

United States  
Environmental Protection  
Agency

Solid Waste and  
Emergency Response  
(OS-420)W1

EPA/910/B-92/001A  
June 1992



# Health and Safety Training for Underground Storage Tank Inspectors

## Instructor's Guide



## GENERAL GUIDANCE FOR THE INSTRUCTOR

### Course length:

This course is designed to be flexible in length, and may be anywhere from 24-40 hours in length. **Limiting the course to a simple discussion of the material here, will result in a 24 hour course, or perhaps longer, depending on the amount of discussion, review and testing that is incorporated.** Although the written material in the manual is kept to a minimum, it covers a great deal of ground. A slower pace, with lots of discussion is likely to prove more valuable than a "whirlwind" tour of the material.

**To increase the length to a 32 hour course,** add one day of hands-on training in use of the equipment described in the text: oxygen meter, photoionization detector, flame ionization detector, Drager tubes, combustible gas indicator etc., and conduct a respirator fit test. **IF THE COURSE IS BEING GIVEN TO REGULATORS OR OTHER INSPECTORS, IT IS STRONGLY RECOMMENDED THAT THE COURSE INCLUDE THESE THINGS, AS "HEAD KNOWLEDGE" ALONE IS NOT SUFFICIENT.** In addition, inspectors and site workers need to meet OSHA training requirements. Twenty four hours of training is required for inspectors and 40 hours for cleanup workers. For those supervising but not actually conducting work on-site, or merely wanting to learn basic safety hazards, 24 hours is probably sufficient.

**To increase the course length to 40 hours,** add a day of field visits to actual sites to provide additional practice using instruments, and to observe and analyze site conditions. This will provide some very valuable experience and help students to gain confidence in their own abilities. What is accomplished in these days will depend in large measure on your own creativity and the type of sites you select. State field offices of the UST agency may be able to help you select sites at the proper stages of development to make site visits productive or interesting, and indicate sites where a visit would not cause antagonism from the owner or other parties.

### **Some potential field activities for days 4 and 5 include:**

- Visit sites where removals, cleanups and installations are underway; have students observe and analyze the site and workers, identifying safe and unsafe practices/conditions.
- Visit a site and have students develop draft safety plan outlines based on the site conditions and activities they have observed. Follow this up with a group discussion of what they would include.
- Practice using the monitoring instruments and properly recording data in the field setting.

### Textbook Format

**Split page:** This manual is designed with a split page format to provide space for the students to take notes alongside the text, rather than on separate sheets of paper. Encourage them to do this, as it keeps all relevant material together.

**Boxes:** All of the word slides (~160) that accompany the course are reproduced in boxes at the top of the appropriate page of text, so that students do not need to feverishly take notes, and can concentrate on the lecture without missing any material. Point this out at the beginning of the course and encourage them to follow along in the book, where possible.

**Lists of objectives:** Objectives that a student should be able to accomplish after completing the course are listed at the beginning of each section. These will help to focus students' attention on the most important portions of the chapter. Note that these objectives are worded in such a way that the student should be able to know when he has met an objective. They use words such as "list", "describe", and "define", as opposed to words such as "know", "understand", "believe" that leave the students unsure whether or not they have mastered the material. It is difficult to be sure when material is "known" or "understood", but easy to determine when a list has been learned to compiled.

The objectives can be used as self-quizzes by the student, or can be used as quick understanding-checks or homework by the instructor. In the course introduction, draw students' attention to the objectives, to help them to focus on what they should look for as they go through the chapter, and explain how you will use them.

**Accident descriptions:** Accidents, by definition, are not planned. But when students are aware of potential accidents, they are more likely to be prevention-oriented. Accident possibilities at sites using a variety of heavy equipment, with a variety of ongoing activities, are almost endless. Where appropriate, a list of relevant real-life accidents has been compiled and placed at the end of each section, to help provide some insight into both the common and the more bizarre things which have occurred on tank sites. Be sure to draw student's attention to these descriptions. Discuss the variety - and similarities - among them, and encourage students to share examples from their own experience as well. Discuss how some of the accidents could have been prevented.

