Transportation, Washington, DC (COMDTINST M16465.30) is a good reference for establishing an effective decontamination program.

4. Emergency response plans. States, along with designated districts within the states, will be developing or have developed local emergency response plans. These state and district plans should be utilized in the emergency response plans called for in the standard. Each employer should assure that its emergency response plan is compatible with the local plan. The major reference being used to aid in developing the state and local district plans is the Hazardous Materials Emergency Planning Guide, NRT-1. The current Emergency Response Guidebook from the U.S. Department of Transportation, CMA's CHEMTREC and the Fire Service Emergency Management Handbook may also be used as resources.

Employers involved with treatment, storage, and disposal facilities for hazardous waste, which have the required contingency plan called for by their permit, would not need to duplicate the same planning elements. Those items of the emergency response plan that are properly addressed in the contingency plan may be substituted into the emergency response plan required in 1910.120 or otherwise kept together for employer and employee use.

5. Personal protective equipment programs. The purpose of personal protective clothing and equipment (PPE) is to shield or isolate individuals from the chemical, physical, and biologic hazards that may be encountered at a hazardous substance site

As discussed in Appendix B, no single combination of protective equipment and clothing is capable of protecting against all hazards. Thus PPE should be used in conjunction with other protective methods and its effectiveness evaluated periodically

The use of PPE can itself create significant worker hazards, such as heat stress, physical and psychological stress, and impaired vision, mobility, and communication. For any given situation, equipment and clothing should be selected that provide an adequate level of protection. However, over-protection, as well as under-protection, can be hazardous and should be avoided where possible.

Two basic objectives of any PPE program should be to protect the wearer from safety and health hazards, and to prevent

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injury to the wearer from incorrect use and/or malfunction of the PPE. To accomplish these goals, a comprehensive PPE program should include hazard identification, medical monitoring, environmental surveillance, selection, use, maintenance, and decontamination of PPE and its associated training.

The written PPE program should include policy statements, procedures, and guidelines. Copies should be made available to all employees, and a reference copy should be made available at the worksite. Technical data on equipment, maintenance manuals, relevant regulations, and other essential information should also be collected and maintained.

6. **Incident command system (ICS).** Paragraph 1910.120(q)(3)(ii) requires the implementation of an ICS. The ICS is an organized approach to effectively control and manage operations at an emergency incident. The individual in charge of the ICS is the senior official responding to the incident. The ICS is not much different than the "command post" approach used for many years by the fire service. During large complex fires involving several companies and many pieces of apparatus, a command post would be established. This enabled one individual to be in charge of managing the incident, rather than having several officers from different companies making separate, and sometimes conflicting, decisions. The individual in charge of the command post would delegate responsibility for performing various tasks to subordinate officers. Additionally, all communications were routed through the command post to reduce the number of radio transmissions and eliminate confusion. However, strategy, tactics, and all decisions were made by one individual.

The ICS is a very similar system, except it is implemented for emergency response to all incidents, both large and small, that involve hazardous substances.

For a small incident, the individual in charge of the ICS may perform many tasks of the ICS. There may not be any, or little, delegation of tasks to subordinates. For example, in response to a small incident, the individual in charge of the ICS, in addition to normal command activities, may become the safety officer and may designate only one employee (with proper equipment) as a backup to provide assistance if needed. OSHA does recommend, however, that at least two employees be designated as back-up personnel since the assistance needed may include rescue.

To illustrate the operation of the ICS, the following scenario might develop during a small incident, such as an overturned tank truck with a small leak of flammable liquid.

The first responding senior officer would implement and take command of the ICS. That person would size-up the incident and determine if additional personnel and apparatus were necessary; would determine what actions to take to control the leak, and, determine the proper level of personal protective equipment. If additional assistance is not needed, the individual in charge of the ICS would implement actions to stop and control the leak using the fewest number of personnel that can effectively accomplish the tasks. The individual in charge of the ICS then would designate himself as the safety officer and two other employees as a back-up in case rescue may become necessary. In this scenario, decontamination procedures would not be necessary.

A large complex incident may require many employees and difficult, time-consuming efforts to control. In these situations, the individual in charge of the ICS will want to delegate different tasks to subordinates in order to maintain a span of control that will keep the number of subordinates, that are reporting, to a manageable level.

Delegation of task at large incidents may be by location, where the incident scene is divided into sectors, and subordinate officers coordinate activities within the sector that they have been assigned.

Delegation of tasks can also be by function. Some of the functions that the individual in charge of the ICS may want to delegate at a large incident are: medical services; evacuation, water supply, resources (equipment, apparatus); media relations; safety, and, site control (integrate activities with police for crowd and traffic control). Also for a large incident, the individual in charge of the ICS will designate several employees as back-up personnel; and a number of safety officers to monitor conditions and recommend safety precautions.

Therefore, no matter what size or complexity an incident may be, by implementing an ICS there will be *one individual in charge* who makes the decisions and gives directions, and, all actions, and communications are coordinated through one central point of command. Such a system should reduce confusion, improve safety, organize and coordinate actions, and should facilitate effective management of the incident.

7. **Site Safety and Control Plans.** The safety and security of response personnel and others in the area of an emergency response incident site should be of primary concern to the incident commander. The use of a site safety and control plan could greatly assist those in charge of assuring the safety and health of employees on the site.

A comprehensive site safety and control plan should include the following: summary analysis of hazards on the site and a risk analysis of those hazards; site map or sketch; site work zones (clean zone, transition or decontamination zone, work or hot zone); use of the buddy system, site communications; command post or command center; standard operating procedures and safe work practices; medical assistance and triage area; hazard monitoring plan (air contaminate monitoring, etc.); decontamination procedures and area, and other relevant areas. This plan should be a part of the employer's emergency response plan or an extension of it to the specific site.

8. **Medical surveillance programs.** Workers handling hazardous substances may be exposed to toxic chemicals, safety hazards, biologic hazards, and radiation. Therefore, a medical surveillance program is essential to assess and monitor workers' health and fitness for employment in hazardous waste operations and during the course of work to provide emergency and other treatment as needed; and to keep accurate records for future reference.

The Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities developed by the National Institute for Occupational Safety and Health (NIOSH), the Occupational Safety and Health Administration (OSHA), the U.S. Coast Guard (USCG), and the Environmental Protection Agency (EPA), October 1985 provides an excellent example of the types of medical testing that should be done as part of a medical surveillance program.

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#### Appendix D—References

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The following references may be consulted for further information on the subject of this standard:

1. OSHA Instruction DFO CPL 2-70—January 29, 1986, *Special Emphasis Program: Hazardous Waste Sites*.

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2. OSHA Instruction DFO CPL 2-2 37A—January 29, 1986, *Technical Assistance and Guidelines for Superfund and Other Hazardous Waste Site Activities*
  3. OSHA Instruction DTS CPL 2.74—January 29, 1986, *Hazardous Waste Activity Form, OSHA 175*.
  4. Hazardous Waste Inspections Reference Manual, U.S. Department of Labor, Occupational Safety and Health Administration, 1986.
  5. Memorandum of Understanding Among the National Institute for Occupational Safety and Health, the Occupational Safety and Health Administration, the United States Coast Guard, and the United States Environmental Protection Agency, *Guidance for Worker Protection During Hazardous Waste Site Investigations and Clean-up and Hazardous Substance Emergencies*. December 18, 1980.
  6. National Priorities List, 1st Edition, October 1984; U.S. Environmental Protection Agency, Revised periodically.
  7. The Decontamination of Response Personnel, Field Standard Operating Procedures (F.S.O.P.) 7; U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Hazardous Response Support Division, December 1984.
  8. Preparation of a Site Safety Plan, Field Standard Operating Procedures (F.S.O.P.) 9; U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Hazardous Response Support Division, April 1985.
  9. Standard Operating Safety Guidelines; U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Hazardous Response Support Division, Environmental Response Team; November 1984.
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  11. Protecting Health and Safety at Hazardous Waste Sites; An Overview, U.S. Environmental Protection Agency, EPA/625/9-85/006; September 1985.
  12. Hazardous Waste Sites and Hazardous Substance Emergencies, NIOSH Worker Bulletin, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health; December 1982.
  13. Personal Protective Equipment for Hazardous Materials Incidents: A Selection Guide; U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health; October 1984.
  14. Fire Service Emergency Management Handbook, International Association of Fire Chiefs Foundation, 101 East Holly Avenue, Unit 10B, Sterling, VA 22170, January 1985.
  15. Emergency Response Guidebook, U.S. Department of Transportation, Washington, DC, 1987.
  16. Report to the Congress on Hazardous Materials Training, Planning and Preparedness, Federal Emergency Management Agency, Washington, DC, July 1986.
  17. Workbook for Fire Command, Alan V. Brunacini and J. David Beageron, National Fire Protection Association, Batterymarch Park, Quincy, MA 02269, 1985.
  18. Fire Command, Alan V. Brunacini, National Fire Protection, Batterymarch Park, Quincy, MA 02269, 1985.
  19. Incident Command System, Fire Protection Publications, Oklahoma State University, Stillwater, OK 74078, 1983.
  20. Site Emergency Response Planning, Chemical Manufacturers Association, Washington, DC 20037, 1986.
  21. Hazardous Materials Emergency Planning Guide, NRT-1, Environmental Protection Agency, Washington, DC, March 1987.
  22. Community Teamwork: Working Together to Promote Hazardous Materials Transportation Safety, U.S. Department of Transportation, Washington, DC, May 1983.
  23. Disaster Planning Guide for Business and Industry, Federal Emergency Management Agency, Publication No. FEMA 141, August 1987.
- (The Office of Management and Budget has approved the information collection requirements in this section under control number 1218-0139)

## **APPENDIX B**

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### **Warning Concentrations of Various Chemicals**

## WARNING CONCENTRATIONS OF VARIOUS CHEMICALS

The following table is a compilation of warning concentrations of various chemicals taken from several sources. A warning concentration is that concentration in air at which a person can detect the material either by its odor, by its taste, or by it causing irritation. Exposure limits, where they exist, are included so that a comparison can be made to determine whether a chemical has adequate warning properties. A material has adequate warning properties if the effects (e.g., odor, taste, or irritation) are detectable and persistent at concentrations "at" or "below" the exposure limit. Note that some sources give a statement like "adequate" or "inadequate" for the warning properties. Because the statement may be used in conjunction with a different exposure limit than is used in this table, it should be used with caution. Some of the chemicals have a range of concentrations because the different sources have different values. This can be due to the variability of human perceptions or different test methods. The sources may have used different endpoints for their testing. This value could be when the first person detected the odor, when everyone could smell it, or when 50% of the test subjects could detect it. Because of these variations, the full range of warning concentrations is given so that the user can decide which value to use.

The warning concentrations given are generally odor thresholds with irritation thresholds given in parentheses. Taste thresholds are noted as special cases. The concentration units used in the table are parts per million unless otherwise noted.



Chemical	Warning Concentration <sup>2</sup>	PEL/TWA/STEL	Exposure Limits <sup>1</sup>		
			REL	TLV	IDLH
Acetaldehyde	0.0001 - 2.3 (50)	100/150		100/150	10000
Acetamide	"odorless when pure"	10			
Acetic acid	0.1 - 24 (10-15)	10		10/15	1000
Acetic anhydride	0.1 - 81.2 (5)	C-5		C-5	1000
Acetone	0.1 - 699	750/1000	250	750/1000	20000
Acetonitrile	40 - 170	40/60	20	40/60	4000
Acetophenone	0.002 - 0.60	WEEL - 10			
Acetyl bromide	5.0 X 10 <sup>4</sup>				
Acetyl chloride	1				
Acrolein	0.05 - 16.6 (0.21-0.5)	0.1/0.3		0.1/0.3	5
Acrylamide	"odorless"	0.3 mg/m <sup>3</sup>	0.3 mg/m <sup>3</sup>	0.3 mg/m <sup>3</sup> ,A2	N.A.
Acrylic acid	0.1 - 1	10		10	
Acrylonitrile	16 - 100, fatigue	2 C-10	1 C-10	2,A2	Ca
Akrol	10				
Aldrin	0.2536 - 0.4027 mg/m <sup>3</sup>	0.25 mg/m <sup>3</sup>	D	0.25 mg/m <sup>3</sup>	Ca
Allyl alcohol	0.08 - 7.2, (0.75-25)	2/4		2/4	150
Allylamine	6.3 - 28.7				
Allyl chloride	0.1 - 10 (50-100)	1/2	1 C-3	1/2	300
Allyl chloroformate	1.4				
Allyl disulfide	0.0012				
Allyl glycidyl ether	< 10	5/10	C-9.6	5/10	270
Allyl isocyanide	0.018				

Chemical	Warning Concentration <sup>2</sup>	PEL/TWA/STEL	Exposure Limits <sup>1</sup>		
			REL	TLV	IDLH
Ally isothiocyanate	0.15 - 0.42	WEEL -/1			
Allyl mercaptan	0.00005 - 0.21				
Ammonia	0.04 - 55 (55-140)	-/35	C-50	25/35	500
Ammonium hydroxide	50				
Ammonium sulfanate	"odorless"	10 mg/m <sup>3</sup> (Total dust) 5 mg/m <sup>3</sup> (Respirable fraction)		10 mg/m <sup>3</sup>	5000 mg/m <sup>3</sup>
n-Amyl acetate	0.00090 - 10 (200)	100		100	4000
sec-Amyl acetate	0.0017 - 0.082	125		125	9000
tert-Amyl acetate	0.0017				
n-Amyl alcohol (1-pentanol)	0.0065 - 35				
Amylene (2-methyl-2-butene)	0.0022 - 2.3				
Amyl isovalerate	0.11				
n-Amyl mercaptan	0.07				
N-Amyl methyl ketone	0.0009 - 0.35				4000
Amyl sulfide	0.0030 - 0.005				
Anethole	0.003				
Aniline	0.5 - 70	2		2	100
Apiol	0.0063				
Arsenic anhydride (arsenic pentoxide)	1	0.01 mg/m <sup>3</sup>	C-0.002 mg/m <sup>3</sup> (as As)	0.2 mg/m <sup>3</sup> (as As)	Ca (as As)
Arsine	0.21 - 0.63	0.05	C-0.002 mg/m <sup>3</sup> (as As)	0.05	Ca
Benzaldehyde	0.003 - 0.69 (4.6)	WEEL - 2/4			
Benzene	1.4 - 120 (2817)	1/5	0.1 C-1	10, A2	Ca
Benzoyl peroxide	"odorless"	5 mg/m <sup>3</sup>	5 mg/m <sup>3</sup>	5 mg/m <sup>3</sup>	7000 mg/m <sup>3</sup>

Chemical	Warning Concentration <sup>2</sup>	PEL/TWA/STEL	Exposure Limits <sup>1</sup>		
			REL	TLV	IDLH
Benzyl alcohol	5.5				
Benzyl chloride	0.01 - 0.31 (8)	1	C-5 mg/m <sup>3</sup>	1	10
Benzyl mercaptan	0.00019 - 0.04 (4.5)		0.1		
Benzyl sulfide	0.0021 - 0.07				
Bornyl acetate	0.0078				
Boron oxide	"immediate irritation"	10 mg/m <sup>3</sup> (Total dust) 5 mg/m <sup>3</sup> (Respirable fraction)		10 mg/m <sup>3</sup>	N.A.
Boron trifluoride	1 - 1.5	C-1	NE	C-1	100
Bromine	0.05 - 3.5 (0.6 intolerable)	0.1/0.3		0.1/0.3	10
Bromoacetone	0.090				
Bromoacetophenone	0.015 - 0.17 (0.04)				
Bromoform	1.3 - 530	0.5		0.5	N.A.
1,3-Butadiene	0.16 - 1.8 (>8000)	1000	LL	10,A2	
n-Butane	5.5 - 5000	800		800	
2-Butoxyethanol	0.1 - 60 (100-195)	25		25	700
Butyl acetate	0.037 - 20 (300)	150/200		150/200	10000
sec-Butyl acetate	3 - 7	200		200	10000
tert-Butyl acetate	0.004 - 47	200		200	10000
Butyl acrylate	0.04 - 0.9	10		10	
Butyl alcohol	0.1 - 20 (25-100)	C-5		C-50	8000
sec-Butyl alcohol	0.1 - 43	100		100/150	10000
tert-Butyl alcohol	0.1 - 73 (100)	100/150		100/150	8000
Butylamine	0.1 - 5 (10-15)	C-5		C-5	2000
sec-Butylamine	0.24 (as n-Butylamine)	C-5		C-5	
tert-Butylamine	0.24 (as n-Butylamine)	C-5		C-5	

Chemical	Warning Concentration <sup>2</sup>	PEL/TWA/STEL	Exposure Limits <sup>1</sup>		
			REL	TLV	IDLH
Butyl cellosolve (see 2-Butylamine)					
Butyl cellosolve acetate	0 20				
n-Butyl chloride	0 9 - 13				
1-Butylene (1-Butene)	0 07 - 26				
2-Butylene (2-Butene)	0.57 - 22				
Butylene oxide	0.71				
Butyl ether	0.24 - 0.47				
n-Butyl formate	17 - 20				
n-Butyl lactate	1 - 7	5		5	
n-Butyl mercaptan	0.00082 - 0.38	0.5	C-0 5	0.5	2500
tert-Butyl mercaptan	0.00009 - 0.06				
Butyl sulfide	0.015 - 0.18				
p-tert-Butyltoluene	5 (5-8)	10/20		10/20	1000
n-Butyraldehyde	0.0046 - 0.039				
Butyric acid	0 00056 - 0.001				
Cadmium dust	"inadequate"	0.2 mg/m <sup>3</sup> C-0.6 mg/m <sup>3</sup>	LL	0.05 mg/m <sup>3</sup>	Ca
Cadmium fume	"inadequate"	0 1 mg/m <sup>3</sup> C-0.3 mg/m <sup>3</sup>	LL	C-0.05 mg/m <sup>3</sup>	Ca
Calcium dodecylbenzene sulfonate		0 3			
Calcium hydroxide	"odorless"			5 mg/m <sup>3</sup>	
Calcium hypochlorite	3.5 (as Chlorine)				
Calcium phosphide	0 13 - 13.4				
Camphor-synthetic	0.003 - 200 (1 77)	2 mg/m <sup>3</sup>		12/18 mg/m <sup>3</sup>	200 mg/m <sup>3</sup>

Chemical	Warning Concentration <sup>2</sup>	PEL/TWA/STEL	Exposure Limits <sup>1</sup>		
			REL	TLV	IDLH
Caprolactam	0.001 - 0.065	Dust - 1/3 mg/m <sup>3</sup> Vapor 5/10		Dust 1/3 mg/m <sup>3</sup> Vapor 5/10	
Carbaryl (Sevin®)	"essentially odorless"	5 mg/m <sup>3</sup>	5 mg/m <sup>3</sup>	5 mg/m <sup>3</sup>	600 mg/m <sup>3</sup>
Carbitol acetate	0.157 - 0.263				
Carbon dioxide	"odorless"	10000/30000	10000 C-30000	5000/30000	50000
Carbon disulfide	0.0011 - 7.7	4/12	1	10	500
Carbon monoxide	"odorless"	35	35 C-200	50/400	1500
Carbon tetrachloride	2 - 700	2	C-2	5,A2	Ca
Cavacrol	0.0023				
Chloral	0.047				
Chlordane	"odorless"	0.5 mg/m <sup>3</sup>		0.5/2.0 mg/m <sup>3</sup>	500 mg/m <sup>3</sup>
Chlorine	0.01 - 5 (1-6)	0.5/1	C-0.5	1/3	30
Chlorine dioxide	0.1 (5.0)	0.1/0.3		0.1/0.3	10
Chloroacetaldehyde	0.93 (0.01-1)	C-1		C-1	250
Chloroacetic acid	0.045	WEEL - 0.3/1			
Chloroacetophenone (CN, Tear Gas)	0.01 - 1.35 (0.024-0.063)	0.05		0.05	100 mg/m <sup>3</sup>
Chlorobenzene	0.1 - 60	75		75	2400
o-chlorobenzylidene malononitrile	(0.2)	C-0.05		C-0.05	2 mg/m <sup>3</sup>
Chlorobromomethane	100 - 400	200		200/250	5000
Chloroform	50 - 307, fatigue (>4096)	2	C-2	10,A2	Ca
Chloromethane (see Methyl chloride)					
Chlorophenol	0.034				
o-Chlorophenol	0.0036				

Chemical	Warning Concentration <sup>2</sup>	PEL/TWA/STEL	Exposure Limits <sup>1</sup>		
			REL	TLV	IDLH
p-Chlorophenol	1.2 - 30				
Chloropicrin	0.8 - 1.1 (0.3-0.37)	0.1		0.1/0.3	4
B-Chloroprene	0.1 - 138	10	C-1	10	Ca
Chlorosulfonic acid	1 - 5 (from HCl produced)	WEEL - 0.3			
o-Chlorotoluene	0.32	50		50/75	
Chlorovinyl arsine	1.6				
Cinnamaldehyde	0.0026				
Citric acid	"odorless"				
Cobalt, Metal Fume & Dust	(> 1 mg/m <sup>3</sup> )	0.05 mg/m <sup>3</sup>	0.05 mg/m <sup>3</sup>	20 mg/m <sup>3</sup>	
Coumarin (Coumaphos, Baymix)	0.0033 - 0.2				
Crag® Herbicide	"none"	10 mg/m <sup>3</sup> (Total dust) 5 mg/m <sup>3</sup> (Respirable fraction)			5000 mg/m <sup>3</sup>
m-Cresol	0.25 - 0.68	5	2.3	5	250
o-Cresol	0.26 - 0.68	5	2.3	5	250
p-Cresol	0.00047 - 0.0455	5	2.3	5	250
Crotonaldehyde	0.01 - 7.35 (45)	2		2	400
Crotyl mercaptan	0.00016 - 0.0099				
Crude-heavy (Loganillas-Crude)	0.1 - 0.5				
Crude-light (Louisiana-Crude)	0.1 - 0.5				
Crude-medium (Barbados-Crude)	0.1 - 0.5				
Cumene	0.04 - 1.2	50		50	8000
Cyanogen chloride (CNCL)	1	C-0.3		C-0.3	50 mg/m <sup>3</sup> (as CN)
Cyclohexane	0.1 - 300 (300)	300		300	1000
Cyclohexanol	0.06 - 160 (100)	50		50	3500

Chemical	Warning Concentration <sup>2</sup>	PEL/TWA/STEL	Exposure Limits <sup>1</sup>		
			REL	TLV	IDLH
Cyclohexanone	0.01 - 4	25	25	25	5000
Cyclohexene	0.18 - 300	300		300	10000
Cyclohexylamine	2.6	10		10	
Cyclopentadiene	0.01 - 250	75		75	2000
2,4-D esters	0.02 - 0.1	10 mg/m <sup>3</sup>		10 mg/m <sup>3</sup>	500 mg/m <sup>3</sup>
DDT (Dichlorodiphenyl trichloroethane)	2.9 mg/m <sup>3</sup>	1 mg/m <sup>3</sup>	LD	1 mg/m <sup>3</sup>	Ca
Decaborane	0.05 - 0.35 (fatigue)	0.05/0.15		0.05/0.15	20
Decanoic acid	0.0020 - 0.35				
Decanal	0.0064 - 0.168				
1-Decylene	0.12				
Diacetone alcohol	0.1 - 1.7	50	50	50	2100
Diacetyl	0.025				
Diallyl ketone	9.0				
Diazomethane	"inadequate"	0.2		0.2	10
Diborane	1.8 - 4, "not reliable"	0.1		0.1	40
Di-N-Butyl amine	0.08 - 0.48				
Dibutyl phosphate	"inadequate"	1/2		1/2	125
Dichlorobenzene	0.005	(see o-, p-)			
o-Dichlorobenzene	0.3 - 50 (20-30)	C-50		C-50	1700
p-Dichlorobenzene	0.18 - 30 (80-160)	75/110		75/110	1000
Dichloroethyl sulfide (Mustard Gas)	0.0023 - 0.19				
Dichlorodifluoromethane	"odorless"	1000		1000	50000
1,3-Dichloro-5,5-dimethyl hydantoin	"adequate", 0.01 (1.14)	0.2/0.4 mg/m <sup>3</sup>		0.2/0.4 mg/m <sup>3</sup>	5 mg/m <sup>3</sup>

Chemical	Warning Concentration <sup>2</sup>	PEL/TWA/STEL	Exposure Limits <sup>1</sup>		
			REL	TLV	IDLH
1,1-Dichloroethane	50 - 1350, "adequate"	100	HWC	200/250	4000
1,2-Dichloroethylene	0 085 - 500	200	200	200	
Dichloroethyl ether	0 0005 - 35 (100-200)	5/10		5/10	250
bis-a-Dichloroethyl sulfide	0.0023				
Dichloroisopropyl ether	0 32				
Dichloromethane (see Methylene chloride)					
dichloromonofluoromethane	"nearly odorless"	10		10	50000
2,4-Dichlorophenol	0.21 - 0 008				
1,2-Dichloropropane	0 1 - 70	75/110		75/110	
2,2-Dichloropropionic acid (Dalapon)	428	1		1	
Dichlorotetrafluoroethane	"nearly odorless"	1000		1000	50000
Dicyclopentadiene	0 003 - 0 020	5		5	
Dieldrin	0 041	0.25 mg/m <sup>3</sup>	LD	0 25 mg/m <sup>3</sup>	Ca
Diesel Fuel No. 1-D	0.25				
Diesel Fuel No. 2-D	0.08				
Diesel Fuel No. 4-D	0.01				
Diethanolamine	0.011 - 0.27	3		3	
Diethylamine	0.01 - 38 (50, animals)	10/25		10/25	2000
Diethylaminoethanol	0 01 - 0.25	10		10	500
Diethylene glycol	"almost odorless"	WEEL - 50 ppm, Total - 10 mg/m <sup>3</sup> , Aerosol only			
Diethylene triamine	10	1		1	
Diethyl ketone	1 - 10	200		200	
Diethyl selenide	0.00014	0.2 mg/m <sup>3</sup> (as Se)	0.2 mg/m <sup>3</sup> (as Se)	0.2 mg/m <sup>3</sup> (as Se)	