**Appendices:** The text has been deliberately kept relatively simple. More detailed material on respiratory protection and monitoring equipment is available in the appendices, for those who wish additional information.

**Slides:** In addition to the word slides, a number of picture slides accompany the course. The instructor notes accompanying each chapter indicate the graphic slides most appropriate for use with that chapter, and provide a small narrative to accompany each slide.

### General Comments

**Involve your students:** Every class is likely to have some experienced people in it. Take advantage of these people and draw them out; get them to share real-world "horror stories" from their own experience, and the course will be more interesting, more lively, and more relevant for everyone.

**Bring "real life" into the classroom:** Several good videos exist that provide safety information and bring a "field presence" into the classroom. These can be obtained from any Regional EPA office. They include:

- What do We Have Here? An inspector's guide to site assessment at closure (30 minutes). This also includes an additional 14 minute section on field testing instruments and a 7 minute segment on soil and water sampling. (Produced by the New England Interstate Water Pollution Commission).

- Doing it Right: proper UST Installation (40 minutes), and
- A question of When; An Overview Of Underground Tank Installation For Inspectors (36 minutes). (Produced by the national Fire Protection Association)

For the 32 and 40 hour courses, you will need to have various pieces of monitoring equipment and examples of personal protective equipment available for students to use.

**Tailor the subject matter to the class need:** This manual is a starting point, but is not intended to be the "perfect course". It provides the basics, but most instructors will want to add their own personal touches. This will also be helpful to the students, if you can slant the class toward your audience. Several different groups of people will be attracted to a health and safety course: workers and inspectors needing to fulfill OSHA safety requirements, managers and supervisors who want a better idea what to expect on a site; contractors who have already had basis training and need CEUs or refresher training for state contractor certification programs. Determine at the beginning who the audience is, what level of detail and hand-on training they need, and what they expect from the class.

**Provide proof of course attendance:** Many students will need to have proof that they have completed a certain number of hours of training. Consider issuing continuing education units (CEUs) or certificates to those who pass the course.

**Testing:** Consider including some review and testing, either through mini quizzes or at the end of the course. Given the short length of the course and the volume of material covered, an open-book test may be appropriate. Students tend to take something more seriously if they know they will be tested on it. Always review answers to the quizzes, to reinforce the correct answers.



## **Guidance for the Instructor: Introductory Section**

### **Suggested Activities:**

- Ask students to briefly identify themselves, state their reasons for taking the course, and tell and what they hope/expect to get out of it. This will help you know what to focus more heavily on, so you can best meet their needs.
- Discuss the manual format, and stress that all word slides are reproduced in the text boxes, eliminating the need for extensive note-taking.
- Describe activities the course will and will not accomplish. (Will it include a respirator fit-test? Will students need additional training prior to using respirators or conducting confined-space entries)?
- Pass around a sign-in sheet to insure the names and addresses of all students are correct. Many students will want to obtain CEUs and/or proof they have completed the course. You will want to issue certificates, continuing education credits, or letters to those who complete the course.

### **Visuals:**

In addition to the word slides shown in this chapter, the following graphic slides are applicable to this chapter:

#### **Slides**

- (Drill rig): Heavy equipment hazards and accidents will be discussed
- (Various confined spaces): the course will cover confined spaces, but you will need additional training before you are actually qualified to make confined space entries
- (Large excavation with dragline): excavations have special safety problems
- (Man smoking during installation): Properties and characteristics of petroleum, particularly flammability of gasoline, and proper activities on UST sites (smoking is not one of them) will be discussed.
- (Man pouring gasoline from drum to small container): Dos and don'ts of petroleum handling will be discussed
- (Monitoring equipment): You will learn the types of monitoring equipment used on UST sites, and advantages and disadvantages of each type.
- (Man sampling): toxicity of petroleum products and exposure potential during various activities such as sampling, will be discussed
- (Person in protective gear): You will learn the various levels of protection, the proper equipment to use and when to wear it

**Other Comments:**

OSHA regulations can be obtained from the Government Printing Office (GPO) at a reasonable cost. Contact them for costs and ordering information. You may wish to also pass on this information to the students.

## **Guidance for the Instructor: Petroleum Types and Characteristics**

### **Additional Suggested Activities:**

- Differences in properties of the various petroleum classes will impact their fate and transport, as well as dictating what methods are effective for leak detection, and the degree of exposure workers may expect. Ask students to predict, based on the properties, which classes will be most likely to produce vapors; to migrate most quickly below ground; to have a benzene exposure hazard; to produce explosions; to be best/least likely observed in groundwater wells or vapor monitors, etc.

### **Visuals:**

In addition to the word slides shown in this chapter, the following graphic slides are applicable to this chapter:

#### **Slides**

- (Oil floating on water in bailer): low specific gravity of petroleum makes it float; this enhances detection and recovery in groundwater monitoring wells.
- (Excavation): Because of the high vapor density gasoline vapors tend to accumulate in low and enclosed areas, such as excavation tanks, and trenches. Always check these areas for vapors.

### **Other Comments:**

## **Guidance for the Instructor: Fires and Explosions**

### **Additional Suggested Activities:**

- Watch the video "A question of When" (36 minutes, NFPA)

### **Visuals:**

In addition to the word slides shown in this chapter, the following graphic slides are applicable:

#### **Slides**

- (Flammable ranges): Vapor mixtures too rich or too lean will not burn. The range where combustion can occur is the flammable range, bounded by the LEL (too rich above this) and the LEL (too lean below this).
- (Fire Triangle): Fuel, ignition source and oxygen are all needed to support combustion. Removing any one of these will prevent it.
- (Petroleum fire): Occurs when vapors in the flammable range are coupled with oxygen and an ignition source.
- (Man cutting tank with torch): Vapors, not liquid product, are the most dangerous petroleum state. Never cut into a tank until all vapors are removed; torches are a good ignition source for completing the fire triangle!
- (Man smoking): another potential ignition source.
- (Backhoe striking tank): equipment striking the metal tank may produce sparks, causing ignition of vapors.
- Grounded equipment): grounding equipment will divert static electricity into the earth, eliminating its buildup.

### **Other Comments:**

For additional material, and if students are interested, you may want to expand on the Open Cup and Closed Cup methods for measuring flash point.

Aviation fuels vary widely in fire hazard:

**Jet A:**

F.P. = 100-150 degrees F

LFL = .7% (significant variability)

UFL = 5% (Significant variability)

**JP-4**

F.P.= 20 degrees F (variable)

LFL = 1.3% (variable)

UFL = 8% (variable)

Accidents involving petroleum transfer are shown in Table 2-1. Stress that petroleum vapor, not the product, is the most dangerous, and that the majority of accident seem to occur during closure

## **Guidance for the Instructor: Oxygen Depletion**

### **Additional Suggested Activities:**

#### **Visuals:**

In addition to the word slides shown in this chapter, the following graphic slides are applicable:

#### **Slides**

- (Tank): Possible area of oxygen deficiency.
- (Excavation): Possible area of oxygen deficiency.
- (Sewer): area for possible accumulation of toxic gasses and/or oxygen deficiency.
- (Oxygen depletion chart): Normal air is 21% oxygen. Below 19.5%, air supplying respirators must be used.

#### **Other Comments:**

## **Guidance for the Instructor: Confined Spaces**

### **Additional Suggested Activities:**

- Discuss the topics a confined space entry plan might be expected to contain and identify other reasons (besides safety) that it would be important to have such a plan.