Chemical	Warning Concentration <sup>2</sup>	PEL/TWA/STEL	Exposure Limits <sup>1</sup>		
			REL	TLV	IDLH
Diethyl succinate	0.021				
Diffuorodibromomethane	"inadequate"	100		100	2500
Diglycidyl ether	5	0.1		0.1	Ca
Diisobutyl carbinol	0.048 - 0.160				
Diisobutyl ketone	0.11 - 0.31 (25-8)	25	25	25	2000
Diisopropylamine	0.1 - 4 (25-50, injury)	5		5	1000
Dimethyl acetamide	21 - 47	10		10	400
Dimethylamine	0.01 - 6 (97-183, animals)	10		10	2000
Dimethylaminoethanol	0.015 - 0.045				
Dimethylaniline	0.001 - 0.2	5/10		5/10	100
Dimethyl ether	0.3 - 9	WEEL - 500			
Dimethylformamide	0.1 - 100	10		10	3500
1,1-Dimethylhydrazine	1 - 14	0.5	0.06	0.5, A2	Ca
Dimethyl sulfate	"nearly odorless"	0.1		0.1, A2	10
dimethyl sulfide	0.001 - 0.020				
Dimethyl sulfoxide	"practically no odor"				
Dimethyl trichiocarbonate	0.0058 - 0.18 mg/m <sup>3</sup>				
Dinitro-o-cresol	"odorless"	0.2 mg/m <sup>3</sup>	0.2 mg/m <sup>3</sup>	0.2 mg/m <sup>3</sup>	5 mg/m <sup>3</sup>
2,6-Dinitrophenol	0.21 (as phenol)				
Dinitrotoluene	"inadequate"	1.5 mg/m <sup>3</sup>	LL	1.5 mg/m <sup>3</sup>	Ca
Dioxane	0.003 - 278 (200-300)	25	C-1	25	Ca
Dioxolane	64 - 128				
Diphenyl (Biphenyl)	0.0008 - 0.06 (3-4)	0.2		0.2	300 mg/m <sup>3</sup>
Diphenyl chloroarsine	0.030				
Diphenylcyanoarsine	0.3				

Chemical	Warning Concentration <sup>3</sup>	PEL/TWA/STEL	Exposure Limits <sup>1</sup>		
			REL	TLV	IDLH
Diphenyl ether (see Phenyl ether)					
Diphenyl sulfide	0.00034 - 0.0047				
Diphosgene (Trichloromethyl chloroformate)	1.2				
Dipropylamine	0.02 - 55				
Dipropylene glycol	"practically odorless"				
Dipropylene glycol methyl ether	34.7 - 1000 (74.3)	100/150		100	N.A.
dithioethylene glycol	0.031				
Dodecanol	0.0064				
Dodecycibenzene sulfonic acid	0.4 - 8				
Epichlorohydrin	0.1 - 16 (100)	2	ME	2	Ca
EPN	"inadequate"	0.5 mg/m <sup>3</sup>		0.5 mg/m <sup>3</sup>	50 mg/m <sup>3</sup>
Ethane	150 - 899			(a)	
1,2-Ethanedithiol	0.0042			0.5	
Ethanol	1 - 5100 (5041)	1000		1000	
Ethanolamine	2 - 4	3/6		3/6	1000
2-Ethoxy-3,4-dihydro-1,2-pyran	0.10 - 0.60				
2-Ethoxyethanol (Cellosolve acetate)	0.55-50	200	LL	5	NN
2-Ethoxyethyl acetate (Cellosolve acetate)	0.056 - 50 (600, animals)	100	5	2500	
Ethyl acetate	0.01 - 50 (200-400)	400		400	1000
Ethyl acrylate	0.00024 - 1 (75)	5/10		5/25	2000
Ethylamine	0.01 - 1 (100, delayed)	10		10	4000
Ethyl benzene	0.1 - 200 (200)	100/125		100/125	2000

Chemical	Warning Concentration <sup>3</sup>	PEL/TWA/STEL	Exposure Limits <sup>1</sup>		
			REL	TLV	IDLH
Ethyl bromide	3.1 - 200 (6500)	200/250		200/250	3500
2-Ethylbutanol	0.07 - 0.77				
Ethyl butyl ketone	0.1 - 10	50		50	3000
Ethyl butyrate	0.0082 - 0.015				
Ethyl chloride (Chloroethane)	4.2	1000	HWC	1000	20000
Ethyl disulfide	0.0028				
Ethylene	261 - 4010			(a)	
Ethylene bromide (see Ethylene dibromide)					
Ethylene chloride (see Ethylene dichloride)					
Ethylene chlorohydrin	"odorless", 0.4	C-1		C-1	10
Ethylene diamine	1 - 11.2 (100)	10		10	2000
Ethylene dibromide	10 - 25	20 C-30 P-50	0.045 C-0.13	A2	Ca
Ethylene dichloride	6.2 - 185	1/2	1 C-2	10	Ca
Ethylene glycol	0.08 - 40	C-50		C-50	
Ethylene imine	"inadequate" 1 - 100+	LL	LL	0.5	Ca
Ethylene oxide	0.1 - 700	1	0.1 C-5	1,A2	Ca
Ethyl ether	0.1 - 9 (200)	400/500		400/500	19000
Ethyl formate	18 - 33 (330)	100		100	8000
Ethyl glycol	25				
Ethyl hexanol	0.075 - 0.138				
Ethyl hexanoate	0.0056				
Ethyl hexyl acetate	0.18				

Chemical	Warning Concentration <sup>2</sup>	PEL/TWA/STEL	Exposure Limits <sup>1</sup>		
			REL	TLV	IDLH
Ethyl hexyl acrylate	0 007 - 0.073	C-5		C-5	
Ethyl isothiocyanate	1.6 - 10.7				
Ethyl mercaptan	0.00051 - 0.075	0.5	C-0.5	0.5	25000
Ethyl methacrylate	0.0067				
n-Ethylmorpholine	0.1 - 25, fatigue (40 - 100)	5		5	2000
Ethyl pelargonate	0.0014				
Ethyl phthalate	"odorless"				
Ethyl selenide	0.0003 - 0.014 mg/m <sup>3</sup>	0.2 mg/m <sup>3</sup> (as Se)	0.02 mg/m <sup>3</sup> (as Se)	0.2 mg/m <sup>3</sup> (as Se)	
Ethyl selenamercaptan	0.0003	0.2 mg/m <sup>3</sup> (as Se)	0.2 mg/m <sup>3</sup> (as Se)	0.2 mg/m <sup>3</sup> (as Se)	
Ethyl silicate	17 - 85 (250)	100		10	1000
Ethyl sulfide	0.00060 - 0.068				
Ethyl isovalerate	0.12				
Ethyl decanoate	0.00017				
Ethyl dichlorarsine	0.14 - 1.4				
Ethyl n-valerate	0.060				
Ethyl undecanoate	0.00054				
Eugenol	0.0046				
Fluoride dust	(5.0 mg/m <sup>3</sup> )	2.5 mg/m <sup>3</sup>	2.5 mg/m <sup>3</sup> (as F)	2.5 mg/m <sup>3</sup>	500 mg/m <sup>3</sup>
Fluorine	0.035 - 3 (25-100)	0.1		1/2	25
Fluorotrichloromethane	5 - 100, "odorless"	C-1000		C-1000	10000
Formaldehyde	0.01 - 60 (0.25-2)	3 C-10	0.016 C-0.1	1/2, A2	Ca
Formic acid	0.024 - 340 (15)	5		5	100

Chemical	Warning Concentration <sup>2</sup>	PEL/TWA/STEL	Exposure Limits <sup>1</sup>		
			REL	TLV	IDLH
Fuel Oil #1 (Kerosene, Jet Fuel)	0.082 - 1				
Fuel Oil #2 (Diesel Oil)	0.082				
Fuel Oil #4	0.5				
Fuel Oil #6 (Bunker-C)	0 - 13				
Furfural	0.006 - 5 (12 2-50)	2		2	250
Furfuryl alcohol	8	10/15	50	10/15	250
Fumaric Acid (trans-Butenedioic)	"odorless"				
Gasoline	0.005 - 10	300/500		300/500	
Glutaraldehyde	0.04	C-0.2		C-0.2	
Glycol diacetate	0.077 - 0.312				
Halothane	33			50	
n-Heptal chloride	0.060				
Heptachlor	0.306 mg/m <sup>3</sup>	0.5 mg/m <sup>3</sup>		0.5 mg/m <sup>3</sup>	100 mg/m <sup>3</sup>
Heptaldehyde	0.050				
n-Heptane	0.5 - 329	400/500	85 C-440	400/500	5000
Heptanol	0.057 - 20				
HETP (see TEPP)					
Hexachlorocyclopentadiene	0.03 - 0.33	0.1		0.01	
Hexachloroethane	0.13	1	LL	10	Ca
Hexamethylenediamine	0.0009	WEEL - 5mg/m <sup>3</sup>			
n-Hexane	65 - 248 (1400-1500)	500/100	100 C-510	50	5000
Hexanoic acid	0.0061				
Hexanol	0.0050 - 0.09				

Chemical	Warning Concentration <sup>2</sup>	PEL/TWA/STEL	Exposure Limits <sup>1</sup>		
			REL	TLV	IDLH
Hexanone (see Methyl Butyl Ketone)					
sec-Hexyl acetate	0.1 - 100 (100)	50		50	400
Hexylene glycol	50	C-25		C-25	
Hydrazine	3 - 4	0.1	C-0 03	0.1, A2	Ca
Hydrocinnamyl alcohol	0.00027				
Hydrogen bromide	2 (3-6)	C-3		C-3	50
Hydrogen chloride	1 - 10 (35)	C-5		C-5	100
Hydrogen cyanide	0.00027 - 5, fatigue	-/4.7	C-4.7	C-10	50
Hydrogen fluoride	0.04 - 0.163	3/6	3 C-6	C-3	30
Hydrogen peroxide	"odorless" (100)	1		1	75
Hydrogen selenide	0 0005 - 3.6, fades fast (1.5)	0.05		0.05	2
Hydrogen sulfide	0.00001 - 1.4 (50-100) (fatigue at high concentration)	10/15	C-10	10/15	300
2-Hydroxypropyl acrylate	0.05	0.5		0.5	
Indene	0.02	10		10	
Iodine	1.73 (1 63 - disappears within 2 minutes)	C-0.1	C-0.1	10	
Iodoform	0 0004 - 0.5	0.6		0.6	
Ionone	5.9 x 10 <sup>-4</sup> -73				
Isoamyl acetate	0.001 - 1	100		100	3000
Isoamyl alcohol	0.01 - 35 (100-150)	100/125		100/125	8000
Isoamyl mercaptan	0 0043 - 0 7				
Isobutyl acetate	0.002 - 7 (< 150)	150		150/187	7500
Isobutyl acrylate	0.009 - 0 012				
Isobutyl cellosolve	0.114 - 0.191				

Chemical	Warning Concentration <sup>2</sup>	PEL/TWA/STEL	Exposure Limits <sup>1</sup>		
			REL	TLV	IDLH
Isobutyl mercaptan	0.00054 - 0.00097				
Isobutyraldehyde	0.047 - 0.336				
Isobutyric acid	0.001				
Isocyanochloride	0.98				
Isodecanol	0.31 - 0.042				
Isopentanoic acid	0.005 - 0.026				
Isopentyl acetate (see Isoamyl acetate)					
Isophorone	0.18 - 8.85 (8.85)	4	4	C-5	800
Isoprene (2-methylbutadiene)	0.005	WEEL - 50			
Isopropanolamine dodecylbenzene sulfate	0.3				
Isopropyl acetate	0.5 - 400 (200)	250/310		250/310	16000
Isopropyl alcohol	7.5 - 300 (400)	400/500	500 C-800	500/500	12000
Isopropylamine	0.1 - 10 (10-20)	5/10		5/10	4000
Isopropyl ether	0.02 - 300 (800)	500		250/310	10000
Isopropyl glycidyl ether	300	50/75	C-50	50/75	1500
Isopropyl Mercaptan	0.00025				
Kerosene	0.082 - 1		100 mg/m <sup>3</sup>		
Ketene	(23)	0.5/1.5		0.5/1.5	50
Kuwait-Crude	0.1 - 0.5				
Lactic acid	4 x 10 <sup>7</sup>				
Lauric acid	0.0034				
Lauryl mercaptan	4 mg/m <sup>3</sup>				
Light Gasoline	800	300/500			

Chemical	Warning Concentration <sup>2</sup>	PEL/TWA/STEL	Exposure Limits <sup>1</sup>		
			REL	TLV	IDLH
Lindane	"practically odorless" 3.9 mg/m <sup>3</sup> - 21.3 mg/m <sup>3</sup>	0.5 mg/m <sup>3</sup>		0.5 mg/m <sup>3</sup>	1000 mg/m <sup>3</sup>
Linoleyl acetate	0.0016				
Lithium hydride	(0.1 mg/m <sup>3</sup> )	0.025 mg/m <sup>3</sup>		0.025 mg/m <sup>3</sup>	55 mg/m <sup>3</sup>
LPG	20000 (propane)	1000		1000	19000
Magnesium dodecyl sulfate	0.2				
Malathion	10 13.5 mg/m <sup>3</sup>	10 mg/m <sup>3</sup> (Total dust) 5 mg/m <sup>3</sup> (respirable fraction)	15 mg/m <sup>3</sup>	10 mg/m <sup>3</sup>	5000 mg/m <sup>3</sup>
Maleic anhydride	0.1 - 0.5 (0.25-1.83)	0.25		0.25	500
Menthol	1.5				
2-Mercaptoethanol	0.12 - 0.65				
Mercury, Inorganic (except Mercury pernitrate)	"odorless"	C-0.1 mg/m <sup>3</sup> (as Hg)	0.05 mg/m <sup>3</sup> (as Hg)	0.1 mg/m <sup>3</sup>	28 mg/m <sup>3</sup>
Mercury, vapor	"odorless"	0.05 mg/m <sup>3</sup>		0.05 mg/m <sup>3</sup>	28 mg/m <sup>3</sup>
Mesitylene (see Trimethylbenzene)					
Mesityl oxide	0.017 - 25	15/25	10	15/25	5000
Methoxynaphthalene	0 00012				
3-Methoxypropylamine	0 2 - 42	WEEL - 10			
Methyl acetate	0.2 - 300 (10000)	200/250		200/250	10000
Methyl acetylene- Propadiene Mixture	100	1000/1250		1000/1250	20000
Methyl acrylate	0.0005 - 20 (75)	10		10	1000
Methylacrylonitrile	2 - 14 (fatigue)	1		1	
Methyl alcohol	10 - 20482 (7500 - 69000)	200/250 C-800	200	200/250	25000
Methylamine	0.001 - 10 (fatigue) (20-100)	10		10	100
Methyl amyl acetate	0.002 - 1048 (1048)				



Chemical	Warning Concentration <sup>2</sup>	PEL/TWA/STEL	Exposure Limits <sup>1</sup>		
			REL	TLV	IDLH
Methyl amyl alcohol (Methyl isobutyl carbinol)	0 01 - 50 (24-50)	25/40		25/40	2000
n-Methylaniline	1.6 - 2	0.5	0.5	100	
Methyl anthranilate	0.00066 - 0 06				
Methyl bromide	20 6 - 1030	5	LL	5	Ca
2-Methyl-2-butanol (tert-Amyl alcohol)	0.23 - 2.3				
Methyl n-butyl ketone	0.07 - 0.09	5	I	5	5000
Methyl n-butyrate	0.0026				
Methyl cellosolve	0.0925 - 92.5 (118)	25	LL	5	NN
Methyl cellosolve acetate	0.64 - 50	25		5	4000
Methyl chloride	10 - 250, "no odor" (500-1000)	50/100	LL	50/100	Ca
Methyl chloroform	20 - 714 (500-1000)	350/450		350/450	1000
Methyl 2-cyanoacrylate	1 - 3	2/4		2/4	
Methylcyclohexane	500 - 630	400		400	10000
Methyl dichloroarsine	0 11				
Methyl biphenyl isocyanate (MDI) (Dichloromethane)	"can adapt to odor" 25 - 227 (5000)	500 C-1000 P-2000	LL	50/175,A2	Ca
Methyl ethanol amine	3,4				
Methyl ethyl ketone (MEK)	0.25 - 85 (200)	C-0.7	200	200/300	3000
Methylethyl pyridine	0 006 - 19				
Methyl formate	204 - 3000, (fatigue (3563))	100/150		100/150	5000
Methyl glycol (1,2-propylene glycol)	60 - 90				
5-Methyl-3-heptanone (Ethyl amyl ketone)	6 (50)	25		25	3000
Methyl hydrazine	1 - 3	C-0 2	C-0.04	C-02,A2	Ca

Chemical	Warning Concentration <sup>2</sup>	PEL/TWA/STEL	Exposure Limits <sup>1</sup>		
			REL	TLV	IDLH
Methyl iodide	(4300)	2	LL	2,A2	Ca
Methyl isoamyl alcohol	0.20				
Methyl isoamyl ketone	0.01 - 0.28	50	100	50	
Methyl isobutyl ketone	0.01 - 47 (100)	50/175	50	50/75	3000
Methyl isocyanate	2.0 (2)	0.02		0.02	20
Methyl isopropyl ketone	0.1 - 4.8	200		200	
Methyl mercaptan	0.0001 - 1.1	0.5	0.5	0.5	400
Methyl methacrylate	0.01 - 1 (170-250)	100		100	4000
2-Methylpentaldehyde	0.09 - 0.136				
2-Methyl-1-pentanol	0.024 - 0.082				
2-Methylpropene (isobutylene)	0.57 - 20				
Methyl salicylate	0.1 - 0.14				
a-Methyl styrene	0.1 - 200 (200)	50/100		50/100	5000
Methyl sulfide (see Dimethyl Sulfide)					
Methyl thiocyanate	0.25 - 3.2				
Methyltrichlorosilane	1				
Methyl vinyl ketone	0.2				
Methylvinyl pyridine	0.040				
Mineral spirits	30				
Morpholine	0.01 - 0.14	20/30		20/30	8000
Musk (Synthetic)	4.0 x 10 <sup>-7</sup>				
Naphtha - coal tar	4.68 - 100 (200-300)	100			10000
Naphtha - petroleum (rubber solvent)	< 500				
Naphthalene	0.001 - 0.8 (15)	10/15		10/15	500

Chemical	Warning Concentration <sup>2</sup>	PEL/TWA/STEL	Exposure Limits <sup>1</sup>		
			REL	TLV	IDLH
2-Naphthol	1.3				
Nickel carbonyl	1 - 3	0.001	0.001	0.05 (as Ni)	Ca
Nitric acid	0.3 - 1.0 (62)	2/4	2	2/4	100
Nitric oxide	"odorless", 0.3 - 1, "poor"	25		25	100
p-Nitroaniline	"odorless"	3 mg/m <sup>3</sup>		3 mg/m <sup>3</sup>	300 mg/m <sup>3</sup>
Nitrobenzene	0.001 - 6	1		1	200
o-Nitrochlorobenzene	0.002				
Nitroethane	2.1 - 200 (100-500)	100		100	10000
Nitrogen dioxide	0.1 - 5.3 (5-20)	-/1	C-1	3/5	50
Nitrogen tetroxide	5				
Nitrogen trifluoride	"no odor-warning properties at potentially dangerous levels"	10		10	2000
Nitromethane	3.5 - 100 (200-500)	100		100	1000
1-Nitropropane	11 - 300 (99-150)	25		25	2300
2-Nitropropane	48 - 300	10	LL	C-10,A2	Ca
Nitrotoluene (m, o, p isomers)		0.05 - 1.74	2		2200
Nitrous oxide	"poor"		25		
Nonane	0.1 - 47	200		200	
n-Octane	0.5 - 235	300/375	75 C-385	300/375	5000
Octanoic Acid	0.0014				
1-Octanol	0.0021 - 0.31	WEEL - 50			
2-Octanol	0.0026				
Oenanthic acid (Heptanoic acid)	0.015				
Oxygen difluoride	0.1 - 0.5, (fatigue)	C-0.05	C-0.5	C-0.05	0.5

Chemical	Warning Concentration <sup>2</sup>	PEL/TWA/STEL	Exposure Limits <sup>1</sup>		
			REL	TLV	IDLH
Ozone	0.0005 - 0.5 (1-3.7)	0.1/0.3		0.1/0.3	10
Parathion	0.48 mg/m <sup>3</sup>	0.1 mg/m <sup>3</sup>	0.15 mg/m <sup>3</sup>	0.1 mg/m <sup>3</sup>	20 mg/m <sup>3</sup>
Pelargonic acid (Nonyl Alcohol)	0.00086				
Pentaborane	0.8 (1)	0.005/0.015		0.005/0.015	3
Pentachlorophenol	9.3 mg/m <sup>3</sup> (0.3 - 10.9 mg/m <sup>3</sup> )	0.5 mg/m <sup>3</sup>		0.5 mg/m <sup>3</sup>	150 mg/m <sup>3</sup>
n-Pentane	2.2 - 1100	600/750	120 C-610	600/750	15000
2,4-Pentanedione	0.01 - 0.024				
2-Pentanone (Methyl propyl ketone)	3 - 14	200	150	200/250	5000
Pentanol (see amyl alcohol)					
Pentene (n-Amylene)	2.2				
n-Pentyl acetate (see n-Amyl acetate)					
1-Pentyl mercaptan	0.00021				
Perchloroethylene (see Tetrachloroethylene)					
Perchloromethyl mercaptan	0.001	0.1		0.1	10
Perchloryl fluoride	10 (but not reliable)	3/6		3/6	385
Pro-Klean-No-818	0.005				
Petroleum distillates (Petroleum naphtha)	< 500	400			1000
Phenol	0.005 - 5 (48)	5	5.2 C-15.6	5	250
Phenyl ether	0.001 - 0.10 (3-4)	1		1/2	N.A.
Phenyl ether-biphenyl mixture	0.1 - 1 (3-4)	1			N.A.
Phenyl isocyanide	0.029 mg/m <sup>3</sup>				

Chemical	Warning Concentration <sup>2</sup>	PEL/TWA/STEL	Exposure Limits <sup>1</sup>		
			REL	TLV	IDLH
Phenyl isothiocyanate	0.43				
Phosgene	0 125 - 6 (dulls senses) (1-2)	0.1	0.1	0.1	2
Phosphine	0.01 - 5 (7.7)	0.3/1		0.3/1	200
Phosphorous pentasulfide	"fatigue", 0.0047 (as H <sup>2</sup> S)	1 mg/m <sup>3</sup>		1/3 mg/m <sup>3</sup>	750 mg/m <sup>3</sup>
Phosphorous trichloride	0.7 (2-4)	0 2/0.5		0.2/0.5	50
Phthalic anhydride	0.05 - 0.12 (30 mg/m <sup>3</sup> )	1		1	16700
2-Picoline	0.023 - 0.046	WEEL - 2/5			
Propane	1000 - 20000	1000		(a)	20000
Propionaldehyde	0.04 - 1				
Propionic acid	0.001 - 20	10		10/15	
n-Propyl acetate	0 05 - 200	200/250		200/250	8000
Propyl alcohol	0.01 - 200 (5500)	200/250		200/250	4000
Propylene	23 - 67 6			(a)	
Propylene diamine	0.014 - 0.067				
Propylene dichloride	0.25 - 130	75/110		75/110	2000
Propylene glycol	"odorless"	WEEL - 500 ppm, Total 10 mg/m <sup>3</sup> Aerosol only			
Propylene glycol dinitrate	0 24	0.05			0.05
Propylene glycol monomethyl ether	10	100/150		100/150	
Propylene oxide	10 - 210 (457-473, animals)	100		20	2000
Propyl mercaptan	0.00075 - 0 02				
n-Propyl nitrate	50 - 90	25/40		25/40	2000
Propyl sulfide	0.011 - 0.17				
Pyridine	0.001 - 5 (fatigue at 5, but taste remains)	5		5	3600

Chemical	Warning Concentration <sup>2</sup>	PEL/TWA/STEL	Exposure Limits <sup>1</sup>		
			REL	TLV	IDLH
Pyrolgallo (1,2,3-trihydroxybenzene)	20				
Quinoline	0.16 - 71	WEEL - 0.1			
Quinone	0.08 - 0.5, fatigue (0.1-0.5)	0.1		0.1	75
Resorcinol (1,3-dihydroxylbenzene)	40	10/20		10/20	
Rotenone	"odorless", 222 mg/m <sup>3</sup>	5 mg/m <sup>3</sup>		5 mg/m <sup>3</sup>	5000 mg/m <sup>3</sup>
Safrole	0.0032				
Selenium oxide	0.0002 mg/m <sup>3</sup>	0.2 mg/m <sup>3</sup> (as Se)		0.2 mg/m <sup>3</sup> (as Se)	100 mg/m <sup>3</sup>
Silver Cyanide	"odorless"	0.01 mg/m <sup>3</sup> (as Se)		0.01 mg/m <sup>3</sup> (as Ag)	50 mg/m <sup>3</sup> (CN)
Skatole (3-Methyl indole)	7.5 x 10 <sup>-4</sup> - 1.68				
Sodium Butyldiphenol sulfonate	0.5 (as alky aryl sulfonate)				
Sodium butylphenylphenol sulfonate	0.5 (as alky aryl sulfonate)				
Sodium hydroxide	"odorless"	C-1 mg/m <sup>3</sup>	C-2 mg/m <sup>3</sup>	C-2 mg/m <sup>3</sup>	250 mg/m <sup>3</sup>
Sodium nitrochlorobenzene sulfonate	0.5 (as alky aryl sulfonate)				
Sodium octyl sulfate	0.2				
Sodium sulfate	"odorless"				
Sorbitol	"odorless"				
Stoddard solvent	1 - 30 (400)	100	350 mg/m <sup>3</sup>	100	5000
Strychnine	"odorless"	100	350 mg/m <sup>3</sup>	100	100
Styrene	0.001 - 200 (200-400)	50/100	50 C-100	50/100	5000
Styrene oxide	0.40				
Sulfoxide	91				

Chemical	Warning Concentration <sup>2</sup>	PEL/TWA/STEL	Exposure Limits <sup>1</sup>		
			REL	TLV	IDLH
Sulfur dichloride (SCl <sub>2</sub> )	0.001				
Sulfur dioxide	0.2 - 5 (6-20) 0.3-taste	2/5	0.5	2/5	100
Sulfuric acid	0.6 - 2.4 mg/m <sup>3</sup>	1 mg/m <sup>3</sup>	1 mg/m <sup>3</sup>	1 mg/m <sup>3</sup>	80 mg/m <sup>3</sup>
Sulfur monochloride (Sulfur chloride, S <sub>2</sub> Cl <sub>2</sub> )	0.001 (2-9)	C-1		C-1	10
Sulfuryl fluoride	"odorless"	5/10		5/10	1000
Tannic acid	2 - 4				
TEPP (HETP, Bladex, Vaportone)	"odorless"	0.05 mg/m <sup>3</sup>		0.004 mg/m <sup>3</sup>	10 mg/m <sup>3</sup>
Terphenyls	> 1	C-0.5		C-0.5	3500 mg/m <sup>3</sup>
1,1,2,2-Tetrachloroethane	0.2 - 8	1	LL	1	Ca
Tetrachlorethylene (Perchloroethylene)	2 - 50 (106-690)	25	ME	50/200	Ca
Tetraethyl-o-silicate	5.0 - 7.2				
Tetrahydrofuran	0.1 - 60	200/250		200/250	20000
Tetramethylbenzene	0.0029				
Tetranitromethane	(0.40)	1		1	5
Thiocresol (Toluenethiol)	0.0027 - 0.02				
Thiophenol (Phenyl mercaptan)	0.001 - 85	0.5		0.5	
Thymol	0.00086				
Toluene	0.02 - 70, fatigue (300-400)	100/150	100 C-200	100/150	2000 C-200
Toluene diisocyanate (TDI)	0.2 - 2.14	0.005/0.02	0.005 C-200	100/150	2000 C-200
Toxaphene (Phenatox)	2.4 mg/m <sup>3</sup>	0.5/1 mg/m <sup>3</sup>		0.5/1 mg/m <sup>3</sup>	200 mg/m <sup>3</sup>
1,2,4-Trichlorobenzene	1.4 - 3	C-5		C-5	
1,1,2-Trichloroethane	0.5 - 167	10	LL	10	Ca