### **Visuals:**

In addition to the word slides shown in this chapter, the following graphic slides are applicable:

#### **Slides**

- (photo of various confined spaces): examples of confined space areas
- (Monitoring tank prior to entry): Be sure you understand conditions of confined spaces on the site. Explosive gasses or oxygen deficiency may be present
- (Inspecting a large tank prior to entry): Know conditions before entry
- (Isolation tag and pipes that have been blind-flanged or "blanked"): Isolate confined spaces from other systems prior to entry
- (Disable and tag-out equipment):
- (Electrical lockout): Each person has a separate key...
- (Improper tank entry): In case of emergence here, worker wearing APR cannot be pulled out
- (Proper tank Entry): Note tripod and harness, SCBA. These assist if worker removal is necessary
- (Buddy system): using the buddy system is a must when working in confined space conditions.
- (Tombstone): avoid the ultimate "confined space" by understanding and avoiding confined space hazards

### **Other Comments:**

## **Guidance for the Instructor: Heavy Equipment**

### **Additional Suggested Activities:**

- Show slides with poor safety practices and have students identify what is being done incorrectly or unsafely in each situation. This is a good way to help teach critical evaluation and get class participation. It is also easy to obtain additional slides, because more often than not, everywhere you look, something is being done wrong!
- When showing slides of equipment, have students identify the major hazards associated with each type.
- Review the accidents at the end of the chapter and discuss how they could have been avoided

### **Visuals:**

In addition to the word slides shown in this chapter, the following graphic slides are applicable:

#### **Slides**

- (Man attaching chain to backhoe bucket): Is he visible to the bucket operator?
- (Man preparing to attach chain to backhoe bucket):
- (Man standing close to chain as tank comes out): If the chain should snap, he's standing right in the way
- (Backhoe): Stand well back to avoid swinging buckets and unstable loads
- (Backhoe pulling tank): Spark generation and chain snapping are possible hazards here
- (Dragline sitting on edge of excavation): Heavy equipment too close to the edge of excavations may cause cave-ins. Heavy loads may also pull it into the excavation, injuring the operator and anyone located in the hole
- (Trackhoe undercutting the ledge it is sitting on): Keep equipment well back from the excavation edge
- (Drill rig): Avoid rotating parts that may sever limbs. Restrain long hair and avoid loose clothing around all moving equipment
- (Dragline-type crane): an older type of crane, it is track-mounted and very heavy (and very stable). It can rotate 360 degrees.
- (Tank being lowered by boom on cherry picker): newer type cranes, these are often found at UST sites because they are truck-mounted and very mobile. They are equipped with outriggers that must be set before the lifting arm is used, and must remain in place until the lift arm is retracted. The further extended the arm, the less weight the crane can lift.



-- (Frayed cable): Minor fraying may not significantly affect performance, but more severe fraying is dangerous; load limits of frayed cable are not known, and cable may snap. Frayed cable may also hang and snarl.

-- (Workers standing under suspended tanks): Workers should use cables or rods to position suspended tanks. They should not stand under tanks and use their bodies or hands to adjust tank position.

-- (Overhead electrical line): A major hazard to cranes; it can be easily snagged, causing electrocution hazards

-- (Trackhoe operating near overhead line): If contact with a live overhead line occurs, equipment operators should remain in the cab of the equipment, sit still, and avoid touching the cab controls and all metal surfaces.

**Other Comments:**

## **Guidance for the Instructor: Excavations**

### **Additional Suggested Activities:**

- Review the accidents listed at the end of the chapter, and discuss how they could have been avoided.

### **Visuals:**

In addition to the word slides shown in this chapter, the following graphic slides are applicable:

#### **Slides**

- (Trench shield or trench box):
- (Trench supports or shoring):
- (Sloping):
- (Dangerous excavation): shows poor shoring, spoil too close to edge, and heavy equipment straddling the trench
- (Spoil piled too close to excavation):
- (Water accumulating in excavation):
- (Ribbon barricades): placing barricades around the work area will prevent people and equipment from getting too close to the excavation edge.
- (Sawhorse barricade with light): lighted barricades reduce nighttime hazards by alerting pedestrians
- (Car in excavation): Roping off or barricading the excavation might have prevented this.