Chemical	Warning Concentration <sup>2</sup>	PEL/TWA/STEL	Exposure Limits <sup>1</sup>		
			REL	TLV	IDLH
o-Tolidine	0.0048 - 20	5	C-0.02 mg/m <sup>3</sup>	2,A2	100
1,1,1-Trichloroethane (Methyl chloroform)	20 - 400 (500-1000)	350/450	C-350	350/450	1000
Trichloroethylene	0.2 - 400 (160)	50/200	25	50/200	Ca
Trichlorofluoromethane	5 - 209	C-1000		C-1000	
Trichlorophenol	0.1 - 0.667				
1,2,3-Trichloropropane	100 (100)	10		10	1000
1,1,2-trichloro-1,2,2-trifluoroethane	0.5 - 200	1000/1250		1000/1250	4500
Triethanolamine dodecylbenzene sulfonate	0.3				
Triethylamine	0.009 - 2.8 (50)	10/15		10/15	1000
Triethylene glycol	"practically odorless"				
Trimethylamine	0.0001 - 1 7	10/15 WEEL - 1		10/15	
Trimethylbenzene (Mesitylene)	0 006 - 2 4	25		25	
Trimethyl phosphite	0.001	2		2	
Trinitrobutylxylene	6.5 x 10 <sup>-6</sup> - 0 0008				
Triphenyl phosphate	"odorless"			3 mg	N.A.
Turpentine	50 - 200 (100-200)	100		100	1900
n-Undecane	0 12				
n-Valeraldehyde	0 001 - 8 2	50		50	
Valeric acid	0.00060				
ios Valeric acid	0.0018				
Vandium pentoxide - Dust/Fume	(0 5 - 2 2 mg/m <sup>3</sup> )	0.05 mg/m <sup>3</sup> 0.05 mg/m <sup>3</sup>	C-0.05 mg/m <sup>3</sup> 0.1 mg/m <sup>3</sup> (as Va)	0.05 mg/m <sup>3</sup> 0.05 mg/m <sup>3</sup>	70 mg/m <sup>3</sup>
Vanillin	3 2 x 10 <sup>-6</sup>				



Chemical	Warning Concentration <sup>2</sup>	PEL/TWA/STEL	Exposure Limits <sup>1</sup>		
			REL	TLV	IDLH
Vinyl acetate	0.1 - 1	10/20	C-4	10/20	
Vinyl chloride	260 - 3000	1	LD	5,A1	Ca
Vinyl toluene	10 - 50 (50)	100		50/100	5000
Warfarin	"odorless"	0.1 mg/m <sup>3</sup>		0.1 mg/m <sup>3</sup>	200 mg/m <sup>3</sup>
Xylene	0.05 - 200, fatigue (100-200)	100/150	100, C-200	100/150	1000
m-Xylene	0.08 - 40	100/150	100, C-200	100/150	1000
o-Xylene	0.08 - 40	100/150	100, C-200	100/150	1000
p-Xylene	0.08 - 40	100/150	100, C-200	100/150	1000
Xylidine	0.0048 - 0.06	2		2	150
Vinylidene chloride (1,1-Dichloroethylene)	190	1		5/20	
V M & P Naphtha	10	300/400	300		

<sup>1</sup> The exposure limits are 8-hour time-weighted averages (TWA) unless otherwise noted.

<sup>2</sup> Fatigue - Indicates that the chemical can cause olfactory fatigue.

(a) Simple asphyxiant Check oxygen concentration.

A1 Confirmed human carcinogen (ACGIH)

A2 Suspected human carcinogen (ACGIH).

animal Irritation concentration based on animal studies

C Ceiling limit Ceiling limits for REL may be limited to 10 minutes, 15 minutes or not to be exceeded for any time Check individual value.

Ca National Institute for Occupational Safety and Health (NIOSH) has recommended that the substance be treated as a potential human carcinogen; IDLH's are not listed for those substances.

HWC "To be handled in the workplace with caution" (NIOSH)

IDLH Immediately Dangerous to Life or Health, *NIOSH Pocket Guide to Chemical Hazards*, September 1985

LD "Reduce exposure to lowest reliably detectable level" (NIOSH)

LL "Reduce exposure to lowest feasible level" (NIOSH).

ME "Minimize occupational exposure" (NIOSH)

N.A. NIOSH has not assigned an IDLH.

NN Not applicable because of NIOSH REL

NE "No exposure limit recommended due to absence of a reliable monitoring method" (NIOSH).

P "Acceptable maximum peak above the acceptable ceiling concentration for an 8-hour shift " Each has a specific time limit

PEL Permissible Exposure Limits, "29 CFR 1910 Subpart Z," Occupational Safety and Health Administration (OSHA).

REL Recommended Exposure Limits, *NIOSH Recommendations for Occupational Safety and Health Standards*, NIOSH, 1988.

TLV Threshold Limit Value, *Threshold Limit Values and Biological Exposure Indices for 1988-1989*, American Conference of Governmental Industrial Hygienists (ACGIH)

STEL Short-term exposure limit.

WEEL *American Industrial Hygiene Association Workplace Environmental Exposure Level Guides*, 1988. This is not a PEL but is placed in that column due to space limitations. The first number is an 8-hour TWA The second number is a short-term TWA The time varies from 1-15 minutes. Check individual values.

## **APPENDIX C**

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### **Hazardous Materials Identification Systems**

## **HAZARDOUS MATERIALS IDENTIFICATION SYSTEMS**

Hazardous materials are frequently stored and transported in large quantities. An accidental release of these materials presents a potential hazard to the public and environment. Such an incident is managed more expeditiously when the hazardous material is specifically identified and characterized. Unfortunately, the contents of storage tanks or trucks may not be specifically or properly identified. Records or shipping papers may be inaccessible. Even with such information, an experienced person must define the hazards and their seriousness.

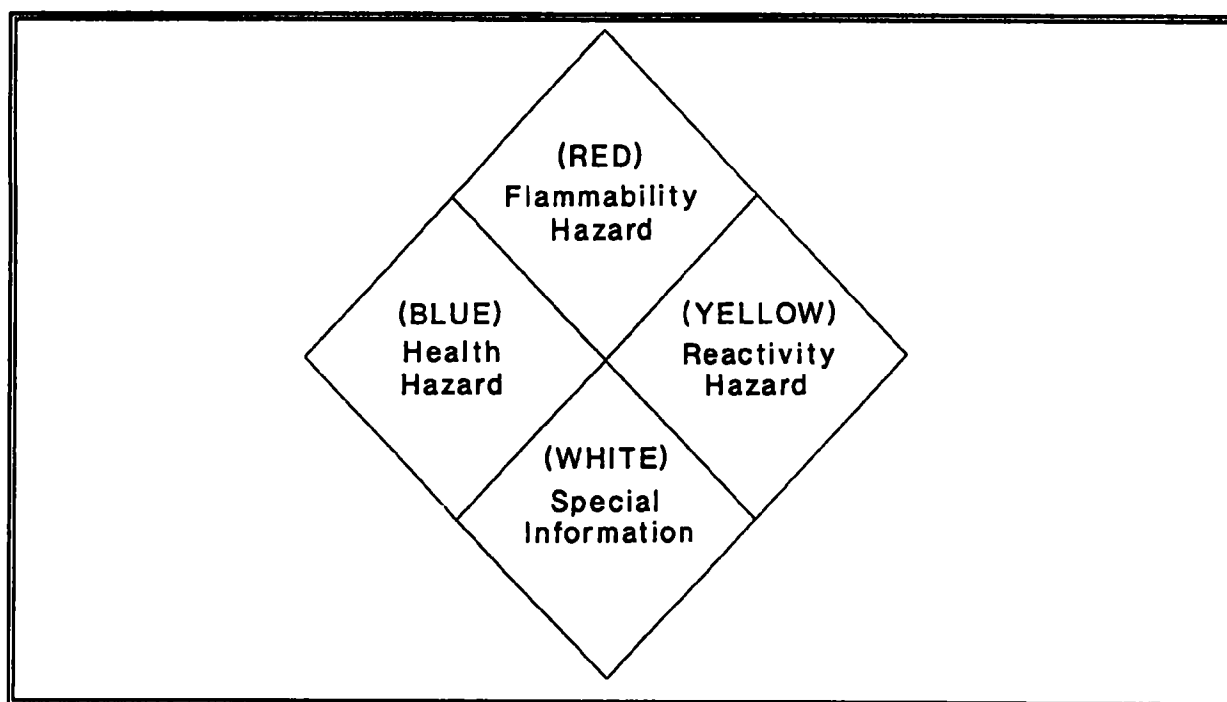
The immediate need for information concerning a hazardous material, required two systems for hazardous material identification. Both help responders to deal with a hazardous material incident quickly and safely, and both were devised for persons untrained in chemistry.

The first is the National Fire Protection Association (NFPA) 704 M System, which is used on storage tanks and smaller containers (fixed facility). The second system is used exclusively on containers and tanks transported in interstate commerce. The U.S. Department of Transportation (DOT) is responsible for this system. Its use, by way of placards and labels, is required under DOT regulations found in the Code of Federal Regulations 49 (49 CFR).

### **NFPA 704 M HAZARD IDENTIFICATION SYSTEM**

NFPA 704 M is a standardized system which uses numbers and colors on a sign to define the basic hazards of a specific material. Health, Flammability, and Reactivity are identified and rated on a scale of 0 to 4 depending on the degree of hazard presented (Figure 1).

The ratings for individual chemicals can be found in the NFPA *Guide to Hazardous Materials*. Other references such as the U.S. Coast Guard Manual, CHRIS Volume 2, and the National Safety Council's *Fundamentals of Industrial Hygiene* contain the NFPA ratings for specific chemicals. Such information can be useful not only in emergencies but also during long-term remedial activities when extensive evaluation must be completed.



**FIGURE 1**  
**NFPA 704 M HAZARD IDENTIFICATION SYSTEM**

### **704 M Hazard Ranking System**

#### **HEALTH HAZARD (BLUE):**

<b><u>Rank</u></b>	<b><u>Description</u></b>	<b><u>Examples</u></b>
<b>4</b>	Materials that on very short exposure could cause death or major residual injury even though prompt medical treatment was given.	Acrylonitrile, Parathion, Bromine
<b>3</b>	Materials that on short exposure could cause serious temporary or residual injury even though prompt medical treatment was given.	Aniline, Sodium Hydroxide, Sulfuric Acid
<b>2</b>	Materials that on intense or continued exposure could cause temporary incapacitation or possible residual injury unless prompt medical treatment was given.	Bromobenzene, Pyridine, Styrene
<b>1</b>	Materials that on exposure would cause irritation but only minor injury even if no hazard beyond that of ordinary combustible material.	Acetone, Methanol
<b>0</b>	Material that on exposure under fire conditions would offer no hazard beyond that ordinary combustible material.	

## FLAMMABILITY HAZARD (RED):


<u>Rank</u>	<u>Description</u>	<u>Examples</u>
4	Materials that (1) rapidly or completely vaporize at atmospheric pressure and normal ambient temperatures and burn rapidly or (2) are readily dispersed in air and burn readily.	1,3-Butadiene, Propane, Ethylene
3	Liquids and solids that can be ignited under almost all ambient temperature conditions.	Phosphorous, Acrylonitrile
2	Materials that must be moderately heated or exposed to relatively high ambient temperatures before ignition can occur.	2-Butanone, Kerosene
1	Materials that must be preheated before ignition can occur.	Sodium, Red Phosphorous
0	Materials that will not burn.	

## REACTIVITY HAZARD (YELLOW):

<u>Rank</u>	<u>Description</u>	<u>Examples</u>
4	Materials that in themselves are readily capable of detonation or of explosive decomposition or reaction at normal temperatures and pressures.	Benzoyl Peroxide, Picric Acid
3	Materials that (1) in themselves are capable of detonation or explosive reaction but require a strong initiating source or (2) must be heated under confinement before initiation or (3) react explosively with water.	Diborane, Ethylene Oxide, 2-Nitropropadene
2	Materials that (1) in themselves are normally unstable and readily undergo violent chemical change but do not detonate or (2) may react violently with water or (3) may form potentially explosive mixtures with water.	Acetaldehyde, Potassium
1	Materials that in themselves are normally stable but which can (1) become unstable at elevated temperatures or (2) react with water with some release of energy but not violently.	Ethyl Ether, Sulfuric Acid
0	Materials that in themselves are normally stable, even when exposed to fire, and that do not react with water.	

## SPECIAL INFORMATION (WHITE):

The white block is designated for special information about the chemical. For example, it may indicate that the material is radioactive by displaying the standard radioactive symbol, or unusually water-reactive by displaying a large W with a slash through it ( $\text{W}/$ ). For more complete information of these various hazards, consult Table 1, Special Information Designators.

<b>TABLE 1</b> <b>SPECIAL INFORMATION DESIGNATORS</b>	
<b>Designator</b>	<b>Special Hazard</b>
<b>W</b>	Water reactive
<b>OXY</b>	Oxidizer or oxidizing properties
<b>COR</b>	Corrosive
	Radioactive
<b>EXP</b>	Explosive
<b>TOX</b>	Toxic
<b>IGN</b>	Ignitable

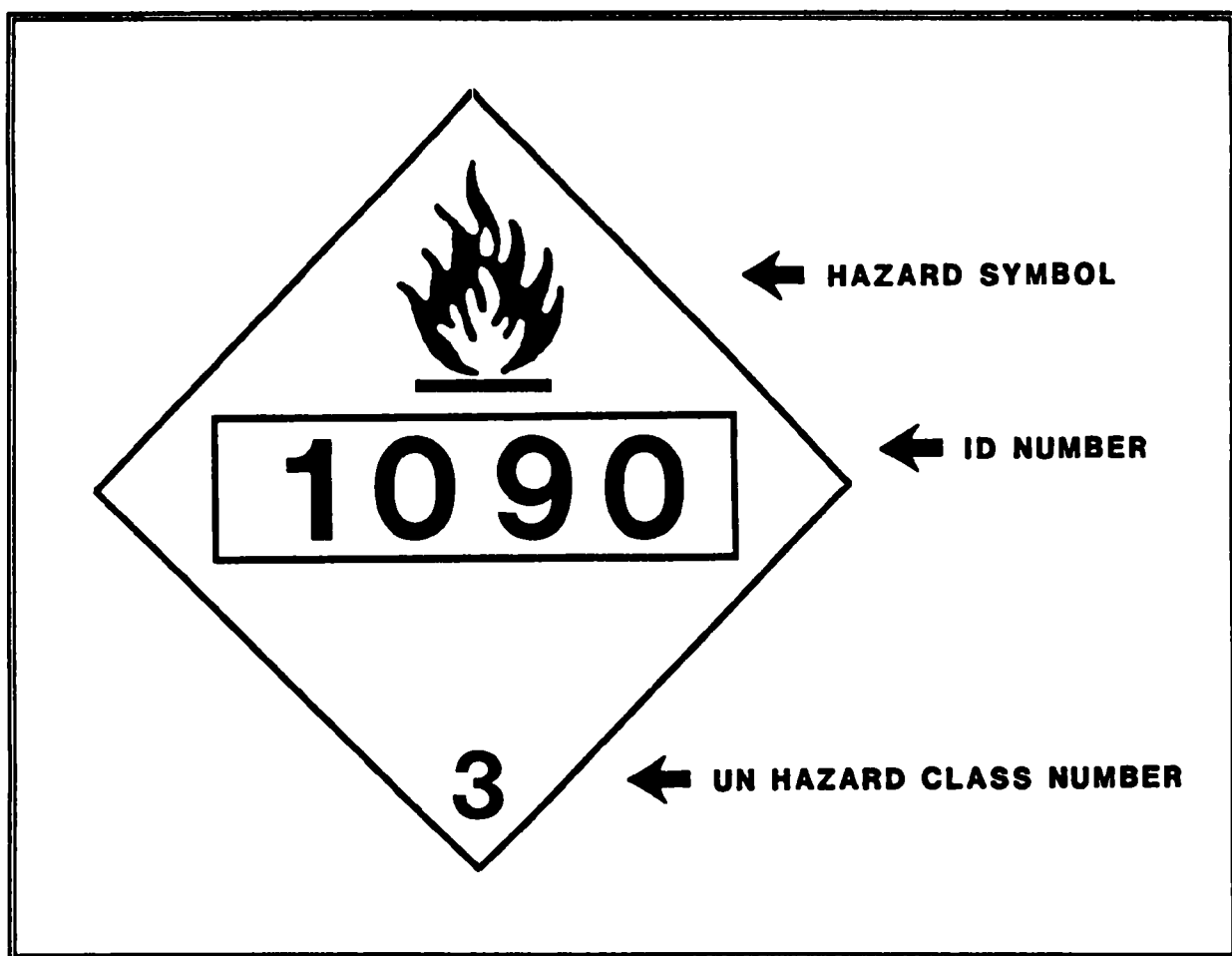
### **DOT HAZARD IDENTIFICATION SYSTEM**

DOT's Hazardous Materials Transportation Administration regulates over 1,400 hazardous materials. The regulations require labels on small containers and placards on tanks and trailers. These placards and labels indicate the nature of the hazard presented by the cargo. The classification used for the placards and labels is based on the United Nations Hazard Classes (Table 2). The UN hazard class number is found in the bottom corner of a DOT placard or label. The various hazards are defined in Table 3.

**TABLE 2**  
**UN HAZARD CLASS SYSTEM**

<b>United Nations Hazard Class Number</b>	<b>Description</b>
<b>1</b>	<b>Explosives</b>
<b>2</b>	<b>Nonflammable/flammable/poison compressed gases</b>
<b>3</b>	<b>Flammable/combustible liquids</b>
<b>4</b>	<b>Flammable solids, spontaneously combustible substances, and water-reactive substances</b>
<b>5</b>	<b>Oxidizing materials, including organic peroxides</b>
<b>6</b>	<b>Class B poisons, irritants, and etiologic (disease-causing) materials</b>
<b>7</b>	<b>Radioactive materials</b>
<b>8</b>	<b>Corrosive materials (acids, alkaline liquids, and certain corrosive liquids and solids)</b>
<b>9</b>	<b>Miscellaneous hazardous materials not covered by any of the other classes</b>

To facilitate handling a hazardous material incident some placards are being altered to accept a 4-digit identification number (Figure 2). This number comes from the Hazardous Material Table in the DOT regulations, 49 CFR 172.101. This ID number also must be written on the shipping papers or manifest. In the event of an incident, the ID number on the placard will be much easier to obtain than the shipping papers. Once the number is obtained, the DOT's *Emergency Response Guide Book* can be consulted. This book describes the proper methods and precautions for responding to a release of each hazardous material with an ID number. The DOT system goes one step further in aiding response personnel than the NFPA system. However, using both systems when responding to hazardous material incidents will help to identify properly and characterize the materials involved.



**FIGURE 2**  
**MODIFICATION OF DOT PLACARD**  
**HAZARDOUS MATERIAL TABLE**  
**49 CFR 172.101**

The following definitions have been abstracted from the Code of Federal Regulations, Title 49-Transportation, Parts 100-177. Refer to referenced sections for complete details.

**Note:** Rulemaking proposals are outstanding or are contemplated concerning some of these definitions.

**HAZARDOUS MATERIAL** - A substance or material which has been determined by the Secretary of Transportation to be capable of posing an unreasonable risk to health, safety, and property when transported in commerce, and which has been so designated. (Sec. 171.8)

**MULTIPLE HAZARDS** - A material meeting the definition of more than one hazard class is classed according to the sequence given in Sec. 173.2.



**TABLE 3**  
**HAZARDOUS MATERIALS DEFINITIONS**

Hazard Class	Definitions
	<u>An Explosive</u> - Any chemical compound, mixture, or device, the primary or common purpose of which is to function by explosion, i.e., with substantially instantaneous release of gas and heat, unless such compound, mixture, or device is otherwise specifically classified in Parts 170-177 (Sec. 173.50).
CLASS A EXPLOSIVE	Detonating or otherwise of maximum hazard. The nine types of Class A explosives are defined in Sec. 173.53.
CLASS B EXPLOSIVE	In general, function by rapid combustion rather than detonation and include some explosive devices such as special fireworks, flash powders, etc. <u>Flammable Hazard</u> . (Sec. 173.88)
BLASTING AGENT	A material designed for blasting which has been tested in accordance with Sec. 173.114a(b) and found to be so insensitive that there is very little probability of accidental initiation to explosion or of transition from deflagration to detonation. (Sec. 173.144a(a))
COMBUSTIBLE LIQUID	Any liquid having a flash point above 100°F and below 200°F as determined by tests listed in Sec. 173.115(d). Exceptions are found in Sec. 173.115(b).
CORROSIVE MATERIAL	Any liquid or solid that causes visible destruction of human skin tissue or a liquid that has a severe corrosion rate on steel. (See Sec. 173.240(a) and (b) for details.)
FLAMMABLE LIQUID	Any liquid having a flash point below 100°F as determined by tests listed in Sec. 173.115(d). For exceptions, see Sec. 173.115(a).
	<u>Pyroforic Liquid</u> - Any liquid that ignites spontaneously in dry or moist air at or below 130°F. (Sec. 173.115(c))
	<u>Compressed Gas</u> - Any material or mixture having in the container a pressure exceeding 40 psia at 70°F, or a pressure exceeding 104 psia at 130°F; or any liquid flammable material having a vapor pressure exceeding 40 psia at 100°F. (Sec. 173.300(a))
FLAMMABLE GAS	Any compressed gas meeting the requirements for lower flammability limit, flammability limit range, flame projection, or flame propagation criteria as specified in Sec. 173.300(b).
NONFLAMMABLE GAS	Any compressed gas other than a flammable compressed gas.
FLAMMABLE GAS	Any solid material, other than an explosive, which is liable to cause fires through friction, retained heat from manufacturing or processing, or which can be ignited readily and when ignited burns so vigorously and persistently as to create a serious transportation hazard. (Sec. 173.150)
ORGANIC PEROXIDE	An organic compound containing the bivalent -O-O structure and which may be considered a derivative of hydrogen peroxide where one or more of the hydrogen atoms have been replaced by organic radicals must be classed as an organic peroxide unless -- (see Sec. 173.151(a) for details).
OXIDIZER	A substance such as chlorate, permanganate, inorganic peroxide, or a nitrate that yields oxygen to readily stimulate the combustion of organic matter (see Sec. 173.151).

**TABLE 3 (Continued)**  
**HAZARDOUS MATERIALS DEFINITIONS**

<b>Hazard Class</b>	<b>Definitions</b>
<b>POISON A</b>	<u>Extremely Dangerous Poisons</u> - Poisonous gases or liquids of such nature that a very small amount of the gas, or vapor of the liquid, mixed with air is <u>dangerous to life</u> . (Sec. 173.326)
<b>POISON B</b>	<u>Less Dangerous Poisons</u> - Substances, liquids, or solids (including pastes and semi-solids), other than Class A or Irritating materials, which are known to be so toxic to man as to afford a hazard to health during transportation; or which, in the absence of adequate data on human toxicity, are presumed to be <u>toxic to man</u> . (Sec. 173.343)
<b>IRRITATING MATERIAL</b>	A liquid or solid substance which upon contact with fire or when exposed to air gives off dangerous or intensely irritating fumes, but <u>not including any poisonous material, Class A</u> . (Sec. 173.381)
<b>ETIOLOGIC AGENT</b>	An "etiologic agent" means a viable micro-organism, or its toxin which causes or may cause human disease. (Sec. 173.386)
<b>RADIOACTIVE MATERIAL</b>	Any material, or combination of materials, that spontaneously emits ionizing radiation, and having a specific activity greater than 0.002 microcuries per gram. (Sec. 173.389) <i>Note</i> . See Sec. 173.389(a) and (1) for details.
<b>ORM-OTHER REGULATION MATERIALS</b>	(1) Any material that may pose an unreasonable risk to health and safety or property when transported in commerce; and (2) does not meet any of the definitions of the other hazard classes specified; or (3) has been reclassified an ORM (specifically or permissively) according to this subchapter (Sec. 173.500(a)). <i>Note</i> : A material with a flashpoint of 100°F may not be classed as an ORM if it is a hazardous waste or is offered in a packaging having a rated capacity of more than 110 gallons.
<b>ORM-A</b>	A material which has an anesthetic, irritating, noxious, toxic, or other similar property and which can cause extreme annoyance or discomfort to passengers and crew in the event of leakage during transportation. (Sec. 173.500 <sup>(b)</sup> (1))
<b>ORM-B</b>	A material (including a solid when wet with water) capable of causing significant damage to a transport vehicle or vessel from leakage during transportation. Materials meeting one or both of the following criteria are ORM-B materials: (i) A liquid substance that has a corrosion rate exceeding 0.250 inch per year (IPY) on aluminum (nonclad 7075-T6) at a test temperature of 130°F. An acceptable test is described in NACE Standard TM-01-69, and (ii) specifically designated by name in Sec. 172.101. (Sec. 173.500 <sup>(b)</sup> (2))
<b>ORM-C</b>	A material which has other inherent characteristics not described as an ORM-A or ORM-B but which makes it unsuitable for shipment, unless properly identified and prepared for transportation. Each ORM-C material is specifically named in Sec. 172.101. (Sec. 173.500 <sup>(b)</sup> (3))
<b>ORM-D</b>	A material such as a consumer commodity which, though otherwise subject to the regulations of this subchapter, presents a limited hazard during transportation due to its form, quantity and packaging. They must be materials for which exceptions are provided in Sec. 172.101. A shipping description applicable to each ORM-D material or category of ORM-D materials is found in Sec. 172.101. (Sec. 173.500 <sup>(b)</sup> (4))

**TABLE 3 (Continued)**  
**HAZARDOUS MATERIALS DEFINITIONS**

<b>Hazard Class</b>	<b>Definitions</b>
<b>ORM-E</b>	A material that is not included in any other hazard class, but is subject to the requirements of this subchapter. Materials in this class include (i) Hazardous waste and (ii) Hazardous substances as defined in Sec. 171.8. (Sec. 173.500 <sup>(b)</sup> (5))
<b>THE FOLLOWING ARE OFFERED TO EXPLAIN ADDITIONAL TERMS USED IN PREPARATION OF HAZARDOUS MATERIALS FOR SHIPMENT. (SEC. 171.8)</b>	
<b>CONSUMER COMMODITY (See ORM-D)</b>	Means a material that is packaged or distributed in a form intended and suitable for sale through retail sales agencies or instrumentalities for consumption by individuals for purposes of personal care or household use. This term also includes drugs and medicines. (Sec. 171.8)
<b>FLASHPOINT</b>	Means the minimum temperature at which a substance gives off flammable vapors which in contact with a spark or flame will ignite. For liquids, see Sec. 173.115, for solids, see Sec. 173.150.
<b>FORBIDDEN</b>	Means that the material is prohibited from being offered or accepted for transportation. <i>Note:</i> This prohibition <u>does not</u> apply if these materials are diluted, stabilized, or incorporated in devices and they are classed in accordance with the definitions of hazardous materials. (Sec. 172.101(d)(1))
<b>HAZARDOUS SUBSTANCES</b>	For transportation purposes, means a material, and its mixtures or solutions, that is identified by the letter "E" in Column 2 of the Hazardous Materials Table to Sec. 172.101 when offered for transportation in one package, or in one transport vehicle if not packaged, and when the quantity of the material therein equals or exceeds the reportable quantity (RQ). For details, refer to Sec. 171.8 and Sec. 172.101, Hazardous Materials Table
<b>HAZARDOUS WASTES</b>	For transportation purposes, means any material that is subject to the hazardous waste manifest requirements of the Environmental Protection Agency in CFR, Title 40, Part 123, Chapter F. (Sec. 171.8) For details on the Hazardous Waste and Consolidated Permit Regulations, refer to CFR, Title 40, Parts 260-267 and Parts 122-125. Questions regarding these regulations, call Toll Free: 800/424-9346 or 202/554-1404.
<b>LIMITED QUANTITY</b>	Means the maximum amount of a hazardous material; as specified in those sections applicable to the particular hazard class, for which there are <u>specific exceptions</u> from the requirements of this subchapter. See Sec. 173.118, 173.118(a), 173.153, 173.244, 173.306, 173.345 and 173.364.
<b>REPORTABLE QUANTITY</b>	For transportation purposes, means the quantity of hazardous substance and/or hazardous waste specified in the Hazardous Material Table, Column 2 and identified by the letter "E" in Column 1. (Sec. 171.8)
<b>SPONTANEOUSLY COMBUSTIBLE MATERIAL (SOLID)</b>	Means a solid substance (including sludges and pastes) which may undergo spontaneous heating or self-ignition under conditions normally incident to transportation or which may, upon contact with the atmosphere, undergo an increase in temperature and ignite. (Sec. 171.8)
<b>WATER REACTIVE MATERIAL (SOLID)</b>	Means any solid substance (including sludges and pastes) which, by interaction with water, is likely to become spontaneously flammable or to give off flammable or toxic gases in dangerous quantities. (Sec. 171.8)

## **U.S. DEPARTMENT OF TRANSPORTATION**

### **Research and Special Programs Administration**

This handout (revised 1981) is designed as a training aid for all interested parties who may become involved with hazardous materials. It does not relieve persons from complying with the Department of Transportation Hazardous Materials Regulations. Final authority for use of these hazard classes and definitions is found in CFR, Title 49, Parts 100-177.

Information Services Division, DMT-11  
Office of Operations and Enforcement  
Materials Transportation Bureau  
Research and Special Programs Administration  
Department of Transportation  
Washington, DC 20590

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Each hazardous material is assigned an identification number. Those numbers that are preceded by a "UN" (United Nations Class) are associated with descriptions considered appropriate for international shipments as well as domestic shipments. Those hazardous materials that are preceded by an "NA" are associated with descriptions that are not recognized for international shipment except to and from Canada. Each label, placard or shipping paper must contain the UN and IMO (International Maritime Organization) hazard class number and, when appropriate, the division number. The number must be Black or another authorized color, located in the lower corner of the placard or label or in the hazardous materials description on shipping papers. The number must be one-half inch (12.7 mm.) or less in height. In certain cases, the Class or Division number may replace the written name of the hazard class in the shipping paper description. The United Nations Class and Division numbers have the following meanings:

#### **Class 1**

#### **Explosives**

Division 1.1	Explosives with a mass explosion hazard
Division 1.2	Explosives with a projection hazard
Division 1.3	Explosives with predominantly a fire hazard
Division 1.4	Explosives with no significant blast hazard
Division 1.5	Very insensitive explosives

#### **Class 2**

#### **Gases**

Division 2.1	Flammable gases
Division 2.2	Nonflammable gases
Division 2.3	Poison gases

<b><u>Class 3</u></b>	<b><u>Flammable liquids</u></b>
Division 3.1	Flashpoint below -18°C (0°F)
Division 3.2	Flashpoint -18°C and above but less than 23°C (73°F)
Division 3.3	Flashpoint of 23°C and up to 61°C (141°F)
<b><u>Class 4</u></b>	<b><u>Flammable solids; Spontaneously combustible materials; and, Materials dangerous when wet</u></b>
Division 4.1	Flammable solids
Division 4.2	Spontaneously combustible materials
Division 4.3	Materials that are dangerous when wet
<b><u>Class 5</u></b>	<b><u>Oxidizers and Organic peroxides</u></b>
Division 5.1	Oxidizers
Division 5.2	Organic peroxides
<b><u>Class 6</u></b>	<b><u>Poisonous and Etiologic (infectious) materials</u></b>
Division 6.1	Poisonous materials
Division 6.2	Etiologic (infectious) materials
<b><u>Class 7</u></b>	<b><u>Radioactive materials</u></b>
<b><u>Class 8</u></b>	<b><u>Corrosives</u></b>
<b><u>Class 9</u></b>	<b><u>Miscellaneous hazardous materials</u></b>

### **Placarding**

Under DOT's requirements, each end and each side of a motor vehicle, rail car, freight container, or portable tank containing hazardous materials must have a diamond-shape placard for the hazardous materials that are transported.

For materials illustrated in Tables 4a and 4b, the placarding rules apply to any quantity transported in a motor vehicle. Freight container or rail car must be placarded as illustrated.

**TABLE 4A**  
**DOT TABLE 1 PLACARDING TABLE 49 CFR 172.504**

<b>United Nations Hazard Class Number</b>	<b>Hazardous Material Described As</b>	<b>Placards</b>
1	Class A explosives	EXPLOSIVES
1	Class B explosives	EXPLOSIVES B
2	Poison A	POISON GAS
4	Flammable solid	FLAMMABLE SOLID (DANGEROUS WHEN WET label only)
7	Radioactive material: Uranium hexafluoride, fissile (containing more than 0.7% U <sup>235</sup> ) Uranium hexafluoride, low specific activity (containing 0.7% or less U <sup>235</sup> )	RADIOACTIVE AND CORROSIVE  RADIOACTIVE AND CORROSIVE

The placarding shown in Table 4a was in effect as of January 1, 1991. If it is used, all DOT hazard communications must be in compliance with it.

**TABLE 4A**  
**DOT TABLE 1 PLACARDING TABLE 49 CFR 172.504**

<b>Category of Material (Hazard or Division Number)</b>	<b>Placard to be Utilized</b>	<b>Reference Number for Placard Design</b>
1.1	Explosives 1.1	172.522
1.2	Explosives 1.2	172.522
1.3	Explosives 1.3	171.522
2.3	Poison Gas	172.540
4.3	Dangerous When Wet	172.542
6.1 (PGI, Inhalation Hazard Only)	Poison	172.554
7 RAD (Yellow III Labeling)	Radioactive	172.556

For the materials illustrated in **Tables 5a** and **5b**, motor vehicles, freight containers, or rail cars are not required to be placarded until the aggregate total weight of the hazardous materials reaches a weight of 1000 pounds or more. If 5000 pounds or more of any materials illustrated in **Table 5a** or **5b** are loaded in a motor vehicle, freight container, or rail car at one facility, then the appropriate placard for that material must be attached to the container, regardless of what placards may already be on the units.

The placarding shown in **Table 5a** is in effect as of January 1, 1991. If it is used, all DOT hazard communications must be in compliance with it.

<b>TABLE 5A</b> <b>DOT TABLE 2 PLACARDING TABLE 49 CFR 172.504</b>		
<b>United Nations Hazard Class Number</b>	<b>Hazardous Material Described as</b>	<b>Placards</b>
3	Class C explosives	DANGEROUS
1.5	Blasting agent	BLASTING AGENT
2	Nonflammable gas	NONFLAMMABLE GAS
2	Nonflammable gas	NONFLAMMABLE GAS
2	Nonflammable gas (chlorine)	CHLORINE
2	Nonflammable gas (fluorine)	POISON
2	Nonflammable gas (oxygen), pressurized liquid)	OXYGEN
2	Flammable gas	FLAMMABLE GAS
3	Combustible Liquid	COMBUSTIBLE
3	Flammable liquid	FLAMMABLE
4	Flammable solid	FLAMMABLE SOLID
5	Oxidizer	OXIDIZER
5	Organic peroxide	ORGANIC PEROXIDE
6	Poison B	POISON
8	Corrosive material	CORROSIVE
9	Irritating material	DANGEROUS

**TABLE 5B**  
**DOT TABLE 2 PLACARDING TABLE 49 CFR 172.504**

<b>United Nations Hazard Class Number</b>	<b>Hazardous Material Described as</b>	<b>Placards</b>
1.4	Explosives 1.4	172.523
1.5	Explosives 1.5	172.524
1.6	Explosives 1.6	172.525
2.1	Flammable gas	172.532
2.2	Nonflammable gas	172.528
3	Flammable	172.542
Combustible Liquid	Combustible	172.544
4.1	Flammable Solid	172.546
4.2	Spontaneously Combustible	172.547
5.1	Oxidizer	172.550
5.2	Organic Peroxide	172.552
6.1 (PGI or II other than PGI Inhalation Hazard)	Poison	172.554
6.1 (PGIII)	Keep Away From Food	172.553
6.2	(NONE)	
8	Corrosive	172.558
9	Class 9	172.560
ORM-D	(NONE)	

In many instances, a placard will contain a 4-digit identification number rather than a descriptive term. This 4-digit number comes from the Hazardous Material Table in the DOT regulations, 49 CFR 172.101. This ID number must also be written on the shipping papers or manifest. To identify the hazardous material, responders should look for the ID number in DOT's *Emergency Response Guide Book*. This book provides basic response guidelines and precautions that should be used during an initial response to a release of hazardous materials.



## **Labeling**

DOT also requires the labeling of individual packages containing hazardous materials. When labeling is required, each label must be affixed to or printed on the surface of the package near the marked proper shipping name. Also, each label must either be affixed to a background of contrasting color or have a dotted or solid line outer border. For hazardous materials that meet the definition of one or more hazards, warning labels representing each hazard are required and must be displayed next to each other. For example, a material classed as a flammable solid, that also meets the definition of a water reactive material, must have both FLAMMABLE SOLID and DANGEROUS WHEN WET labels affixed to the package. When two or more packages containing hazardous materials are packaged within the same overpack, the outside container must be labelled as required with each hazardous material that is contained within the overpack. Reference Label Chart, following page.

In addition, each label that is affixed to or printed on a package must be durable and weather resistant. The colors on a label must be able to withstand without substantial change: (1) a 72-hour fadeometer test or (2) a 30-day exposure to conditions incident to transportation that reasonably could be expected to be encountered by the labeled package (e.g., differing weather conditions, temperature changes, and handling by numerous persons).

## **Package Identification**

Packages or containers that are used for the shipment of hazardous materials must be manufactured, assembled, and marked in accordance with the DOT requirements. Each package or container must identify the DOT specification in effect on the date that the package or container was manufactured. In addition, each specification container must be marked in an unobstructed area with letters and numerals identifying the container specification (e.g., DOT-1A, DOT-17E-304HT, DOT-23G40). The name and address or symbol of the person making this mark must be registered with the Director, OHMT. These markings must be at least one-half inch high and should be stamped, embossed, burned, or printed on the package to ensure that the markings can be seen and are understood. Tank cars and appurtenances may only be used for the transportation of hazardous materials where the tank cars have been approved by the Association of American Railroads' Committee on Tank Cars for use in transporting hazardous materials. Each tank car that has been approved by the Committee on Tank Cars can be identified by a DOT specification number that has been embossed or marked in the tank car by the manufacturer. Likewise, packages may be identified by numbers which are printed on the package by the manufacturer. For example, the EPA regulations required that all pesticides be registered with the EPA. This pesticide registration number is useful for identifying the particular pesticide and the manufacturer.

## **Containers of Radioactive Material**

Radioactive materials may be packaged in drums, tanks, or other suitable packages. A container of gamma radioactive material generally includes some additional "shielding" material such as lead or iron to prevent the radiation from being emitted through the container.

Alpha and beta radioactive material may be packaged in containers that are of sufficient quality to hold a hazardous material.

Containers of radioactive material must be clearly labelled. Each label must be durable, clearly visible, bear the radiation caution symbol, and the words: "CAUTION, RADIOACTIVE MATERIAL" or "DANGER, RADIOACTIVE MATERIAL." In addition, the label should provide sufficient information to permit individuals handling the containers to take adequate precautions to avoid or minimize exposures.

### **Shipping Papers**

When hazardous materials are transported, the materials must be specifically identified on the shipping paper. A shipping paper should describe the shipping name of the hazardous material, its classification and its ID number. With certain exceptions, shipping papers identifying hazardous materials are required to be:

- in the cab of the motor vehicle
- in the possession of a train crew member
- kept in a holder on the bridge of a vessel
- in an aircraft pilot's possession.

The DOT regulations require that a (shipping) description on the shipping paper include:

- the shipper's name and address
- the consignee's name and address
- the proper shipping name as shown in the commodity list
- the proper hazard classification of the shipment (e.g., oxidizing material, flammable liquid)
- the identification number (preceded by "UN" or "NA") that has been assigned to the hazardous material
- the total quantity by weight or volume
- a certification by the shipper that the shipment has been properly prepared
- emergency response information (Material Safety Data Sheets [MSDS] or ERG or equivalent) and 24-hour emergency response telephone number.

Typically, the shipping paper that accompanies a shipment of hazardous materials that is transported by highway is called a Bill of Lading. A Bill of Lading is a receipt that is issued by the trucker that lists all materials of shipment as well as the hazardous materials that are being transported. A Bill of Lading must be prepared in accordance with DOT requirements for shipping papers that are described above. The driver of the motor vehicle or truck containing the hazardous material must clearly make this shipping distinctive and recognizable from other shipping papers by tabbing it or having it appear first. Also, the driver of the motor vehicle at the vehicle's controls must be certain that the shipping paper is either within his immediate reach or visible to a person entering the driver's cab. When the driver is not at the controls, the shipping paper may be either in a holder which is mounted to the inside of the door on the driver's side of the vehicle, or on the driver's seat.

## **FEDERAL HAZARD COMMUNICATION STANDARD (HazCom)**

In 1983, the Occupational Safety and Health Administration (OSHA) announced its Federal Hazard Communications Standard, 29 CFR 1910.1200, referred to as HazCom. The law guarantees the right to information about hazardous chemicals in the workplace. This law is referred to as the "Right to Know" law.

The Federal Hazard Communication Standard, HazCom, establishes requirements in the following four areas:

- Determining the chemical hazards in a workplace
- Labeling chemicals that are hazardous
- Maintaining MSDS that provide information about the hazardous chemicals
- Providing a written hazardous chemical training program.

### **Determining Chemical Hazards in a Workplace**

There are many different hazardous chemicals. HazCom groups hazardous chemicals into two (2) types: physical hazards and health hazards.

Chemicals that are physical hazards are flammable, corrosive, or reactive. Flammable chemicals can cause fires; corrosive chemicals can cause chemical burns; and reactive chemicals can cause explosions or release toxic fumes.

Chemicals that are health hazards are toxic chemical poisons. Overexposure to these chemicals can cause acute, or immediate, effects such as nausea or vomiting. Overexposure to some of these chemicals can cause chronic, or long-term, effects such as liver damage or cancer.

### **Labeling Requirements**

HazCom requires that all containers of hazardous chemicals entering or leaving the workplace must be labeled. The label must show the identity of the hazardous chemical, appropriate hazard warnings (i.e., flammable, corrosive), and the name and address of the manufacturer, distributor, or importer.

The label may also include picture symbols that help to identify the hazard and show the proper personal safety equipment to use when working with the chemical.

Labeling is also required for portable containers filled with chemicals from other containers. Tanks and other nonmovable containers may be labeled by using the National Fire Protection Association (NFPA) fire diamonds or the Hazardous Materials Identification System (HMIS) labels.

## **Material Safety Data Sheets**

MSDS required by HazCom must contain the following information:

- The identity of the material
- An emergency telephone number
- A list of hazardous ingredients
- Fire and explosion data
- Health hazard data
- Precautions for safe handling and use
- Proper employee protection measures

## **Written Training Program**

Written training programs are required by HazCom. The training program details how a company intends to implement HazCom, and the type and kinds of training the company intends to conduct.

## **HazCom Identification Systems**

Labeling for hazardous chemicals entering or leaving the workplace are governed by federal regulations. HazCom and Department of Transportation (DOT) regulations govern labels, placards, and warning signs for shipping hazardous chemicals.

Each of the different types of signs and labels serves a purpose. One type of chemical labeling are written warnings such as:

- Corrosive - Chemicals that cause chemical burns
- Flammable - Chemicals that can cause fires
- Toxic - Poisonous chemicals
- Oxidizer - Chemicals that support combustion
- Dangerous when wet - Chemicals that react with water and explode or produce toxic fumes

Another type of labeling is color coding. Three systems that are used in color coding are the National Fire Protection Association's 704 M Hazard Identification System (see above), the Hazardous Materials Identification System (HMIS) and Department of Transportation (DOT).























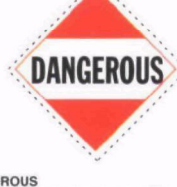



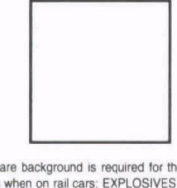


The Hazardous Materials Identification System (HMIS) labels also use the colors red, blue, yellow and white and number 0 through 4. HMIS labels are rectangular, with the colors in horizontal stripes. As with the NFPA system, the red, blue, and yellow stripes indicate fire, health, and reactivity respectively, and higher numbers show more severe hazards. The white section is used to show the proper personal protection gear to be used when working with the hazardous chemical.

DOT labels are similar to the picture symbols discussed earlier. DOT labels are color-coded squares or diamonds that are attached to hazardous chemicals being shipped. Some examples of DOT labels are:

- **Red**                      Flammable liquid or gas              Flame
- **Yellow**                      Oxygen or oxidizer              Flame circled at base
- **Orange**                      Explosive              Explosion
- **Green**                      Compressed gas              Gas cylinder
- **Black & White**              Corrosive              Drops eating a hole in a person's hand
- **Blue**                      Dangerous when wet              Flame

DOT placards are fixed to the outside of the vehicles that carry hazardous chemicals. They are similar to the warning labels, but they may not carry a written warning. Instead, they may contain a 4-digit number that is the United Nations identification code for that material being shipped.

# HM 181 HAZARDOUS MATERIALS PLACARDING CHART

<div>CLASS 1</div> <div></div> <div>EXPLOSIVES 1.1, 1.2, &amp; 1.3 *The Division number 1.1, 1.2 or 1.3 and compatibility group are in black ink. Placard any quantity of Division number 1.1, 1.2 or 1.3 material.</div>	<div>CLASS 1</div> <div></div> <div>EXPLOSIVES 1.4 *The compatibility group is in black ink. Placard 454 kg (1001 lbs.) or more of 1.4 Explosives.</div>	<div>CLASS 1</div> <div></div> <div>EXPLOSIVES 1.5 *The compatibility group is in black ink. Placard 454 kg (1001 lbs.) or more of 1.5 Blasting Agents.</div>	<div>CLASS 1</div> <div></div> <div>EXPLOSIVES 1.6 *The compatibility group is in black ink. Placard 454 kg (1001 lbs.) or more of 1.6 Explosives.</div>	<div>CLASS 2</div> <div></div> <div>OXYGEN Placard 454 kg (1001 lbs.) or more aggregate gross weight of either oxygen compressed and oxygen, refrigerated liquid. See 172.504(f)(7).</div>
<div>CLASS 2</div> <div>Division 2.1</div> <div></div> <div>FLAMMABLE GAS Placard 454 kg (1001 lbs.) or more of flammable gas. See DANGEROUS.</div>	<div>CLASS 2</div> <div>Division 2.2</div> <div></div> <div>NON-FLAMMABLE GAS Placard 454 kg (1001 lbs.) or more aggregate gross weight of non-flammable gas. See DANGEROUS.</div>	<div>CLASS 2</div> <div>Division 2.3</div> <div></div> <div>POISON GAS Placard any quantity of Division 2.3 material.</div>	<div>CLASS 3</div> <div></div> <div>FLAMMABLE Placard 454 kg (1001 lbs.) or more gross weight of flammable liquid. See DANGEROUS.</div>	<div>CLASS 3</div> <div></div> <div>GASOLINE May be used in the place of FLAMMABLE on a placard displayed on a cargo tank or a portable tank being used to transport gasoline by highway. See 172.542(c).</div>
<div>CLASS 3</div> <div></div> <div>COMBUSTIBLE Placard a combustible liquid when transported in bulk. A FLAMMABLE placard may be used in place of a Combustible placard on a cargo tank or a compartmented tank car. See 172.504(f)(2).</div>	<div>CLASS 3</div> <div></div> <div>FUEL OIL May be used in place of COMBUSTIBLE on a placard displayed on a cargo tank or portable tank being used to transport by highway fuel oil not classed as a flammable liquid. See 172.544(c).</div>	<div>CLASS 4</div> <div>Division 4.1</div> <div></div> <div>FLAMMABLE SOLID Placard 454 kg (1001 lbs.) or more gross weight of flammable solid. See DANGEROUS.</div>	<div>CLASS 4</div> <div>Division 4.2</div> <div></div> <div>SPONTANEOUSLY COMBUSTIBLE Placard 454 kg (1001 lbs.) or more gross weight of spontaneously combustible material. See DANGEROUS.</div>	<div>CLASS 4</div> <div>Division 4.3</div> <div></div> <div>DANGEROUS WHEN WET MATERIAL Placard any quantity of Division 4.3 material.</div>
<div>CLASS 5</div> <div>Division 5.1</div> <div></div> <div>OXIDIZER Placard 454 kg (1001 lbs.) or more gross weight of oxidizing material. See DANGEROUS.</div>	<div>CLASS 5</div> <div>Division 5.2</div> <div></div> <div>ORGANIC PEROXIDE Placard 454 kg (1001 lbs.) or more gross weight of organic peroxide. See DANGEROUS.</div>	<div>CLASS 6</div> <div>Division 6.1 Packing Groups I &amp; II</div> <div></div> <div>POISON Placard 454 kg (1001 lbs.) or more gross weight of Packing Groups I &amp; II. See DANGEROUS. Placard any quantity of Inhalation Hazard 6.1, PGI.</div>	<div>CLASS 6</div> <div>Division 6.1 Packing Group III</div> <div></div> <div>KEEP AWAY FROM FOOD Placard 454 kg (1001 lbs.) or more gross weight of Packing Group III. See DANGEROUS. A POISON placard may be used in place of a KEEP AWAY FROM FOOD placard.</div>	<div>CLASS 7</div> <div></div> <div>RADIOACTIVE Placard any quantity of packages bearing the RADIOACTIVE YELLOW III label. Certain low specific activity radioactive materials in "exclusive use" will not bear the label, but the RADIOACTIVE placard is required.</div>
<div>CLASS 8</div> <div></div> <div>CORROSIVE Placard 454 kg (1001 lbs.) or more gross weight of corrosive material. See DANGEROUS.</div>	<div>CLASS 9</div> <div></div> <div>MISCELLANEOUS A Class 9 placard is not required. However, you may placard 454 kg (1001 lbs.) or more gross weight of a material which presents a hazard during transport, but which is not included in any other hazard class. See DANGEROUS.</div>	<div></div> <div>DANGEROUS Placard 454 kg (1001 lbs.) gross weight of two or more categories of hazardous materials listed in Table 2. A freight container, unit load device, transport vehicle or rail car which contain non-bulk packages with two or more categories of hazardous materials that require different placards specified in Table 2 may be placarded with DANGEROUS placards instead of the separate placarding specified for each of the materials in Table 2. However, when 2,268 kg (5000 lbs.) or more of one category of material is loaded therein at one loading facility, the placard specified in Table 2 for that category must be applied. Division 1.4 (explosives) Division 1.5 (blasting agents) Division 1.6 (explosives) Division 2.1 (flammable gas) Division 2.2 (non-flammable gas) Class 3 (flammable liquid) Combustible liquid Division 4.1 (flammable solid) Division 4.2 (spontaneously combustible) Division 5.1 (oxidizer) Division 5.2 (organic peroxide) Division 6.1, PG I &amp; II, other than PG I INHALATION HAZARD (poison) Division 6.1, PG III (keep away from food) Class 8 (corrosive) Class 9 (miscellaneous)</div>	<div>SUBSIDIARY RISK PLACARD</div> <div></div> <div>DANGEROUS WHEN WET Class or division numbers do not appear on subsidiary risk placards.</div>	
<div></div> <div>FUMIGATED Placard motor vehicle, freight container or rail car on or near each door when fumigated with Division 6.1 (Poison) or Division 2.3 (Poison gas).</div>	<div></div> <div>RAIL Placard empty tank cars for residue of material last contained.</div>	<div></div> <div>The square background is required for the following placards when on rail cars: EXPLOSIVES 1.1 or 1.2, POISON GAS or POISON GAS-RESIDUE (Division 2.3, Hazard Zone A); POISON or POISON-RESIDUE (Division 6.1, PGI, Hazard Zone A). The square background is required for placards on motor vehicles transporting highway route controlled quantities of radioactive materials (Class 7).</div>	<div>DISPLAY OF IDENTIFICATION NUMBER WHEN TRANSPORTING HAZARDOUS MATERIALS IN PORTABLE TANKS, CARGO TANKS AND TANK CARS.</div> <div></div> <div>ORANGE PANEL</div> <div></div> <div>PLACARD</div>	



# HM 181 HAZARDOUS MATERIALS PLACARDING CHART

## §172.502 Prohibited and permissive placarding

- (a) Prohibited placarding Except as provided in paragraph (b) of this section, no person may affix or display on a packaging, freight container, unit load device, motor vehicle or rail car —
- Any placard described in this subpart unless —
  - The material being offered or transported is a hazardous material,
  - The placard represents a hazard of the hazardous material being offered or transported; and
  - Any placarding conforms to the requirements of this subpart
- (2) Any sign or other device that, by its color, design, shape or content, could be confused with any placard prescribed in this subpart
- (b) Exceptions (1) The restrictions in paragraph (a) of this section do not apply to a bulk packaging, freight container, unit load device, transport vehicle or rail car which is placarded in conformance with the TDG Regulations the IMDG Code or the UN Recommendations.
- (2) The restrictions of paragraph (a) of this section do not apply to the display of an identification number on a white square-on-point configuration in accordance with §172.336(b) of this part.
- (c) Permissive placarding Placards may be displayed for a hazardous material, even when not required, if the placarding otherwise conforms to the requirements of this subpart

## §172.504 General placarding requirements

- (a) General. Except as otherwise provided in this subchapter, each bulk packaging, freight container, unit load device, transport vehicle or rail car containing any quantity of a hazardous material must be placarded on each side and each end with the type of placards specified in Tables 1 and 2 of this section and in accordance with other placarding requirements of this subpart, including the specifications for the placards named in the tables and described in detail in §§172.619 through 172.558
- (b) DANGEROUS placard A freight container, unit load device, transport vehicle or rail car which contains non-bulk packagings with two or more categories of hazardous materials that require different placards specified in Table 2 may be placarded with DANGEROUS placards instead of the separate placarding specified for each of the materials in Table 2. However, when 2,268 kg (5,000 pounds) or more of one category of material is loaded therein at one loading facility, the placard specified in Table 2 of paragraph (e) of this section for that category must be applied
- (c) Exception for less than 454 kg (1,001 pounds) Except for bulk packagings and hazardous materials subject to §172.505, when hazardous materials covered by Table 2 of this section are transported by highway or rail, placards are not required on—
- A transport vehicle or freight container which contains less than 454 kg (1,001 pounds) aggregate gross weight of hazardous materials covered by Table 2 of paragraph (e) of this section, or
  - A rail car loaded with transport vehicles or freight containers, none of which is required to be placarded
- The exceptions provided in paragraph (c) of this section do not prohibit the display of placards in the manner prescribed in this subpart if not otherwise prohibited (see §172.502) on transport vehicles or freight containers which are not required to be placarded
- (d) Exception for empty non-bulk packages A non-bulk packaging that contains only the residue of a hazardous material covered by Table 2 of paragraph (e) of this section need not be included in determining placarding requirements
- (e) Placarding tables Placards are specified for hazardous materials in accordance with the following tables

Table 1		
Category of material (Hazard class or division number and additional description, as appropriate)	Placard name	Placard design section reference (§)
1.1	EXPLOSIVES 1.1	172.552
1.2	EXPLOSIVES 1.2	172.522
1.3	EXPLOSIVES 1.3	172.522
2.3	POISON GAS	172.540
4.3	DANGEROUS WHEN WET	172.548
6.1 (PG I, Inhalation hazard only)	POISON	172.554
7 (Radioactive Yellow III label only)	RADIOACTIVE	172.556

\* RADIOACTIVE placard also required for exclusive use shipments of low specific activity material in accordance with §173.425(b) or (c) of this subchapter






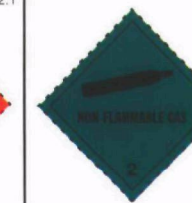







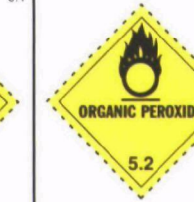


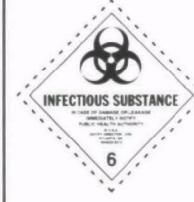





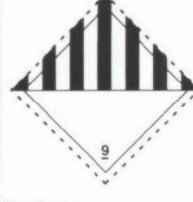
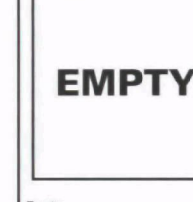

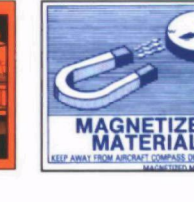
Table 2		
Category of material (Hazard class or division number and additional description, as appropriate)	Placard name	Placard design section reference (§)
1.4	EXPLOSIVES 1.4	172.523
1.5	EXPLOSIVES 1.5	172.524
1.6	EXPLOSIVES 1.6	172.525
2.1	FLAMMABLE GAS	172.532
2.2	NON-FLAMMABLE GAS	172.528
3	FLAMMABLE	172.542
Combustible liquid	COMBUSTIBLE	172.544
4.1	FLAMMABLE SOLID	172.546
4.2	SPONTANEOUSLY COMBUSTIBLE	172.547
5.1	OXIDIZER	172.550
5.2	ORGANIC PEROXIDE	172.552
6.1 (PG I or II, other than PG I Inhalation hazard)	POISON	172.554
6.1 (PG III)	KEEP AWAY FROM FOOD	172.553
6.2	(None)	
8	CORROSIVE	172.558
9	CLASS 9	172.560
ORM-D	(None)	

- (f) Additional placarding exceptions (1) When more than one division placard is required for Class 1 materials on a transport vehicle, rail car, freight container or unit load device, only the placard representing the lowest division number must be displayed
- (2) A FLAMMABLE placard may be used in place of a COMBUSTIBLE placard on —
- A cargo tank or portable tank,
  - A compartmented tank car which contains both flammable and combustible liquids
- (3) A NON-FLAMMABLE GAS placard is not required on a transport vehicle which contains non-flammable gas if the transport vehicle also contains flammable gas or oxygen and it is placarded with FLAMMABLE GAS or OXYGEN placards, as required
- (4) OXIDIZER placards are not required for Division 5.1 materials on freight containers, unit load devices, transport vehicles or rail cars which also contain Division 1.1 or 1.2 materials and which are placarded with EXPLOSIVES 1.1 or 1.2 placards, as required
- (5) For transportation by transport vehicle or rail car only, an OXIDIZER placard is not required for Division 5.1 materials on a transport vehicle, rail car or freight container which also contains Division 1.5 explosives and is placarded with EXPLOSIVES 1.5 placards, as required
- (6) The EXPLOSIVE 1.4 placard is not required for those Division 1.4 Compatibility Group S (1.4S) materials that are not required to be labeled 1.4S
- (7) For domestic transportation of oxygen, compressed or oxygen, refrigerated liquid, the OXYGEN placard in §172.530 of this subpart may be used in place of a NON-FLAMMABLE GAS placard
- (8) Except for a material classed as a combustible liquid that also meets the definition of a Class 9 material, a COMBUSTIBLE placard is not required for a material classed as a combustible liquid when transported in a non-bulk packaging For a material in a non-bulk packaging classed as a combustible liquid that also meets the definition of a Class 9 material, the CLASS 9 placard may be substituted for the COMBUSTIBLE placard
- (9) For domestic transportation, a Class 9 placard is not required. A bulk packaging containing a Class 9 material must be marked on each side and each end with the appropriate identification number displayed on an orange panel or a white-square-on-point display configuration are required by subpart D of this part.
- (10) For domestic transportation of Division 6.1, PG III materials, a POISON placard may be used in place of a KEEP AWAY FROM FOOD placard
- (g) For shipments of Class 1 (explosive) materials by aircraft or vessel, the applicable compatibility group letter must be displayed on the placards required by this section

## §172.505 Placarding for subsidiary hazards

- (a) Each transport vehicle, freight container, portable tank and unit load device that contains a poisonous material subject to the "Poison-Inhalation Hazard" shipping description of §172.101 must be placarded with a POISON or POISON GAS placard, as appropriate, on each side and each end, in addition to any other placard required for that material in §172.504. Duplicate POISON or POISON GAS placard is not required
- (b) In addition to the RADIOACTIVE placard which may be required by §172.504(e) of this subpart each transport vehicle, portable tank or freight container that contains 454 kg (1,001 pounds) or more gross weight of fissile or low specific activity uranium hexafluoride shall be placarded with a CORROSIVE placard on each side and each end
- (c) Each transport vehicle, portable tank, freight container or unit load device that contains a material which as a subsidiary hazard of being dangerous when wet, as defined in §173.124 of this subchapter, shall be placarded with DANGEROUS WHEN WET placards, on each side and each end, in addition to the placards required by §172.504
- (d) Hazardous materials that possess secondary hazards may exhibit subsidiary placards that correspond to the placards described in this part, even when not required by this part (see also §172.519(b)(4) of this subpart)




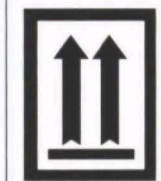
# HM 181 HAZARDOUS MATERIALS LABELING CHART

<b>CLASS 1</b> Explosive 1.1 1.2 1.3  *Include appropriate division number and compatibility group	<b>CLASS 1</b> Explosive 1.4  *Include appropriate compatibility group	<b>CLASS 1</b> Explosive 1.5  *Include appropriate compatibility group	<b>CLASS 1</b> Explosive 1.6  *Include appropriate compatibility group	<b>CLASS 2</b> Division 2.1  Flammable gas	<b>CLASS 2</b> Division 2.2  Non-flammable gas	<b>CLASS 2</b> Division 2.2  Oxygen
<b>CLASS 2</b> Division 2.3  Poison gas	<b>CLASS 3</b>  Flammable liquid	<b>CLASS 4</b> Division 4.1  Flammable solid	<b>CLASS 4</b> Division 4.2  Spontaneously combustible	<b>CLASS 4</b> Division 4.3  Dangerous when wet	<b>CLASS 5</b> Division 5.1  Oxidizer	<b>CLASS 5</b> Division 5.2  Organic peroxide
<b>CLASS 6</b> Division 6.1  Poison-Packing Groups I and II	<b>CLASS 6</b> Division 6.1  Poison - Packing Group III	<b>CLASS 6</b> Division 6.2  Infectious substance	 The Etiologic Agent label may be required (42 CFR 72.3)	<b>CLASS 7</b>  Radioactive I	<b>CLASS 7</b>  Radioactive II	<b>CLASS 7</b>  Radioactive III
<b>CLASS 8</b>  Corrosive	<b>CLASS 9</b>  Miscellaneous	<b>SUBSIDIARY RISK LABELS</b> Explosives Flammable Gas Flammable Liquid Flammable Solid Corrosive Oxidizer Poison Spontaneously Combustible Dangerous When Wet  The hazard class or division number may not be displayed on a subsidiary label.		 Empty	<b>FOR AIRCRAFT</b>  	

## D.O.T. GENERAL GUIDELINES ON USE OF WARNING LABELS

- Shipper must furnish and attach appropriate label(s) to each package of hazardous material offered for shipment unless exempted from labeling requirements.
- If the material in a package has more than one hazard classification, the package must be labeled for each hazard. (Ref. Title 49, CFR, Sec. 172.402).
- When two or more hazardous materials of different classes are packed within the same packaging or outer enclosure, the outside of the package must be labeled for each material involved. (Ref. Title 49, CFR, Sec. 172.404).
- Radioactive materials requiring labeling, must be labeled on two opposite sides of the package. (Ref. Title 49, CFR, Sec. 172.403(f)).
- Labels must not be applied to a package containing only material which is not subject to Parts 170 - 189 of this subchapter or which is exempted therefrom. This does not prohibit the use of labels in conformance with U.N. recommendations ("Transport of Dangerous Goods"), or with the IMO requirements ("International Maritime Dangerous Goods Code"), ICAO Technical Instructions, or TDG Regulations (Ref. Title 49, CFR, Sec. 172.401).

## HAZARDOUS MATERIALS PACKAGE MARKINGS

<b>SAMPLE PACKAGING MARKING</b> Proper Shipping Name.....ACETONE UN I.D. Number.....UN 1090 WARNING LABEL..... 	CONSUMER COMMODITY <b>ORM-D</b>  CONSUMER COMMODITY <b>ORM-D-AIR</b>			<b>INHALATION HAZARD</b>	
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# HM 181 HAZARDOUS MATERIALS LABELING CHART

## §172.400 General labeling requirements.

(a) Except as specified in §172.400a, each person who offers for transportation or transports a hazardous material in any of the following packages or containment devices, shall label the package or containment device with labels specified for the material in the 172.101 Table and in this subpart:

- (1) A non-bulk package;
  - (2) A bulk packaging, other than a cargo tank, portable tank, or tank car, with a volumetric capacity of less than 18 m<sup>3</sup> (640 cubic feet), unless placarded in accordance with subpart F of this part,
  - (3) A portable tank of less than 3785 L (1000 gallons) capacity, unless placarded in accordance with subpart F of this part;
  - (4) A DOT Specification 106 or 110 multi-unit tank car tank, unless placarded in accordance with subpart F of this part; and
  - (5) An overpack, freight container or unit load device, of less than 18 m<sup>3</sup> (640 cubic feet), which contains a package for which labels are required, unless placarded or marked in accordance with §172.512 of this part.
- (b) Labeling is required for a hazardous material which meets one or more hazard class definitions, in accordance with Column 6 of the §172.101 Table and the following table.

Hazard class or division	Label name	Label design or section reference (§)
1 1	EXPLOSIVE 1 1	172 411
1 2	EXPLOSIVE 1 2	172 411
1 3	EXPLOSIVE 1 3	172 411
1 4	EXPLOSIVE 1 4	172 411
1 5	EXPLOSIVE 1 5	172 411
1 6	EXPLOSIVE 1 6	172 411
2 1	FLAMMABLE GAS	172 417
2 2	NON-FLAMMABLE GAS	172 415
2 3	POISON GAS	172 416
3 (Flammable liquid)	FLAMMABLE LIQUID	172 419
Combustible liquid	(none)	
4 1	FLAMMABLE SOLID	172 420
4 2	SPONTANEOUSLY COMBUSTIBLE	172 422
4 3	DANGEROUS WHEN WET	172 423
5 1	OXIDIZER	172 426
5 2	ORGANIC PEROXIDE	172 427
6 1 (Packing Groups I and II)	POISON	172 430
6 1 (Packing Group III)	KEEP AWAY FROM FOOD	172 431
6 2	INFECTIOUS SUBSTANCE 1	172 432
7 (see §172 403)	RADIOACTIVE WHITE-I	172 436
7	RADIOACTIVE YELLOW-II	172 438
7	RADIOACTIVE YELLOW-III	172 440
7 (empty packages, see §173 427)	EMPTY	172 450
8	CORROSIVE	172 442
9	CLASS 9	172 446

<sup>1</sup>The ETIOLOGIC AGENT label specified in regulations of the Department of Health and Human Services at 42 CFR 72.3 may apply to packages of Infectious substances

## §172.400a Exceptions from labeling.

- (a) Notwithstanding the provisions of §172.400, a label is not required on -
- (1) A cylinder containing a Division 2 1 or Division 2.2 gas that is
    - (i) Not poisonous;
    - (ii) Carried by a private or contract motor carrier;
    - (iii) Not overpacked; and
    - (iv) Durably and legibly marked in accordance with CGA Pamphlet C-7, appendix A.
  - (2) A package or unit of military explosives (including ammunition) shipped by or on behalf of the DOD

when in —

- (i) Freight containerload, carload or truckload shipments, if loaded and unloaded by the shipper or DOD, or
  - (ii) Unitized or palletized break-bulk shipments by cargo vessel under charter to DOD if at least one required label is displayed on each unitized or palletized load
  - (3) A package containing a hazardous material other than ammunition that is —
    - (i) Loaded and unloaded under the supervision of DOD personnel, and
    - (ii) Escorted by DOD personnel in a separate vehicle.
  - (4) A compressed gas cylinder permanently mounted in or on a transport vehicle.
  - (5) A freight container, aircraft unit load device or portable tank, which —
    - (i) Is placarded in accordance with Subpart F of this part, or
    - (ii) Conforms to paragraph (a) (3) or (b) (3) of §172.512
  - (6) An overpack or unit load device in or on which labels representative of each hazardous material in the overpack or unit load device are visible.
  - (7) A package of low specific activity radioactive material, when transported under §173.425(b) of this subchapter.
- (b) Certain exceptions to labeling requirements are provided for small quantities and limited quantities in applicable sections in part 173 of this subchapter

## §172.401 Prohibited labeling.

(a) Except as provided in paragraph (c) of this section, no person may offer for transportation or no carrier may transport any package bearing a label specified in this subpart unless —

- (1) The package contains a material that is a hazardous material, and
  - (2) The label represents a hazard of the hazardous material in the package
- (b) No person may offer for transportation and no carrier may transport a package bearing any marking or label which by its color, design, or shape could be confused with or conflict with a label prescribed by this part.

(c) The restrictions in paragraphs (a) and (b) of this section, do not apply to packages labeled in conformance with —

- (1) Any United Nations recommendation, including the class number (see §172.407), in the document entitled "Transport of Dangerous Goods",
- (2) The International Maritime Organization (IMO) requirements, including the class number (see §172 407), in the document entitled "International Maritime Dangerous Goods Code";
- (3) The ICAO Technical Instructions, or
- (4) The TDG Regulations.

## §172.402 Additional Labeling requirements.

(a) Subsidiary hazard labels. Each package containing a hazardous material —

- (1) Shall be labeled with primary and subsidiary hazard labels as specified in Column 6 of the §172.101 Table; and
- (2) For other than Class 2 or Class 1 materials (for subsidiary labeling requirements for Class 1 materials see paragraph (e) of this section), if not already labeled under paragraph (a) (1) of this section, shall be labeled with subsidiary hazard labels in accordance with the following table.

## SUBSIDIARY HAZARD LABELS

Subsidiary hazard level (packing group)	Subsidiary Hazard (Class or Division)					
	3	4 1	4 2	4 3	5.1	6.1
I	X	•••	•••	X	X	X
II	X	X	X	X	X	X
III	•	N	X	X	N	N

X — Required for all modes.

• — Required for transport by vessel only

•• — Required for transport by aircraft and vessel only.

••• — Impossible as subsidiary hazard

N — None required

(b) Display of hazard class on labels. The appropriate hazard class or, for Division 5.1 or 5.2 the division number, shall be displayed in the lower corner of a primary hazard label and may not be displayed on a subsidiary label

(c) Cargo Aircraft Only label. Each person who offers for transportation or transports by aircraft a package containing a hazardous material which is authorized on cargo aircraft only shall label the package with a CARGO AIRCRAFT ONLY label specified in §172 448 of this subpart.

(d) Radioactive Materials. Each package containing a radioactive material that also meets the definition of one or more additional hazards, except Class 9, shall be labeled as a radioactive material as required by §172 403 of this subpart and for each additional hazard

(e) Class 1 (explosive) Materials. In addition label specified in Column 6 of the §172.101 Table, each package of Class 1 material that also meets the definition for

(1) Division 6 1, Packing Groups I or II, shall be labeled POISON; or

(2) Class 7, shall be labeled in accordance with §172 403 of this subpart.

## §172.403 Contains special requirements for RADIOACTIVE materials. See regulations.

## §172.405 Authorized label modifications.

(a) For Classes 1, 2, 3, 4, 5, 6, and 8, text indicating a hazard (for example FLAMMABLE LIQUID) is not required on a primary or subsidiary label when —

(1) The label otherwise conforms to the provisions of this subpart, and

(2) The hazard class or, for Division 5.1 or 5.2 the division number, is displayed in the lower corner of the label, if the label corresponds to the primary hazard class of the hazardous material.

(b) For a package containing Oxygen, compressed, or Oxygen, refrigerated liquid, the OXIDIZER label specified in §172 426 of this subpart, modified to display the word "OXYGEN" instead of "OXIDIZER", and the class number "2" instead of "5.1", may be used in place of the NON-FLAMMABLE, OXIDIZER labels. Notwithstanding the provisions of paragraph (a) of this section, the word "OXYGEN" must appear on the label.

## **APPENDIX D**

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### **Glossary and Acronym List**

## **GLOSSARY**

**Accident** - An unexpected event generally resulting in injury, loss of property, or disruption of service.

**Action Level** - A quantitative limit of a chemical, biological, or radiological agent at which actions are taken to prevent or reduce exposure or contact.

**Acute Exposure** - A dose that is delivered to a receptor in a single event or in a short period of time.

**Air Surveillance** - Use of air monitoring and air sampling during a response to identify and quantify airborne contaminants on and off-site, and monitor changes in air contaminants that occur over the lifetime of the incidents

**Aquifer** - A water bearing formation of permeable rock, sand, or gravel capable of yielding water to a well or spring.

**Chronic Exposure** - Low doses repeatedly delivered to a receptor over a long period of time.

**Confinement** - Control methods used to limit the physical area or size of a released material. Examples: dams, dikes, and absorption processes.

**Containment** - Control methods used keep the material in its container. Examples: Plugging and patching.

**Contaminant/Contamination** - An unwanted and non-beneficial substance.

**Control** - Chemical or physical methods used to prevent or reduce the hazards associated with a material. Example: Neutralizing an acid spill.

**Decontamination** - The process of physically removing contaminants from individuals and equipment or changing their chemical nature to innocuous substances

**Degree of Hazard** - A relative measure of how much harm a substance can do.

**Direct-Reading Instruments** - A portable device that rapidly measures and displays the concentration of a contaminant in the environment.

**Emergency** - A sudden and unexpected event calling for immediate action.

**Emergency Removal** - Action or actions undertaken, in a time-critical situation, to prevent, minimize, or mitigate a release that poses an immediate and/or significant threat(s) to human health or welfare or to the environment. (See also **Removal Action**)

**Environmental Assessment** - The measurement or prediction of the concentration, transport, dispersion, and final fate of a released hazardous substance in the environment.

**Environmental Emergencies** - Incidents involving the release (or potential release) of hazardous materials into the environment which require immediate action.

**Environmental Hazard** - A condition capable of posing an unreasonable risk to air, water, or soil quality, and to plants or wildlife.

**Environmental Sample** - Samples that are considered to contain no contaminants or low concentrations of contaminants as compared to hazardous samples.

**Episode** - Incident.

**First Responder** - The first personnel to arrive on the scene of a hazardous materials incident. Usually officials from local emergency services, firefighters, and police.

**Groundwater** - Water found in the saturated portions of geologic formations beneath the surface of land or water.

**Hazard** - A circumstance or condition that can do harm. Hazards are categorized into four groups: biological, chemical, radiation, and physical.

**Hazard Classes** - A series of nine descriptive terms that have been established by the UN Committee of Experts to categorize the hazardous nature of chemical, physical, and biological materials. These categories are:

1. Explosives
2. Nonflammable and flammable gases
3. Flammable liquids
4. Flammable solids
5. Oxidizing materials
6. Poisons, irritants, and disease-causing materials
7. Radioactive materials
8. Corrosive materials
9. Dangerous materials

**Hazard Evaluation** - The impact or risk the hazardous substance poses to public health and the environment.

**Hazardous** - Capable of posing an unreasonable risk to health and safety (Department of Transportation). Capable of doing harm.

**Hazardous Material** - A substance or material which has been determined by the Secretary of Transportation to be capable of posing an unreasonable risk to health, safety, and property when transported in commerce, and which has been so designated. (Department of Transportation)

**Hazardous Sample** - Samples that are considered to contain high concentrations of contaminants.

**Hazardous Substance** - 1) A material and its mixtures or solutions that are listed in the Appendix to the Hazardous Materials Table, 49 CFR 172.101, when offered for transportation in one package,

or in one transport vehicle if not packaged, and when the quantity of the material therein equals or exceeds the reportable quantity. 2) Any substance designated pursuant to Section 311(b)(2) (A) of the Federal Water Pollution Control Act, (B) any element, compound, mixture solution, or substance designated pursuant to Section 102 of this Act, (C) any hazardous waste having the characteristics identified under or listed pursuant to Section 3001 of the Solid Waste Disposal Act (but not including any waste of the regulation of which under the Solid Waste Disposal Act has been suspended by Act of Congress), (D) any toxic pollutant listed under Section 307(a) of the Federal Water Pollution Control Act, (E) any hazardous air pollutant listed under Section 112 of the Clean Air Act, and (F) any imminently hazardous chemical substance or mixture with respect to which the Administrator has taken action pursuant to Section 7 of the Toxic Substances Control Act. The term does not include petroleum, including crude oil or any fraction thereof which is not otherwise specifically listed or designated as a hazardous substance under subparagraphs (A) through (F) of this paragraph, and the term does not include natural gas, natural gas liquids, liquified natural gas, or synthetic gas usable for fuel (of mixtures of natural gas and such synthetic gas).

**Hazardous Waste** - Any material that is subject to the hazardous waste manifest requirements of the Environmental Protection Agency specified in 40 CFR, Part 262 or would be subject to these requirements in the absence of an interim authorization to a State under 40 CFR Part 123, Subpart F.

**Incident** - The release or potential release of a hazardous substance or material into the environment.

**Incident Characterization** - The process of identifying the substance(s) involved in an incident, determining exposure pathways and projecting the effect it will have on people, property, wildlife and plants, and the disruption of services.

**Incident Evaluation** - The process of assessing the impact released or potentially released substances pose to public health and the environment.

**Information** - Knowledge acquired concerning the conditions or circumstances particular to an incident.

**Inspection** - Same as investigation.

**Intelligence** - Information obtained from existing records or documentation, placards, labels, signs, special configuration of containers, visual observations, technical records, eye witnesses, and others.

**Investigation** - On-site and off-site survey(s) conducted to provide a qualitative and quantitative assessment of hazards associated with a site.

**Limited Quantity** - With the exception of Poison B materials, the maximum amount of a hazardous material for which there is a specific labeling and packaging exception.

**Mitigation** - Actions taken to prevent or reduce the severity of threats to human health and the environment.

**Monitoring** - The process of sampling and measuring certain environmental parameters on a real-time basis for spatial and time variations. For example, air monitoring may be conducted with direct-reading instruments to indicate relative changes in air contaminant concentrations at various times.

**National Contingency Plan** - Policies and procedures that the Federal Government follows in implementing responses to hazardous substances.

**Off-Site** - Presence outside of the worksite.

**On-Site** - Presence within the boundaries of the worksite.

**Pathways of Dispersion** - The environmental medium (water, groundwater, soil, and air) through which a chemical is transported.

**Persistent Chemicals** - A substance which resists biodegradation and/or chemical transformation when released into the environment and tends to accumulate on land, in air, in water, or in organic matter.

**Planned Removal (Non-Time-Critical Removal)** - The removal of released hazardous substances that pose a threat or potential threat to human health or welfare or to the environment from a site within a non-immediate time period. Under CERCLA: Actions intended to minimize increases in exposure such that time and cost commitments are limited to 12 months and/or two million dollars. (See also **Emergency Removal**.)

**Pollutant** - A substance or mixture which after release into the environment and upon exposure to any organism will or may reasonably be anticipated to cause adverse effects in such organisms or their offspring.

**Pollutant Transport** - An array of mechanisms by which a substance may migrate outside the immediate location of the release or discharge of the substance. For example, pollution of groundwater by hazardous waste leachate migrating from a landfill.

**Qualified Individual** - A person who through education, experience, or professional accreditation is competent to make judgements concerning a particular subject matter. A Certified Industrial Hygienist may be a qualified individual for preparing a site safety plan.

**Regulated Material** - A substance or material that is subject to regulations set forth by the Environmental Protection Agency, the Department of Transportation, or any other federal agency.

**Release** - Any spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing of hazardous substances into the environment.

**Remedial Actions** - As in the National Contingency Plan, responses to releases on a National Priority List that are consistent with treatment-oriented remedy that is protective of human health and the environment and that permanently and significantly reduces toxicity, mobility, or volume of hazardous substances.

**Removal Actions** - Any appropriate actions(s) taken to abate, minimize, stabilize, mitigate, or eliminate the release or threat of release that poses a threat to human health or welfare or to the environment. As set forth in the National Contingency Plan, these actions shall be terminated after \$2 million has been obligated or 12 months have elapsed from the date of initial response.

**Reportable Quantity** - As set forth in the Clean Water Act, the minimum amount (pounds or kilograms) of a hazardous substance that may be discharged in a 24 hour period that requires notification of the appropriate government agency.

**Response Actions** - Actions taken to recognize, evaluate, and control an incident.

**Response Operations** - Same as Response Actions.

**Risk** - The probability that harm will occur.

**Risk Assessment** - The use of factual base to define the health effects of exposure of individuals or populations to hazardous materials and situations.

**Risk Management** - The process of weighing policy alternatives and selecting the most appropriate regulatory action integrating the results of risk assessment with engineering data and with social and economic concerns to reach a decision.

**Routes of Exposure** - The manner in which a contaminant enters the body through inhalation, ingestion, skin absorption, and injection.

**Safety** - Freedom from man, equipment, material, and environmental interactions that result in injury or illness.

**Sampling** - The collection of representative portion of the universe. Example: the collection of a water sample from a contaminated stream.

**Severe** - A relative term used to describe the degree to which hazardous material releases can cause adverse effects to human health and the environment.

**Site** - Location.

**Site Safety Plan** - Written, site-specific safety criteria that establishes requirements for protecting the health and safety of responders during all activities conducted at an incident.

**Toxicity** - The ability of a substance to produce injury once it reaches a susceptible site in or on the body.

**Work Plan** - Written directives that specifically describe all work activities that are to take place at a work site.

## ACRONYMS

ACGIH - American Conference of Governmental Industrial Hygienists

AIHA - American Industrial Hygiene Association

ANSI - American National Standards Institute

APF - assigned protection factor

APR - air-purifying respirator

ASR - atmosphere-supplying respirator

ASTM - American Society for Testing and Materials

BEIs - biological exposure indices

BOD - biological oxygen demand

B of M - Bureau of Mines

Btu - British Thermal Unit

C - Ceiling

CAG - Carcinogen Assessment Group

CDC - Centers for Disease Control

CERCLA - Comprehensive Environmental Response, Compensation and Liability Act (1980)

CFR - Code of Federal Regulations

CGI - combustible gas indicator

CHEMTREC - Chemical Transportation Emergency Center

CHRIS - Chemical Hazard Response Information System

CMA - Chemical Manufacturers' Association

CPC - chemical protective clothing

CPE - chlorinated polyethylene

CPM - counts per minute



**CRC** - CRC Press - A publisher of scientific reference books

**CRP** - community relations plan

**DDT** - Dichlorodiphenyltrichloroethane

**DECON** - decontamination

**DFM** - diesel fuel marine

**DHHS** - U.S. Department of Health and Human Services

**DOD** - U.S. Department of Defense

**DOI** - U.S. Department of the Interior

**DOL** - U.S. Department of Labor

**DOT** - U.S. Department of Transportation

**DRI** - direct-reading instruments

**EERU** - Environmental Emergency Response Unit

**EL** - exposure limit

**EPA** - U.S. Environmental Protection Agency

**ERCS** - Emergency Response Cleanup Services (under EPA contract)

**ERT** - Environmental Response Team

**eV** - electron volt

**FEMA** - Federal Emergency Management Agency

**FES** - fully encapsulating suit

**FID** - flame ionization detector

**FIT** - Field Investigation Team (under contract to EPA)

**FM** - factory mutual

**GC** - gas chromatograph or gas chromatography

**GFCI** - ground-fault circuit interruptor

**HASP** - health and safety plan

**HazCom** - Federal Hazard Communications Standard

**HEPA** - high-efficiency particulate air filter (common use: "HEPA filter")

**HMIS** - Hazardous Materials Identification System

**IDLH** - immediately dangerous to life or health

**IP** - ionization potential

**IR** - infrared radiation

**IUPAC** - International Union of Pure and Applied Chemists

**LC<sub>50</sub>** - lethal concentration, 50%

**LD<sub>50</sub>** - lethal dose, 50%

**LC<sub>Lo</sub>** - lethal concentration - low

**LD<sub>Lo</sub>** - lethal dose - low

**LEL** - lower explosive limit

**LFL** - lower flammable limit

**MACs** - maximum allowable concentrations

**mg/L** - milligrams per liter

**mg/m<sup>3</sup>** - milligrams per cubic meter

**MIRAN** - Trade name for series of Foxboro Miniature Infrared Analyzers

**MOS** - metal oxide semiconductor

**Mr/hr** - milliroentgens per hour

**MSD** - mass spectroscopy detector

**MSDS** - material safety data sheets

**MSHA** - Mine Safety and Health Administration

**MUC** - maximum use concentration

**MUL** - maximum use limits

**NBR** - nitrile-butadiene rubber (synonym. Buna-N)

**NCP** - National Contingency Plan

**NEC** - National Electrical Code

**NFPA** - National Fire Protection Association

**NIOSH** - National Institute for Occupational Safety and Health

**NOAA** - National Oceanic and Atmospheric Administration

**NOS or n.o.s.** - not otherwise specified

**NPL** - National Priorities List

**NRC** - Nuclear Regulatory Commission

**NRR** - noise reduction rating

**NRT** - National Response Team

**OHMTADS** - Oil and Hazardous Materials Technical Assistance Data System

**ORM** - other regulated material (specific classes such as ORM-A, ORM-E, etc.)

**OSC** - on-scene coordinator

**OSHA**- Occupational Safety and Health Administration

**OVA** - organic vapor analyzer

**OVM** - organic vapor meter

**PCB** - polychlorinated biphenyl

**PEL** - permissible exposure limit

**PF**- protection factor

**PID** - photoionization detector

**ppb** - parts per billion

**PPE** - personal protective equipment

**ppm** - parts per million

**ppt** - parts per trillion

**PVA**- polyvinyl alcohol

**PVC** - polyvinyl chloride

**QA/QC** - quality assurance and quality control

**RCRA** - Resource Conservation and Recovery Act

**REL** - recommended exposure limits

**REMFIT** - Field Investigation Team for remedial actions (under contract to EPA)

**RI/FS** - remedial investigation and feasibility study

**RPF** - required protection factor

**RRP** - regional response plan

**RRT** - Regional Response Team

**SAR** - supplied-air respirator

**SBR** - styrene-butadiene rubber

**SCBA** - self-contained breathing apparatus

**SOPs** - standard operating procedures

**SOSGs** - standard operating safety guides

**SpG** - specific gravity

**STEL** - short-term exposure limit

**TAT** - Technical Assistance Team (under contract to EPA)

**TC<sub>Lo</sub>** - toxic concentration - low

**TCDD** - tetrachlorodibenzo-*p*-dioxin

**TCE** - trichloroethylene

**TD<sub>Lo</sub>** - toxic dose - low

**THR** - toxic hazard rating

**TLVs** - threshold limit values

**TWA** - time-weighted average

**2, 4, 5-T** - 2,4,5-trichlorophenoxyacetic acid

**UEL** - upper explosive limit

**UFL** - upper flammable limit

**UL** - Underwriters Laboratories

**UN** - United Nations

**USCG** - United States Coast Guard

**USGS**- United States Geological Survey

**WEEL** - Workplace Environmental Exposure Levels

## Workbook

# **HAZARDOUS MATERIALS INCIDENT RESPONSE OPERATIONS**

## **WORKBOOK**

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# USING AIR MONITORING INSTRUMENTS I

## I. OBJECTIVE

In this exercise, students will operate air monitoring instruments including: Combustible Gas Indicators, Oxygen Indicators, and Colorimetric Indicator Tubes and Pumps. Students will analyze and interpret the data gathered from the instruments.

## II. PROCEDURE

The exercise has been divided into three stations. Each station will be equipped with air monitoring instruments and gas sampling bags. Each team (consisting of at least two students) must complete the following tasks at the appropriate station.

### Station A Combustible Gas Indicators (CGIs)

Three gas sampling bags contain mixtures of flammable gas/vapors in air, one each at concentrations:

- below the LEL
- between the LEL and UEL
- above the UEL

Measure each bag using both CGIs. Record concentrations on the answer sheet at the end of this exercise. In Column 4, identify the mixture in each bag.

### Station B Oxygen Indicators

Two gas sampling bags contain different concentrations of oxygen. Sample each bag with each of the two instruments. Record results on the answer sheet.

### Station C Colorimetric Indicator Tubes and Pumps

Two gas sampling bags contain mixtures of toluene in air and carbon dioxide in air. Using the colorimetric indicator tubes and pumps, measure each bag according to manufacturer's instructions (see end of this exercise). Record type of gas and concentrations on answer sheet.

## III. GENERAL OPERATING INSTRUCTIONS

General operating instructions for combustible gas indicators, oxygen indicators, and colorimetric indicator tubes and pumps are as follows. Specific air monitoring instrument instructions are also given for all equipment used in this exercise. When performing the



exercise procedures at each station, use these instructions as a guide to proper instrument use. The following instructions have been rewritten for brevity and clarity. In actual use, instruments should be operated and calibrated according to the manufacturer's instructions.

### **Combustible Gas Indicators (CGIs) & Oxygen Indicators (O<sub>2</sub>Is)**

In addition to the following instructions, the instruments should be checked prior to use in a noncontaminated, fresh air environment. Furthermore, units incorporating an aspirator bulb or other air-drawing device should be checked for leaks in the following manner:

- Attach all hoses, probes, and other air-drawing devices.
- If instrument has a battery-operated pump, turn instrument on. Place a finger over probe or hose end.\*
- If instrument is equipped with an aspirator bulb, place a finger over probe or hose end. Squeeze the bulb.\*

\* In a leak-free system, the bulb remains collapsed or pump labors. In a leaking system, the bulb regains its shape or pump does not labor. If the instrument does not pass a leak test, notify an instructor.

### **Colorimetric Indicator Tubes and Pumps**

In addition to the following instructions, all colorimetric indicator tubes and pumps should be field checked prior to use. This check tests for leaks in the following manner:

- Insert unbroken tube into pump's tube holder.
- If using a bellows-type pump, squeeze bellows. After 30 minutes (per Draeger), bellows should not regain its original shape nor should chain be taut. Start this test and move to piston pump (returning to bellows after using the piston pump).
- If using a piston-type pump, align index marks on handle and cap of pump. Pull back and lock handle. After 60 seconds rotate handle 1/4 turn. Handle should return within 1/4 inch of zero cc mark.

If a pump fails these tests, it should be serviced according to manufacturer's instructions.

### **MSA Model 2A Explosimeter Combustible Gas Indicator**

1. Turn the explosimeter on by lifting the end of the "locking" bar on the "Rheostat" knob and rotating the "Rheostat" knob clockwise 1/4 turn. The bar stays up while the instrument is in use. Do not attempt to depress the bar.
2. Flush the instrument with fresh air by squeezing and releasing the aspirator bulb at least 10 times.
3. Rotate the "Rheostat" knob until the meter needle rests at zero. (Avoid large clockwise rotation which sends large current through the filament, perhaps shortening its useful life.)
4. To sample, place the hose or probe end in the atmosphere to be measured and operate the aspirator bulb at least ten times.
5. While squeezing the bulb, read the percent of Lower Explosive Limit (% LEL) as the meter needle reaches the maximum level.
6. Before sampling the next bag, purge the instrument with clean air by aspirating the bulb 5 times or until the needle drops back to zero.
7. Turn the explosimeter "Off" by rotating the "Rheostat" knob counterclockwise until it "clicks." The locking bar will then retract into the "Rheostat" knob.

### **Bacharach Model GPK Oxygen/Combustible Gas Indicator**

1. Rotate the "Function" switch clockwise to the "Volt Test" position. The motor starts and the "% Oxygen" and "Sniffer" needles move up scale.
2. Lift and rotate the "Volt Adj" knob to bring the "Gas Detector" needle over the green arrow. The knob is supplied with a clutch to prevent accidental decalibration).
3. Turn the "Function" switch clockwise to "On". The "% Oxygen" needle should be at about 20.8% and the "Gas Detector" needle should drop to about zero.
4. Lift and rotate the "Oxy Cal" knob to adjust the "% Oxygen" needle to black "Calibrate" line.
5. Lift and rotate the "Zero Adj" knob to adjust the "Gas Detector" needle to zero.
6. Momentarily place finger over hose or thread "Air Intake" nipple and observe the pump laboring.
7. To sample, place hose end or probe in atmosphere to be measured. Within 30 seconds, steady-state readings are indicated on "% Oxygen" and "Gas Detector" scales.
8. Before sampling the next bag, allow the instrument to purge itself by pulling in clean air until the "Gas Detector" needle drops to zero and the "% Oxygen" returns to normal. If they do not, repeat steps 4 and 5.
9. After readings have been taken, allow instrument to purge, then rotate "Function" switch counterclockwise to "Off."

### **MSA Model 245 Oxygen Indicator**

1. To calibrate the instrument in normal air, remove the "Remote Sampling Adaptor" or draw clean air into the sampler by squeezing the aspirator bulb 6-7 times.
2. Press the "Read" switch. The meter needle should indicate 21 % oxygen, represented by the hash mark on "Meter Scale."
3. If the needle does not indicate 21%, adjust by rotating the "Calibration Potentiometer" (on top of instrument) clockwise to increase reading or counterclockwise to decrease it. Use the screwdriver provided.
4. Connect the "Remote Sampling Adaptor" to the face of the sensor.
5. To sample, place the hose or probe in the atmosphere to be sampled, press the "Read" button and squeeze aspirator at least 6 or 7 times.
6. Read the meter needle once it has stabilized. Reading can be done while aspirator bulb is being squeezed.
7. After taking a reading, clean the unit by flushing fresh air through it until the meter returns to normal. If the meter does not return to normal, repeat step 3.
8. Turn the instrument off by releasing "Read" switch.

### MSA Model 260 Oxygen/Combustible Gas Indicator

1. Turn the center "On-Off" control clockwise to the far right "Horn-Off" position. Both meter needles will move, one or both lights may light.
2. Adjust the meter needle on the % oxygen meter by pulling up and turning the "O<sub>2</sub> Calibrate" knob. (The knob is supplied with a clutch to prevent accidental field decalibration). Adjust the needle to read 20.8% O<sub>2</sub> represented by the hash mark located directly below the 21% mark.
3. Adjust the meter needle on the % LEL meter by pulling up and turning the "LEL Zero" knob. Adjust the needle to read 0% on the meter face.
4. Press the red alarm "Reset" button to deactivate the alarm circuit. If either of the alarm lamps located in the upper corners of the control panel were lit, they will extinguish upon depressing this button.
5. Press the black check button and observe the needle movement on the % LEL meter. The needle should fall within the black battery arc on the meter face. If it fails to reach this level, the battery needs recharging.
6. Momentarily hold finger over the threaded "Air Intake" nipple or over the end of the hose (if attached) and listen and watch the "Flow" indicator for signs of pump laboring.
7. Turn the "O<sub>2</sub> Calibrate" knob counterclockwise while observing the % oxygen meter. At the 19.5% reading, the left alarm lamp will illuminate. Return the needle to the 20.8% O<sub>2</sub>. Depress the red "Reset" button to reactivate the alarm circuit.
8. Turn the "LEL Zero" knob clockwise until the needle reads 25%. The right alarm lamp will illuminate. Return the needle to zero % LEL. Depress the red "Reset" button to reactivate the alarm circuit.
9. To operate the "Combo" unit, place the hose or probe end in the atmosphere to be sampled and wait for the needle deflection to stabilize on the O<sub>2</sub> and % LEL meter.
10. If the unit senses an oxygen deficient (< 19.5% O<sub>2</sub>) or a combustible (> 25% LEL) atmosphere, the alarm circuit will activate and remain so until the atmosphere concentrations return to normal levels. When back at normal levels, the red reset button must be pushed to silence and reactivate the alarm.
11. After all readings are at baseline, turn the unit off by turning the function knob counterclockwise to "Off".

### **MSA Model 261 Oxygen/Combustible Gas Indicator**

1. Turn the center "On-Off" control clockwise to the far right "Horn-Off" position. Both meter needles will move, one or both lights may light.
2. Adjust the meter needle on the % oxygen meter by pulling up and turning the "O<sub>2</sub> Calibrate" knob. (The knob is supplied with a clutch to prevent accidental field decalibration). Adjust the needle to read 20.8% O<sub>2</sub> represented by the hash mark located directly below the 21% mark.
3. Adjust the meter needle on the % LEL meter by pulling up and turning the "LEL Zero" knob. Adjust the needle to read 0% on the meter face.
4. Press the red alarm "Reset" button to deactivate the alarm circuit. If either of the alarm lamps located in the upper corners of the control panel were lit, they will extinguish upon depressing this button, and the center green lamp will periodically illuminate. If the red lights continue to flash and/or the green lamp is not illuminated, do not use the unit. Consult an instructor.
5. Press the black check button and observe the needle movement on the % LEL meter. The needle should fall within the black battery arc on the meter face. If it fails to reach this level, the battery needs recharging.
6. Return the center function knob to the "On" position while observing the green "Horn-Off" lamp. The lamp will change from a flashing state to a continuous illuminated state when the knob is placed in the "on" position. This indicates the pump is operating and the audible alarm is activated.
7. Turn the "O<sub>2</sub> Calibrate" knob counterclockwise while observing the % oxygen meter. At the 19.5% reading, the left alarm lamp will illuminate and the horn will sound. Return the needle to the 20.8% reading. Depress the red "Reset" button to reactivate the alarm circuit.
8. Turn the "LEL Zero" knob clockwise until the needle reads 25%. The right alarm lamp will illuminate and the horn will sound. Return the needle to zero % LEL. Depress the red reset button to reactivate the alarm circuit.
9. To operate the "Combo" unit, place the hose or probe end in the atmosphere to be sampled and wait for the needle deflection to stabilize on the O<sub>2</sub> and % LEL meter.
10. If the unit senses an O<sub>2</sub> deficient (< 19.5% O<sub>2</sub>) or a combustible (> 25% LEL) atmosphere, the alarm circuit will activate and remain so until the atmosphere concentrations return to normal levels. When back at normal levels, the red reset button must be pushed to silence and reactivate the alarm.
11. The Model 261 is equipped with a locking mechanism that locks the needle if the LEL meter reaches 100% or higher. The needle will stay at 100 even if subsequent

concentrations are greater than the UEL or drop below the LEL. To unlock, the unit must be turned off and then on.

12. When finished sampling and all readings return to normal, turn the unit off by rotating the function knob counterclockwise to "Off."

### **Sensidyne/Gastec Gas Sampling System**

1. Break off both tips of a fresh colorimetric indicator tube in the tube breaker hole in the side of the pump head.
2. Insert the tube into the tube holder with the arrow on the tube pointing towards the pump. Insert the other end of the tube in the test atmosphere.
3. Align the index marks on the handle and the cap of the pump.
4. Pull the handle straight back to the desired volume of 1/2 (50 cc), or 1 pump stroke (100 cc's) as specified in the tube's instruction. The handle automatically locks at these volumes.
5. Wait for the time specified in the tube's instructions, or wait until the red button pops up to the blue line on the "Flow Finish Indicator" if the pump is equipped with one.
6. Rotate the handle 90° to unlock it and push the handle in.
7. Realign the index marks for next stroke or test. Refer to the tube's instructions for required number of strokes.
8. Read the concentration of the chemical in air at the stained-unstained interface.



### **Draeger Indicator Tube Pump**

1. Break off both tips of a fresh colorimetric indicator tube in the break-off eyelet on the front cover plate or in break-off husk (an accessory).
2. Insert the tube into the pump head with the arrow on the tube pointing towards the pump.
3. Hold the pump between your thumb and the base of your index finger with the front cover plate contacting your finger.
4. Insert the end of the tube into the sample atmosphere.
5. Compress the bellows completely with a squeezing motion assuring that the total volume of the bellows is used.
6. Release your grip and allow the chain to become taut, signifying that 100 cc of air have been pulled through the tube. Be sure to keep the tube end in the sample atmosphere during the specified time.
7. Complete steps 4 and 5 as many times as the tube's instructions state.
8. Read the concentration of the material in air at stained-unstained interface.

## ANSWER SHEET

### STATION A: Combustible Gas Indicators

Concentrations			
	<u>MSA Model 2A</u> % LEL	<u>Bacharach Model GPK</u> % LEL      % Oxygen	<u>Mixture (check one)</u>
Bag A	_____	_____	<div style="display: flex; justify-content: space-between;"> <div>_____ &lt; LEL</div> <div>_____ LEL - UEL</div> <div>_____ &gt; UEL</div> </div>
Bag B	_____	_____	<div style="display: flex; justify-content: space-between;"> <div>_____ &lt; LEL</div> <div>_____ LEL - UEL</div> <div>_____ &gt; UEL</div> </div>
Bag C	_____	_____	<div style="display: flex; justify-content: space-between;"> <div>_____ &lt; LEL</div> <div>_____ LEL - UEL</div> <div>_____ &gt; UEL</div> </div>

### STATION B: Oxygen Meters

% Oxygen		
<u>MSA Model 245</u>	<u>MSA Model 260/261</u>	
Bag 1	_____	% LEL: _____
Bag 2	_____	% LEL: _____

### STATION C: Colorimetric Indicator Tubes and Pumps

Concentrations		
	<u>Sensidyne/Gastec</u>	<u>Draeger</u>
Gas:		
_____	_____	_____
_____	_____	_____

## **NOTES**

## USING AIR MONITORING INSTRUMENTS II

### I. OBJECTIVE

The students will calibrate an HNU PI-101 and measure concentrations of various gas samples. The students will learn how to operate the instrument and record pertinent data gathered.

### II. PROCEDURE

A. Students will divide into groups as directed by the instructor.

B. Each station contains an HNU PI-101 and four gas bags. The gas bags contain:

- 100 ppm toluene
- 100 ppm acetone
- 50 ppm hexane
- 100 ppm methane

If the actual concentrations differ from above, the instructor will inform you of the changes.

C. Read the following instructions for the instrument. The instructor will demonstrate the check-out of the instrument and explain the function of the controls.

#### HNU PI-101 Photoionizer Operating Instructions

1. Turn the six position "Function Switch" to the BATTERY CHECK position. The needle on the meter should read within or above the green "Battery Check" on the scale. If not, recharge the battery. If the red battery indicator light comes on, the battery must be recharged. Inform the instructor if the battery is not at optimum charge.
2. Turn the "Function Switch" to any "Range Setting" (i.e. 0-20, 0-200, or 0-2000). The lamp can be checked by holding the exposed tip of a solvent-based marking pen next to the end of the probe. The meter will show a deflection.
3. Turn the "Function Switch" to the STANDBY position and rotate the "Zero Adjustment" until the meter reads zero. Note: No zero gas is needed since this is an electronic zero adjustment. If the span adjustment setting is changed after the zero is set, the zero should be rechecked and adjusted, if necessary. Wait 15 to 20 seconds to ensure that the zero reading is stable. If necessary, readjust the zero.

The instrument is ready for operation.

## **STEP 1**

Record the following. The EPA sticker number can be used if no serial number is found.

HNU Serial Number: \_\_\_\_\_

HNU Probe Number: \_\_\_\_\_

HNU Lamp Energy: \_\_\_\_\_

## **STEP 2**

With the assistance of the instructor and/or the technician, calibrate the instrument using isobutylene.

To calibrate the HNU PI-101, connect the probe inlet to the calibration gas source. Set the "Function Switch" to the correct range setting for the concentration of the test gas. Unlock the "Span Control" by moving the black lever counter clockwise. Adjust the "Span Control" the desired reading is obtained. Turning the "Span Control" knob clockwise increases the numbers on the span. The span will not turn past 0 or 10 (window number). The number on the "Span Control" is the calibration setting for the test gas. The setting is read with the number in the "window" as the integer and the number on the dial as a decimal.

HNU span setting \_\_\_\_\_

### **STEP 3**

With the instruments at the same span settings from Step 1, make and record readings for the following gas bags.

	<b><u>Actual Concentration</u></b>	<b><u>HNU Reading</u></b>
Toluene	100 ppm	_____
Acetone	100 ppm	_____
Hexane	50 ppm	_____
Methane	100 ppm	_____

Calculate the relative response for each of the chemicals. Relative response = 100% times INSTRUMENT READING divided by ACTUAL CONCENTRATION.

	<b><u>HNU</u></b>
Toluene	_____
Acetone	_____
Hexane	_____
Methane	_____

### **STEP 4**

Calibrate the instrument to acetone using the **100 ppm acetone bag**. Adjust the span setting until the instrument reads **100**. Record the span setting.

HNU span setting \_\_\_\_\_

### **STEP 5**

Take a reading of the atmosphere in and around the container of solvent at the front of the room. Take care that the probe does not come in contact with the liquid. Record your results below.

<b><u>LOCATION</u></b>	<b><u>READING</u></b>
1 foot from opening	_____
6 inches from opening	_____
over opening	_____
inside container	_____

### **STEP 6**

Conduct a room survey and record your readings at each of the containers.

	<b><u>READING</u></b>
Container #1	_____
Container #2	_____
Container #3	_____
Container #4	_____

After obtaining the readings, the instructor will then reveal the contents of each container. From what you learned in steps three and four, obtain the actual concentration of acetone in container #4.

	<b><u>Actual Concentration</u></b>
Acetone (Container #4)	_____

### **STEP 7**

The instructor will demonstrate the effects of electromagnetic radiation on the instruments.

## **STEP 8**

Answer the following questions.

1. Does the instrument respond the same for all chemicals?
2. Is it important to know what energy lamp you are using? Why?
3. What is the span control used for? Why would you change the span from its original setting for benzene (isobutylene) calibration.
4. Your instrument is calibrated to benzene. You read 200 on your meter during an investigation of a hazardous waste site. How do you report your findings? What additional information is needed?



## **NOTES**

# **AIR-PURIFYING RESPIRATORS**

## **I. OBJECTIVE**

Students will be able to perform a qualitative fit test for a full-face air-purifying respirator. While wearing full-face, air-purifying respirators, students will operate communication devices (Motorola HT600 radios).

In this exercise, students will also demonstrate proper donning and doffing of escape masks.

## **II. PROCEDURE**

- A. The instructor demonstrates fit-testing methods using the isoamyl acetate.
- B. Select at least two styles of full-face APRs. With the assistance of another student, fit test each APR using the isoamyl acetate.

Select the proper cartridge for the particular testing method:

- Isoamyl Acetate - Organic Vapor Cartridge

- C. Check radios for proper operation (see following instructions).
- D. Don air-purifying respirators and separate into two groups (group number indicated at bottom of handout).
- E. Transmit messages given on handouts and write down messages received. Speak slowly and clearly. Verify that a message has been received before proceeding to the next one. You may need to repeat a message several times. (If there is more than one person per radio, take turns transmitting and receiving.)

### **Respirator Fit-Testing Instructions**

1. Place head into the test atmosphere and breath normally for about ten seconds. If no odor is detected proceed to the next step.
2. Breath deeply for 10 seconds. If no odor is detected, proceed to the next step.
3. Move head from side to side pausing at each extreme to inhale once. If no odor is detected, proceed to next step.
4. Move head up and down, hold head up and inhale deeply at least once. If no odor is detected, proceed to next step.
5. Speak loudly and slowly while counting backwards from 100 to 75. Recite name, address or other script (i.e. the rainbow passage). If no odor is detected, proceed to next step.
6. Make an exaggerated face or expression. If no odor is detected, proceed to next step.
7. Bend at the waist and move head around. If no odor is detected, proceed to next step.
8. Jog in place for 10 seconds. If no odor has been detected, the fit test has passed.

## **FIT-TEST RECORD**

Name: \_\_\_\_\_

Location: \_\_\_\_\_

Date: \_\_\_\_\_

**Isoamyl  
Acetate**

Type of mask:  
Manufacturer:  
Model/Size:

pass/fail

Type of mask:  
Manufacturer:  
Model/Size:

pass/fail

Type of mask:  
Manufacturer:  
Model/Size:

pass/fail

Type of mask:  
Manufacturer:  
Model/Size:

pass/fail

Type of mask:  
Manufacturer:  
Model/Size:

pass/fail

Comments:

## **Motorola HT600 Radio Operating Instructions**

### ***To check radio controls:***

1. Turn on radio by rotating the on-off/volume control clockwise 1/2 turn. A power-up alert tone is generated for approximately one half second. If this short alert tone is not heard or if a continuous alert tone is generated, inform the instructor.
2. Select channel 1, 2, 3, or 4 using the channel selector switch. **For this exercise, the instructor will assign channels.** Channels 5 and 6 are not usable.
3. Push one of the monitor buttons (small buttons on side near top of unit) and adjust the volume.
4. Place toggle switch (squell select switch) to the left position (speaker with a slash symbol). This helps to eliminate interference from other users on these channels.
5. The bi-color, light-emitting diode (LED) indicates normal transmission (continuous red), low battery (flashing red), or channel busy (flashing green).

### ***To transmit message:***

1. To transmit, hold radio approximately 2 inches from your mouth and speak slowly and clearly while depressing the push-to-talk button on the left side. If the green LED on top is flashing, or other persons are heard, do not transmit until they are finished. If the radio beeps when you attempt to transmit, there is another user on the channel.
2. When finished transmitting, release the push-to-talk button.
3. Do not transmit unnecessarily. Do not use profanity. These are not CB radios. They are business band radios that operate on shared channels with other businesses.
4. When reading chemical names or other difficult words it is best to spell the words. Many chemicals may differ by only one or two letters or numbers. For example, potassium chloride (salt substitute) and potassium chlorate (shock sensitive oxidizer used in explosives).
5. Answer a question by using "affirmative" or "negative" for yes or no.
6. When you are finished transmitting and expect a reply, say "over." When you are finished and do not expect a reply say "out" or "clear."
7. Turn the radio off when exercise is complete.

***Radio safety:***

1.     **Avoid physical abuse of the radio such as carrying it by the antenna.**
2.     **DO NOT hold the radio such that the antenna is very close to, or touching, exposed parts of the body, especially the face or eyes, while transmitting. The radio will perform best if the microphone is two or three inches away from the lips and the radio is vertical.**
3.     **DO NOT hold the transmit switch on when not actually desiring to transmit.**
4.     **DO NOT operate a portable transmitter near unshielded electrical blasting caps or in an explosive atmosphere unless it is a type especially qualified for such use.**

## Escape Mask Donning and Doffing

### *Donning Procedures:*

1. Choose an escape mask to don.
2. Don the North 845, Scott Scat-Pak, or ISI ELSA.
3. Lift flap and remove hood.
4. Turn valve ON by turning knob counterclockwise.
5. Slip hood over head making sure that the hose outlet is in front of the face.

### *Doffing Procedures:*

1. Remove hood.
2. Turn valve OFF by turning clockwise.

## APR COMMUNICATIONS EXERCISE: TEAM 1

After going through the check-out procedure in the classroom, don your air-purifying respirator. Each group of partners is issued two radios on matched frequencies. Partners numbered 1 leave the classroom with a radio; partners numbered 2 remain in the classroom with a radio. The teams take turns transmitting the following messages (Team 1 members transmit first). The teams write the messages they receive in the blank spaces. Repeat or verify messages as necessary.

1. "ARE YOU RECEIVING MY TRANSMISSION?"
2. "FOUND ONE DRUM OF ACETONE."
3. "THE PINT BOTTLES CONTAIN A BLUE LIQUID."
4. "26 BOTTLES, 16 DRUMS, 60 VIALS, 70 BOXES."
5. "THE CHEMICAL IS TOLUENE DIISOCYANATE. YOUR TURN TO TRANSMIT."
6. \_\_\_\_\_
7. \_\_\_\_\_
8. \_\_\_\_\_
9. \_\_\_\_\_
10. \_\_\_\_\_
11. "A BARREL CONTAINING CALCIUM HYPOCHLORITE."
12. "THE PLACARD IS RED WITH THE NUMBER 1203."
13. "THE CGI READS 10% AND THE O<sub>2</sub> IS 20.5%."
14. "THE HNU IS READING 15."
15. "THE SHIPPER'S ADDRESS IS 22 TWAIN, CHATTANOOGA, TENNESSEE. YOUR TURN TO TRANSMIT."
16. \_\_\_\_\_
17. \_\_\_\_\_
18. \_\_\_\_\_
19. \_\_\_\_\_
20. \_\_\_\_\_



## APR COMMUNICATIONS EXERCISE: TEAM 2

After going through the check-out procedure in the classroom, don your air-purifying respirator. Each group of partners is issued two radios on matched frequencies. Partners numbered 1 leave the classroom with a radio; partners numbered 2 remain in the classroom with a radio. The teams take turns transmitting the following messages (Team 1 members transmit first). The teams write the messages they receive in the blank spaces. Repeat or verify messages as necessary.

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_
4. \_\_\_\_\_
5. \_\_\_\_\_
6. "THIS DRUM CONTAINS A SOLID MATERIAL."
7. "THE CHEMICAL IS LISTED AS A CARCINOGEN, A TERATOGEN, AND A MUTAGEN."
8. "I GET A pH OF 1."
9. "THE WALKWAY LOOKS UNSTABLE."
10. "THERE ARE TWO CHEMICALS: TOLUENE AND METHYL ETHYL KETONE." YOUR TURN TO TRANSMIT."
11. \_\_\_\_\_
12. \_\_\_\_\_
13. \_\_\_\_\_
14. \_\_\_\_\_
15. \_\_\_\_\_
16. "THE OVA IS READING 100."
17. "WE HAVE A RADIATION READING OF 200 micro/R."
18. "MY MASK IS FOGGING UP."
19. "THEY SAY THE ROAD IS COVERED WITH DEAD OXEN."
20. "COME BACK TO THE CLASSROOM."

## **SELF-CONTAINED BREATHING APPARATUS**

### **I. OBJECTIVE**

Given an MSA self-contained breathing apparatus (SCBA) unit, the student will be able to conduct a regular SCBA inspection and check-out.

### **II. PROCEDURE**

- A. The instructor will review monthly SCBA inspection procedures and demonstrate the regular SCBA inspection and check-out procedures for the class.
- B. Using the following instructions, each student will perform a regular SCBA check-out. Students should repeat the check-out until they have successfully completed the checkout.

## **MONTHLY SCBA INSPECTION**

1. Check cylinder label for current hydrostatic test date.
2. Inspect cylinder for large dents or gouges in metal or fiberglass.
3. Inspect cylinder gauge for damage.
4. Perform a complete SCBA checkout.
5. Fill out appropriate records with results and recommendations.

## **REGULAR SCBA CHECK-OUT PROCEDURES**

### ***Preliminary Checks***

1. High-pressure hose connector is tight on cylinder fitting.
2. By-pass valve is closed.
3. Mainline valve is closed.
4. Regulator outlet is not covered or obstructed.

### ***Backpack/Harness Assembly***

1. Inspect straps for wear, damage, and completeness.
2. Inspect buckle for wear and proper functioning.
3. Inspect backplate for damage and proper fastening to cylinder.

### ***Cylinder and High Pressure Hose Assembly***

1. Check cylinder to ensure that it is firmly fastened to backplate.
2. Open cylinder valve. Listen or feel for leakage around packing and hose connection.
3. Check high pressure hose assembly for damage or leaks.

### ***Regulator***

1. Cover regulator outlet with palm of hand.
2. Open mainline valve.
3. Note stoppage of air flow after positive pressure builds.
4. Close mainline valve.
5. Remove hand from regulator outlet.
6. Open by-pass valve slowly to assure proper function.
7. Close by-pass valve.
8. Cover regulator outlet again with palm of hand.
9. Open mainline valve.
10. Note pressure reading on regulator gauge.
11. Close cylinder valve while keeping hand over regulator outlet.
12. Slowly move hand on the outlet to allow air to flow slowly.
13. Note pressure when low-pressure warning alarm sounds; it should read between 550–650 psi.
14. Remove hand from regulator outlet.
15. Close mainline valve.

### ***Facepiece and Breathing Tube***

1. Inspect head harness and facepiece for damage, serrations, and deteriorated rubber.
2. Inspect lens for damage and proper seal in facepiece.
3. Inspect exhalation valve for damage and dirt build-up.
4. Stretch breathing tube and inspect for holes and deterioration.
5. Inspect connector for damage and presence of washer.
6. Perform negative pressure test with facepiece donned.

### ***Storage of SCBA Unit***

1. Fully extend all straps.
2. Close cylinder valve.
3. Bleed pressure from high pressure hose by opening mainline valve.
4. Disconnect high pressure hose from cylinder.
5. Remove empty cylinder and replace with a full cylinder (approximately 1500 psi).
6. Reconnect high pressure hose to cylinder.
7. Close by-pass valve.
8. Close mainline valve.
9. Store facepiece and breathing tube.

## **Emergency Hand Signals**

**1. Hand Gripping Throat:**

"Out of air, can't breathe!"

**2. Gripping partner's wrist or placing both hands around waist:**

"Leave area immediately, no debating!"

**3. Hands on top of head:**

"Need assistance."

**4. Thumbs up:**

"Yes," "affirmative," "I understand."

**5. Thumbs down:**

"No," "negative," "I do not understand."

## **NOTES**

# **RADIATION SURVEY INSTRUMENTS**

## **I. OBJECTIVE**

This exercise familiarizes students with the operation of radiation survey instruments. Students will operate instruments under controlled conditions to determine the type of radiation being emitted, interpret instrument readings, and learn radiation survey techniques.

## **II. INSTRUMENT OPERATING PROCEDURES**

A wide variety of monitoring instruments are available for radiation surveys. Although each instrument is unique in its uses and limitations, in general, many features are common to all instruments. Therefore, familiarity with the operation of one instrument should transfer over to other instruments.

This exercise features a Ludlum Model 19 Micro R Meter. The instrument uses an internally mounted, 1 inch  $\times$  1 inch NaI(Tl) scintillator.

### **Ludlum Model 19 Controls**

The following controls are essential to operation of the Model 19:

- "AUDIO ON-OFF" Toggle Switch: In the ON position, operates the unimorph speaker, located on the left side of the instrument. The frequency of the clicks is relative to the rate of the incoming pulses. The higher the rate is, the higher the audio frequency. The audio should be turned OFF when not required to reduce battery drain.
- "F/S": Fast-Slow Toggle Switch provides meter response. Selecting the "F" position of the toggle switch provides 90% of full scale meter deflection in 3 seconds. In "S" position, 90% of full scale meter deflection takes 11 seconds. In "F" position, there is fast response and large meter deviation. "S" position should be used for slow response and damped, meter deviation.
- "BAT": BATTERY Pushbutton Switch, when depressed, indicates the battery charge status on the meter. The range selector switch must be out of the OFF position.
- "RES" Button: when depressed, provides a rapid means to drive the meter to zero.
- "L": Light Pushbutton Switch, when depressed, lights the meter face.
- "Range Selector Switch" is a six-position switch marked OFF, 5000, 500, 250, 50, and 25. Moving the range selector switch to one of the range positions provides the operator with an overall range of 0-5000 micro R/hr.



- The meter face is made up of two scales, 0–50 and 0–25, plus battery test. The 0–50 scale corresponds to the 50, 500, and 5000 positions on the range selector switch. The 0–25 scale corresponds to the 25 and 250 positions on the range selector switch. Note that range positions 5000, 500, and 50 are printed in black and correspond to the meter scale, printed in black. The range positions 250 and 25 are printed in red and correspond to the meter scale, printed in red.

### **Ludlum Model 19 Operation**

1. Range Selector Switch: Select the 0–5000 range.
2. BAT TEST Button: Depress. Check the BAT test on the appropriate scale. Replace the batteries if the meter pointer is below the battery CHK line.
3. Light Button: Depress. Check for light on the meter face.
4. Meter Response Switch: Check the response in the "F" and "S" positions.
5. Audio ON-OFF Switch: Check for audio indication.
6. Check the instrument for the proper scale indication with a known source. Check all the ranges for the appropriate scale indication.
7. Reset Button: Depress. Check to see that the meter pointer returns to the zero position.
8. The instrument is ready for monitoring.
9. During monitoring, use the lowest range scale that will still provide an on-scale reading.
10. Please remember that the Model 19 gives readings in micro-Roentgens (micro R).  
1000 micro R = 1 milli R.

### **III. EXERCISE PROCEDURES**

- A. Using the Model 19, perform the requested operations at the following stations. Record results on the following answer sheet.**

**Station 1: Record a background reading for the room.**

**Station 2: Measure the exposure rate due to the source at the three distances, as marked.**

**Station 3: Screen the "samples" for the presence of radiation and record the reading for radiation present (if any).**

**Station 4: Locate the "contamination" and record reading.**

## ANSWER SHEET

**Serial Number:** \_\_\_\_\_

**Station 1:** Background \_\_\_\_\_ micro R/HR

**Station 2:** Source \_\_\_\_\_ micro R/HR

1 foot (30.5 cm) \_\_\_\_\_ micro R/HR

2 feet (61 cm) \_\_\_\_\_ micro R/HR

**Station 3:** Radioactive Sample(s) \_\_\_\_\_ (letter)

Reading at surface of container \_\_\_\_\_ micro R/HR

**Station 4:** Location of contamination: \_\_\_\_\_  
\_\_\_\_\_

### **Answer the following:**

1. How does distance between the source of radiation and probe affect the reading?
2. If an instrument indicates an exposure of 50 mR/hr and a person worked in that area for 5 hours, what would be the total exposure?
3. Differentiate radiation monitoring procedures for unknown versus known situations.
4. What type of protection is adequate to perform a survey at a site that may have radioactive materials?

## **LEVEL B DRESSOUT**

### **I. OBJECTIVE**

In this exercise, students will don and doff level B protection and operate air monitoring in a drum sampling exercise.

### **II. PROCEDURE**

A. Level B dressout will be demonstrated.

B. Don level B.

1. Gather rain suit, gloves (inner gloves and outer gloves), boots, hard hat and SCBA.
2. Inspect and check out SCBA.
3. Put on rain suit.
4. Put on boots.
5. Put on SCBA (with a buddy's assistance).
6. Put on SCBA facepiece (with breathing tube connected).
7. Put on gloves (when taping, tuck glove inside sleeve and tape sleeve to glove leaving a pull tab).
8. When instructed, connect breathing tube to SCBA regulator outlet and go on air.

C. When instructed, use air monitoring instruments to sample drums and write down results.

**D. Doff level B protection.**

- 1. Remove outer gloves (remove tape if used).**
- 2. Remove hard hat and boots.**
- 3. Remove SCBA.**
- 4. Remove rain suit.**
- 5. Remove facepiece.**
- 6. Remove inner gloves.**
- 7. Store SCBA.**

**Sampling Results**

**INSTRUMENT**

**CONCENTRATION**

**MIXTURE**

Combustible Gas Indicator

\_\_\_\_\_

\_\_\_\_\_ < LEL

\_\_\_\_\_ LEL to UEL

\_\_\_\_\_ > LEL

Oxygen Indicator

\_\_\_\_\_

Colorimetric Indicator  
Tubes and Pumps

\_\_\_\_\_ Acetone

\_\_\_\_\_ Alcohol

\_\_\_\_\_ Toluene

HNU (Span = 9.8)

\_\_\_\_\_

## **NOTES**

## **LEVEL A DRESSOUT**

### **I. OBJECTIVE**

Following the level A demonstration, students will don and doff level A protection. Students will perform tasks and activities while dressed in level A in order to experience the physical limitations associated with wearing level A protection.

### **II. PROCEDURE**

A. Collect and lay out level A protective equipment:

1. SCBA
2. Fully encapsulating suit
3. Three pairs of gloves
  - inner gloves
  - suit gloves
  - outer (line man's gloves) gloves
4. Boots

B. Wipe the inside and outside of the SCBA facepiece lens and the inside of the suit lens with anti-fog solution.

C. Follow the level A donning procedures as demonstrated (see following procedures).

D. Follow instructions for specific tasks and activities to be performed.

E. After completing the exercise, doff equipment and properly store it (see following procedures).



### **Donning Level A**

Prior to wearing a fully encapsulating suit, inspect it thoroughly for damage and potential malfunction.

1. While sitting, step into legs, place feet properly, and gather suit around waist.
2. Put on steel toe/shank boots over feet of suit.
3. Put on disposable boot covers (optional).
4. Don SCBA with assistance of partner.
5. Don SCBA facepiece and perform negative pressure check.
6. Put on hard hat if one is to be worn with suit. If suit has built-in headband or hard hat see step 10.
7. Put on inner gloves.
8. Put arms into sleeves of suit.
9. Pull suit up and over SCBA, placing hood on top of air cylinder.
10. Adjust headband of suit or of hard hat if suit in suit by reaching up inside suit behind head or having partner adjust it (this adjustment may be made prior to donning the suit).
11. Put on outer gloves.
12. Place hood on head.
13. Connect breathing tube to regulator.
14. Secure suit by closing all fasteners.

### **Doffing Level A**

During removal, protect wearer's air supply and prevent transfer of contaminants from suit to wearer.

1. Remove disposable outer clothing such as gloves, boot covers, etc.
2. Remove boots.
3. Open suit.
4. Raise hood over head and place on air cylinder.
5. Remove arms from suit (one at a time).
6. Lower suit to waist.
7. While sitting (preferably) remove both legs from suit.
8. Remove SCBA.
9. Roll off inner gloves.
10. Store SCBA.
11. Dry suit, properly fold, and store.

## **NOTES**

# DECONTAMINATION

## I. OBJECTIVE

In this exercise, personnel decontamination methods and techniques are demonstrated and practiced. Students gain practical experience in setting up decontamination lines and practicing decontamination procedures.

## II. PROCEDURE

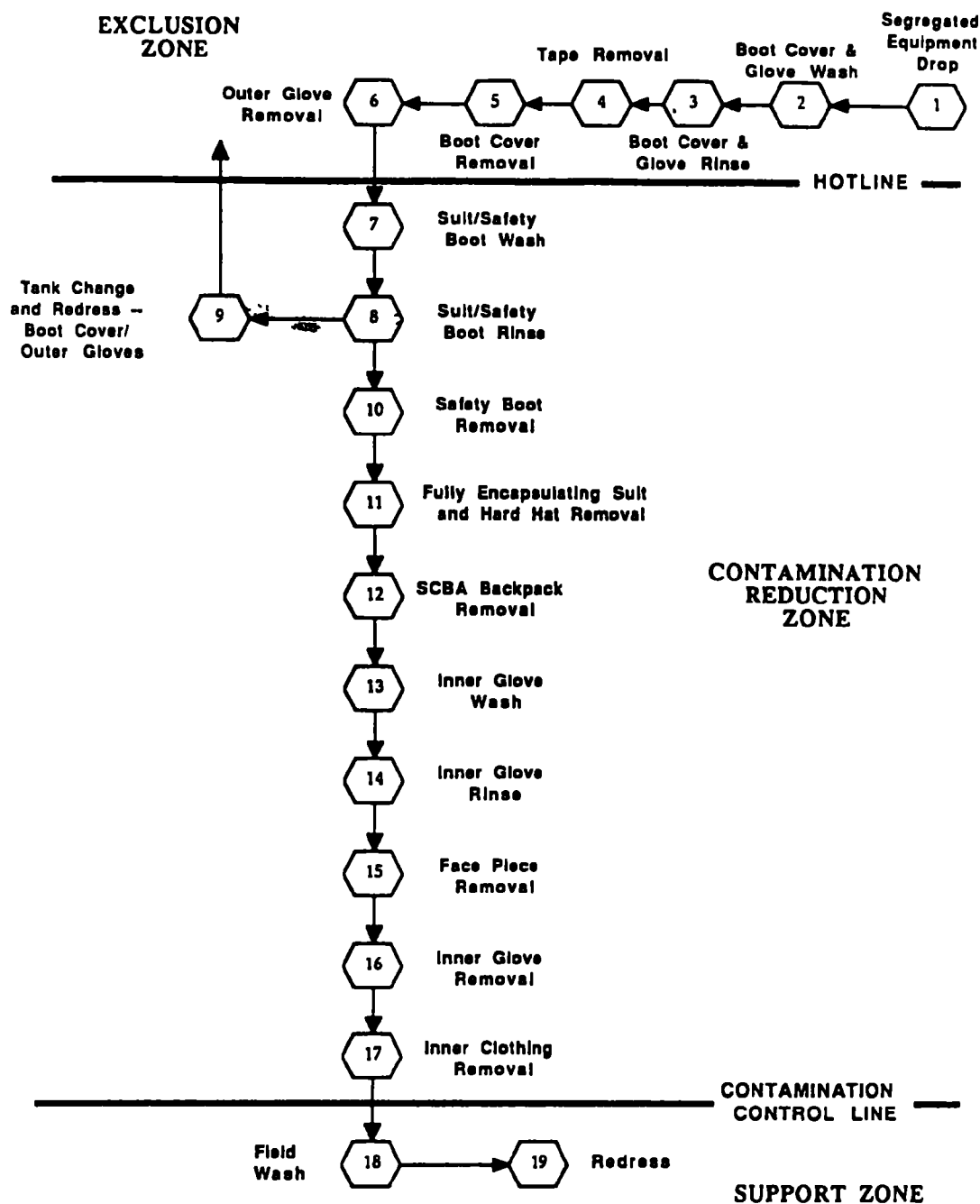
- A. The instructor gives a brief review of the decontamination procedure for Levels B and C protection.
- B. The instructor divides students into two groups: Level B Decontamination and Level C Decontamination. One volunteer from each group dons Level B<sup>a</sup> or Level C<sup>b</sup> protection as appropriate for their respective group.
- C. Students construct a decontamination line applicable for the assigned level of protection and scenario given by the instructor. Decontamination equipment provided for each group includes:
  - 3 wash tubs
  - 6 Hudson sprayers
  - 6 brushes
  - 6 step stools
  - 7 garbage cans
  - 2 buckets
  - 3 sponges
- D. Justify any decisions to add, combine, or eliminate steps or procedures. A set of decontamination equipment will be made available to each subgroup in the exercise area.
- E. Don appropriate level of protection (i.e., PVC splash gear and air-purifying respirators [APRs]) and decontaminate the volunteer entering the line from the "Exclusion Zone."
- F. Discuss each group's decontamination line.
- G. Disassemble the decontamination lines and properly store the equipment.

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<sup>a</sup> Level B equipment: SCBA, two-piece splash suit, inner gloves, outer gloves, boots, disposable boot covers, hard hat, and taped joints at outer gloves and boots.

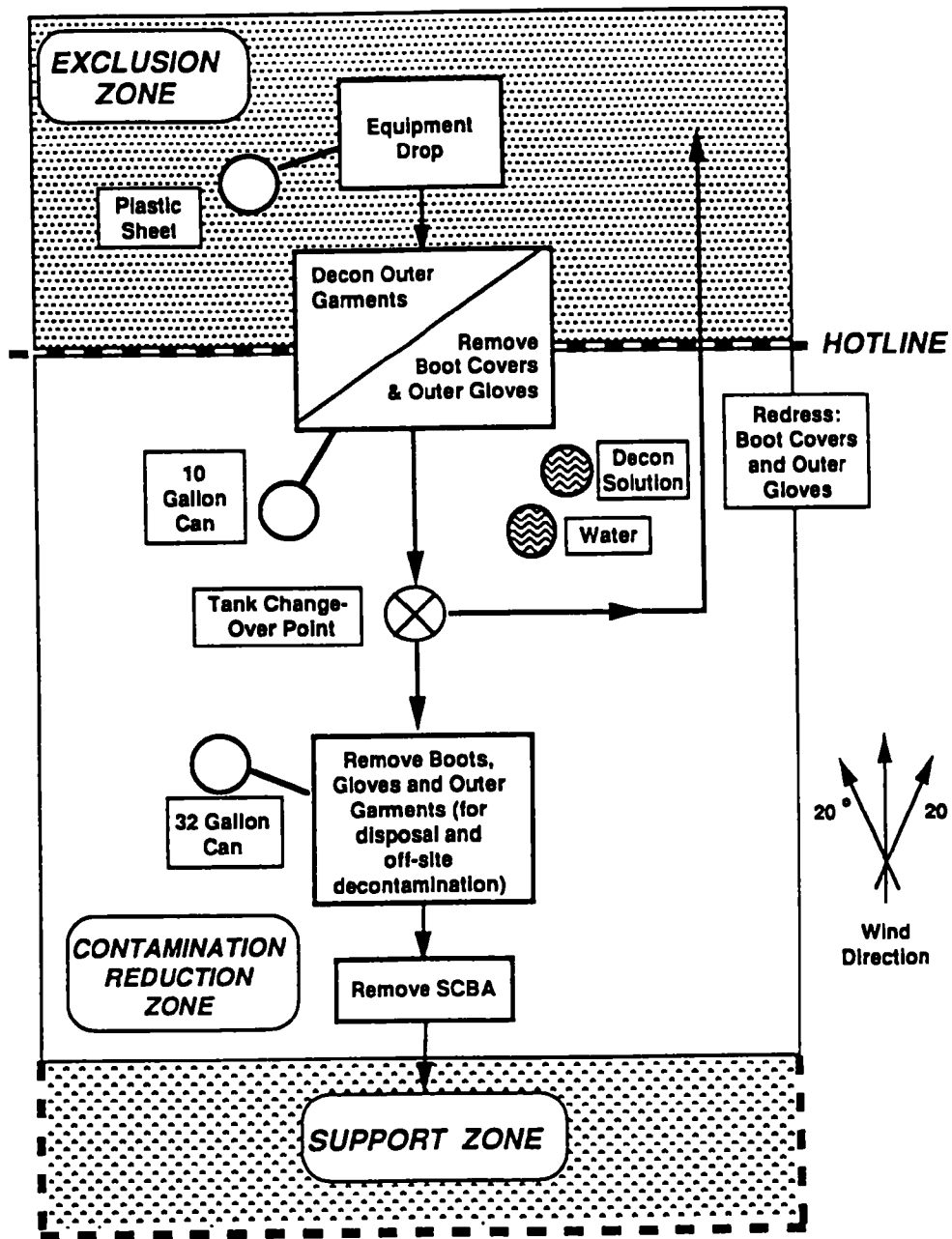
<sup>b</sup> Level C equipment: full-face APR, two-piece splash suit, inner gloves, outer gloves, boots, disposable boot covers, hard hat, and taped joints at outer gloves and boots.

## MAXIMUM DECONTAMINATION LAYOUT FOR LEVEL A PROTECTION



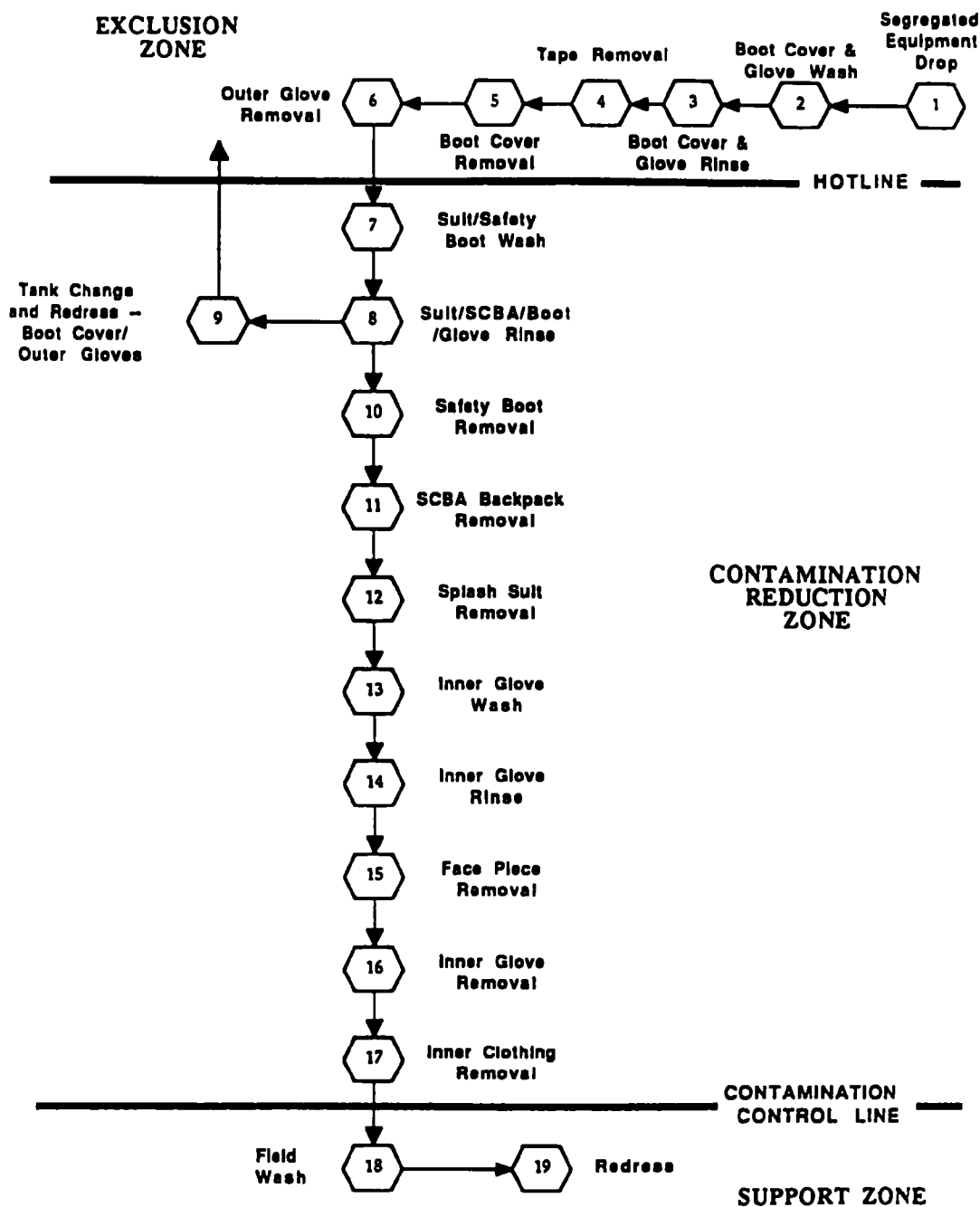
Source: U.S. EPA. 1992. *Standard Operating Safety Guides*. Publication No. 9285.1-03. U.S. Environmental Protection Agency, Washington, DC. p. 167.

# **MINIMUM DECONTAMINATION LAYOUT FOR LEVELS A & B PROTECTION**



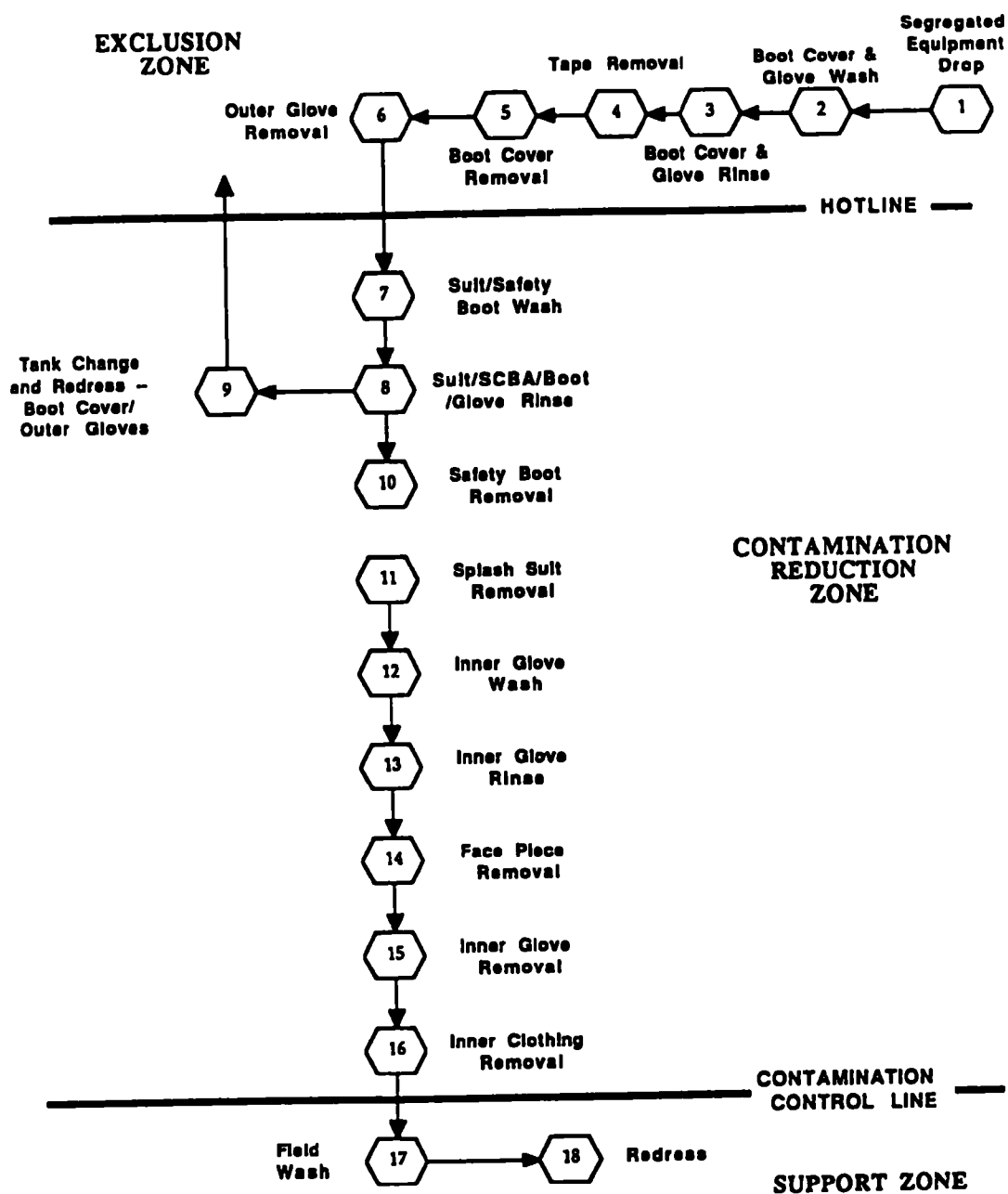
Source: U.S. EPA. 1992. *Standard Operating Safety Guides*. Publication No. 9285.1-03. U.S. Environmental Protection Agency, Washington, DC. p. 169.

## MAXIMUM DECONTAMINATION LAYOUT FOR LEVEL B PROTECTION



Source: U.S. EPA. 1992. *Standard Operating Safety Guides*. Publication No. 9285.1-03. U.S. Environmental Protection Agency, Washington, DC. p. 171.

## **MAXIMUM DECONTAMINATION LAYOUT FOR LEVEL C PROTECTION**



Source: U.S. EPA. 1992. *Standard Operating Safety Guides*. Publication No. 9285.1-03. U.S. Environmental Protection Agency, Washington, DC. p. 175.



## **NOTES**

# **SITE SAFETY AND WORK PLAN DEVELOPMENT**

## **I. OBJECTIVE**

Students will plan and develop a site safety plan and work plan for the given exercise scenario.

## **II. PROCEDURE**

- A.** Given the exercise scenario, each team of students will plan and develop a site safety plan using the following generic site safety plan.
- B.** Each team submits one site safety plan and work plan to the instructor for review before implementation.

## **Generic Site Safety Plan\***

### **SITE DESCRIPTION**

Date \_\_\_\_\_ Location \_\_\_\_\_

Hazards \_\_\_\_\_

Area affected \_\_\_\_\_  
\_\_\_\_\_

Surrounding population \_\_\_\_\_

Topography \_\_\_\_\_

Weather conditions \_\_\_\_\_

Additional information \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

### **ENTRY OBJECTIVES (actions, tasks to be accomplished, etc.)**

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

### **ONSITE ORGANIZATION/COORDINATION**

Team Leader	_____
Scientific Advisor	_____
Site Safety Officer	_____
Public Info. Officer	_____
Security Officer	_____
Recordkeeper	_____
Financial Officer	_____
Field Team Leader	_____
Field Team Members	_____
	_____
	_____
	_____
	_____
	_____

- \* Generic site safety plan based on a plan developed from the U.S. Coast Guard. It is not all inclusive and should only be used as a guide, not a standard. From *Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities*, NIOSH/OSHA/USCG/EPA, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, October 1985.

## **Generic Site Safety Plan**

### **ONSITE ORGANIZATION/COORDINATION (continued)**

Federal agency representatives \_\_\_\_\_  
\_\_\_\_\_

State agency representatives \_\_\_\_\_  
\_\_\_\_\_

Local agency representatives \_\_\_\_\_  
\_\_\_\_\_

Contractor(s) \_\_\_\_\_  
\_\_\_\_\_

### **ONSITE CONTROL**

\_\_\_\_\_ has been designated to coordinate access control and security onsite. A safe perimeter has been established at (distance and description of controlled areas) \_\_\_\_\_

\_\_\_\_\_. No authorized person should be within this area.

The onsite Command Post and staging area have been established at \_\_\_\_\_  
\_\_\_\_\_.

The prevailing wind conditions are \_\_\_\_\_. This location is upwind from the Exclusion Zone.

Control boundaries have been established, and the Exclusion Zone, hot line, Contamination Reduction Zone, and Support Zone have been identified and designated as follows: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_.

These boundaries are identified by: (marking of zones [e.g., red boundary tape - hot line; traffic cones - Support Zone]) \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_.

## Generic Site Safety Plan

### HAZARD EVALUATION

Hazards known or suspected to be onsite. The primary hazards of each are identified.

Substances Involved	Concentrations (if known)	Primary Hazard (e.g., toxic, inhalation)
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

Additional hazards found onsite include: (e.g., slippery ground, uneven terrain)

Hazardous substance information form(s) for the involved substance(s) have been completed and are attached.

### PERSONAL PROTECTIVE EQUIPMENT

Based on the evaluation of potential hazards, the following levels of personal protection have been designated for the applicable work areas or tasks:

Work Area/Zone	Job Function/Task	Level of Protection				
		A	B	C	D	Other
_____	_____	A	B	C	D	Other
_____	_____	A	B	C	D	Other
_____	_____	A	B	C	D	Other
_____	_____	A	B	C	D	Other
_____	_____	A	B	C	D	Other
_____	_____	A	B	C	D	Other

Specific protective equipment for each level of protection is as follows:

Level A	_____	Level C	_____
	_____		_____
	_____		_____
	_____		_____

Level B	_____	Level D	_____
	_____		_____
	_____		_____
	_____		_____

Other: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

## **Generic Site Safety Plan**

### **PERSONAL PROTECTIVE EQUIPMENT (continued)**

The following protective clothing materials are required for the involved substances:

<b>Substance</b>	<b>Material Type (i.e., PVC, Viton)</b>
_____	_____
_____	_____
_____	_____
_____	_____

If air-purifying respirators are used, (filter type) \_\_\_\_\_, is the appropriate canister for use with the involved substances and concentrations. A competent individual has determined that all criteria for using this type of respiratory protection have been met.

**NO CHANGES TO THE SPECIFIED LEVELS OF PROTECTION SHALL BE MADE WITHOUT THE APPROVAL OF THE SITE SAFETY OFFICER AND THE TEAM LEADER.**

### **ONSITE WORK PLANS**

Work parties consisting of \_\_\_\_\_ persons will perform the following tasks:

<b>Project Team Leader</b>	<b>(name)</b> _____	<b>(function)</b> _____
		_____
		_____
<b>Work Party #1</b>	_____	_____
		_____
		_____
<b>Work Party #2</b>	_____	_____
		_____
		_____
<b>Rescue Team</b>	_____	_____
		_____
		_____
<b>Decon. Team</b>	_____	_____
		_____
		_____
		_____

The work parties were briefed on the contents of this plan at \_\_\_\_\_.

## Generic Site Safety Plan

### COMMUNICATION PROCEDURES

Channel \_\_\_\_\_ has been designated as the radio frequency for personnel in the exclusion zone. All other onsite communications will use channel \_\_\_\_\_.

Personnel in the Exclusion Zone should remain in constant radio communication or within site of the Project Team Leader. Any failure of radio communication requires an evaluation of whether personnel should leave the Exclusion Zone.

\_\_\_\_\_ is the emergency signal to indicate that all personnel should leave the Exclusion Zone.

The following standard hand signals will be used in case of failure of radio communications:

- hand gripping throat: "Out of air, can't breathe"
- gripping partner's wrist or both hands around waist: "Leave area immediately"
- hands on top of head: "Need assistance"
- thumbs up: "OK, I am alright, I understand"
- thumbs down: "No, negative"

Telephone communication to the Command Post should be established as soon as possible. The phone number is \_\_\_\_\_.

### DECONTAMINATION PROCEDURES

Personnel and equipment leaving the Exclusion Zone shall be thoroughly decontaminated. The standard level \_\_\_\_ decontamination protocol shall be used with the following decontamination stations:

- |          |          |             |
|----------|----------|-------------|
| 1. _____ | 5. _____ | 9. _____    |
| 2. _____ | 6. _____ | 10. _____   |
| 3. _____ | 7. _____ | Other _____ |
| 4. _____ | 8. _____ | _____       |

Emergency decontamination will include the following stations: \_\_\_\_\_  
\_\_\_\_\_

The following decontamination equipment is required: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

(Detergent & water, etc.) \_\_\_\_\_ will be used as the decontamination solution.

## Generic Site Safety Plan

### **SITE SAFETY AND HEALTH PLAN**

#### **Site Safety Officer**

\_\_\_\_\_ is the designated Site Safety Officer and is directly responsible to the Project Team Leader for safety recommendations onsite.

#### **Emergency Medical Care**

(Names of qualified personnel) \_\_\_\_\_ are the qualified EMTs onsite.

(Medical facility, address, and telephone number) \_\_\_\_\_

is located within \_\_\_\_\_ minutes of this location. (name of person) \_\_\_\_\_ was contacted at (time) \_\_\_\_\_ and briefed on the situation, the potential hazards, and the substances involved. A map of alternative routes to this medical facility is available at (command post, etc.) \_\_\_\_\_

First aid equipment is available onsite at the following locations:

#### Equipment

(i.e., first-aid kit, emergency eye wash, shower)

#### Location

_____	_____
_____	_____
_____	_____
_____	_____

Emergency medical information for substance present:

#### Substance

#### Exposure Symptoms

#### First-Aid Instructions

_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

List of Emergency Phone Numbers:

Police	_____
Fire	_____
Hospital	_____
Airport	_____
Public Health Advisor	_____



## **Generic Site Safety Plan**

### **SITE SAFETY AND HEALTH PLAN (continued)**

#### **Environmental Monitoring**

The following monitoring instruments shall be used onsite at the specified intervals:

Combustible Gas Indicator	continuously/hourly/daily/other _____
Oxygen Meters	continuously/hourly/daily/other _____
HNU/OVA	continuously/hourly/daily/other _____
Colorimetric Tubes (type)	continuously/hourly/daily/other _____

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Other

_____	continuously/hourly/daily/other _____
_____	continuously/hourly/daily/other _____

#### **Emergency Procedures (modified as required for site)**

The following standard procedures will be used by onsite personnel. The Site Safety Officer shall be notified of any onsite emergencies and shall be responsible for ensuring that the appropriate procedures are followed.

**Personnel Injury in the Exclusion Zone:** Upon notification of an injury in the Exclusion Zone, the designated emergency signal \_\_\_\_\_ shall be sounded. All site personnel shall assemble at the decontamination line. The rescue team will enter the Exclusion Zone (if required) to remove the injured person to the hot line. The Site Safety Officer and Project Team Leader should evaluate the nature of the injury and the affected person should be decontaminated to the extent possible prior to movement to the Support Zone. The onsite EMT shall initiate the appropriate first aid, and contact should be made with an ambulance and the designated medical facility. No persons shall reenter the Exclusion Zone until the cause of the injury (or symptoms) is determined.

**Personnel Injury in the Support Zone:** Upon notification of an injury in the Support Zone, the Project Team Leader and Site Safety Officer will assess the nature of the injury. If the cause of the injury or loss of the injured person does not affect the performance of site personnel, operations may continue, with the onsite EMT initiating the appropriate first aid and necessary follow-up as stated above. If the injury increases the risk to others, the designated emergency signal \_\_\_\_\_ shall be sounded and all site personnel shall move to the decontamination line for further instructions. Onsite activities will stop until the added risk is removed or minimized.

**Fire/Explosion:** Upon notification of a fire or explosion onsite, the designated emergency signal \_\_\_\_\_ shall be sounded and all site personnel assembled at the decontamination line. The fire department shall be alerted and all personnel moved to safe distance from the involved area.

**Personal Protective Equipment Failure:** If any site worker experiences a failure or alteration of protective equipment that affects the protection factor, that person and his/her buddy shall immediately leave the Exclusion Zone. Reentry shall not be permitted until the equipment has been repaired or replaced.

## Generic Site Safety Plan

### **SITE SAFETY AND HEALTH PLAN (continued)**

**Other Equipment Failure:** If any other equipment onsite fails to operate properly, the Project Team Leader and Site Safety Officer shall be notified and then determine the effect of this failure on continuing operations onsite. If the failure affects the safety of personnel or prevents completion of the Work Plan tasks, all personnel shall leave the Exclusion Zone until the situation is evaluated and appropriate actions taken.

The following emergency escape routes are designated for use in those situations where escape from the Exclusion Zone cannot occur through the decontamination line: (describe alternate routes for evacuation)

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In all situations, when an onsite emergency results in evacuation of the Exclusion Zone, personnel shall not reenter until:

1. The conditions resulting in the emergency have been corrected.
2. The hazards have been reassessed.
3. The Site Safety Plan has been reviewed.
4. Site Personnel have been briefed on any changes in the Site Safety Plan.

### **Personal Monitoring**

The following personal monitoring will be in effect onsite:

**Personal exposure sampling:** (use of personal sampling pumps, air monitors etc., worn by personnel to monitor exposure)

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**Medical monitoring:** The expected air temperature will be \_\_\_\_ °F. If it is determined that heat stress monitoring is required (mandatory if over 70 °F), the following procedures shall be followed: \_\_\_\_\_

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*All site personnel have read the above plan and are familiar with its provisions.*

	(name)	(signature)
Site Safety Officer	_____	_____
Project Team Leader	_____	_____
Other Site Personnel	_____	_____
	_____	_____
	_____	_____
	_____	_____
	_____	_____
	_____	_____

## **NOTES**

## **APPENDIX A**

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### **Abandoned Warehouse Scenario**

# **HAZARDOUS MATERIALS INCIDENT RESPONSE OPERATIONS**

## **Abandoned Warehouse Scenario**

Five days ago, police received a report that drums of chemicals were found at a vacant warehouse. Two children discovered the drums while playing inside an abandoned, unsecured warehouse.

The police department informed the fire department of the situation. The fire department investigated the scene. They discovered about 40 drums in the old warehouse. During their investigation, they did not find any leaking containers and did not detect combustible levels of gases or vapors while using their combustible gas indicator. The fire department determined that there was no emergency or threat of fire. Thus, further investigation has been turned over to your team, the Toxic Waste Investigation Team.

The owner of the building, a land developer, stated that he had no knowledge of the drums prior to this time. The building has been abandoned for 10 years. He said he wants any information that you can provide concerning this situation. He also said that a blueprint of the building is not available. He knows that all of the utilities were disconnected in the warehouse.

The police department stated that they will provide security if it becomes an emergency situation. They will assist in evacuating nearby residents and will control nearby traffic if needed. (If police assistance is requested, they will be controlling the outside of the area; therefore, you will not see them.)

The fire department will provide emergency medical service and will be on stand-by in the event of fire. They will not be present at the warehouse during the investigation, so they must be called if their assistance is needed. (If they are called to assist, simply note them as being present.)

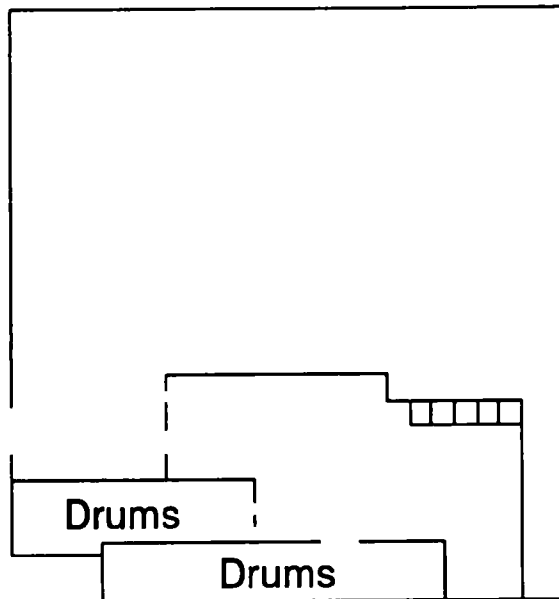
The fire department produced a rough map (from memory) and wrote a list of information that they could read from the drum labels in the warehouse. This is the only information that they have.

## Warehouse Information Noted by Fire Department

At least one drum of each of the following chemicals was noted in the warehouse:

- Toluene
- Methylene chloride
- Sodium hydroxide
- Acetone
- Amyl alcohol
- Butyl alcohol
- Isopropyl alcohol
- Ammonium hydroxide
- Muriatic acid
- Aluminum arsenide
- Calcium hydrochloride

Parking Lot



## **APPENDIX B**

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### **Superfund Site Scenario (Road)**

# **HAZARDOUS MATERIALS INCIDENT RESPONSE OPERATIONS**

## **Superfund Site Scenario (Road)**

The city police department has requested that you, the state's Toxic Waste Investigation Team, investigate a suspect illegal waste site. The site was reported to the police by Mr. Edward Haney, a real estate appraiser who found several drums while conducting a property appraisal. Mr. Haney reported to the police that he felt physically ill and went to an emergency room after leaving the property. He reported that his eyes and skin felt irritated and that he felt nauseous and short of breath.

The objectives of the Toxic Waste Investigation Team are:

1. Characterize the site, using air monitoring instruments, to determine whether any harmful concentrations are present.
2. Identify the contents of the drums and determine what hazards they may pose to people who live or work in the immediate area.
3. Provide a recommendation on how the site should be remediated.

Mr. Haney wants to know what's on that property!

### **GROUND RULES**

1. Instrument readings will be provided by the instructor accompanying the entry team. The entry team members will be expected to calibrate and operate the instruments in the proper manner.
2. No entries into the site will be allowed without an instructor accompanying the entry team.
3. The instructors will be "invisible," but will answer justifiable questions.
4. Mock telephone calls may be made through an available instructor. All telephone calls should be logged, listing the time the call was made and the information that was obtained.
5. Nothing may be simulated without the approval of an instructor. Simulations should be recorded in the logbook.
6. Security and other team members should refrain from using any actions of a physical nature.
7. Any additional equipment may be requested through an instructor. The instructor will determine whether the equipment will be made available to the team.