### **Other Comments:**

## **Guidance for the Instructor: Toxicity**

### **Additional Suggested Activities:**

#### **Visuals:**

In addition to the word slides shown in this chapter, the following graphic slides are applicable:

#### **Slides**

-- (Exposure routes): The four main exposure routes are the eyes, skin, respiratory tract and digestive system

-- (Skin and lungs): The most likely routes of entry for petroleum are absorption through the skin and by inhalation

#### **Other Comments:**

This topic is very complicated, and the student may get "buried". Exposure routes and types, and main symptoms of exposure are important. However, it probably is not necessary for students to know all of the differences in toxic effects between the various petroleum types. You may wish to skip some of the detail in this chapter, using Table 2-3, as a convenient summary.

Gasoline is so commonly used and is so familiar to most people that many do not take exposure seriously. They have cleaned paint brushes, killed weeds, de-greased car parts, and filled their lawn mowers. Stress that they need to be aware that this familiarity can lead to overexposure if care is not taken; the skin is the main exposure route.

## **Guidance for the Instructor: Sampling**

### **Additional Suggested Activities:**

- During the field portion of the course, practicing correct methods for taking samples from monitoring wells and areas of contaminated soil.

### **Visuals:**

In addition to the word slides shown in this chapter, the following graphic slides are applicable:

#### Slides

- (Soil sampling from drill): take samples from core or backhoe bucket; avoid entry into the excavation.
- (Man mouth-piping sample from drum to jar): A good way to ingest petroleum
- (Bailer): Obtain samples indirectly from bailers or through other means. Avoid direct contact with contaminated soil and water as much as possible.

### **Other Comments:**

### **Guidance for the Instructor: Site Safety Plans**

#### **Additional Suggested Activities:**

- Describe (or actually visit) a site, and have students outline a draft safety plan or discuss as a group, what elements would be needed. Discuss the merits of generic and site-specific safety plans.

#### **Visuals:**

In addition to the word slides shown in this chapter, the following graphic slides are applicable:

Slides -----

#### **Other Comments:**

## **Guidance for the Instructor: Personal Protective Equipment**

### **Additional Suggested Activities:**

- Obtain samples of the various materials (tyvek, viton, etc.) and allow students to examine them to get a better feel for their differences. Point out positive and negative factors associated with the different materials.
- Obtain several different styles of goggles and point out the good and poor features of each.

### **Visuals:**

In addition to the word slides shown in this chapter, the following graphic slides are applicable:

#### **Slides**

- (Various goggle types): Cushion-filled goggles and face shields are recommended for inspectors.
- (Various boot types): Class 75 steel toe/shank safety shoes are recommended for inspectors
- (Various glove types): When choosing gloves, strength and permeability are factors to consider. Neoprene, nitrile and viton are all good protection against petroleum
- (Level D protection): Used only when no respiratory or skin protection is required
- (Level C protection): Adds an air purifying respirator to level D
- (Level B protection): Adds an air supplying respirator; wear when the highest level of respiratory protection is needed
- (Level A protection): Provides the highest level of both skin and respiratory protection
- (Spider): Be alert for unexpected biological hazards
- (Rattlesnake): Biological hazard
- (Man with bee stings): swarming insects may pose a hazard
- (Man with shotgun): If you encounter this type of hazard, don't argue: leave and return with the U.S. Marshal

### **Other Comments:**

## **Guidance for the Instructor: Respiratory Protection**

### **Additional Suggested Activities:**

- It is strongly suggested that the course include a respirator fit test. UST inspectors should have respiratory training, and will need to get it elsewhere, if it is not offered here. In addition, the additional day will help them to meet OSHA requirements.

### **Visuals:**

In addition to the word slides shown in this chapter, the following graphic slides are applicable:

#### Slides

- (Scott half-face respirator):
- (MSA full-face respirator):
- (Assorted MSA gas masks and a full face respirator):
- (Scott full-face respirator):
- (Air purifying respirator): These remove contaminants but do not add oxygen. Change the cartridges frequently. They should not be used if oxygen levels fall below 19.5%
- (Air supplying respirator): These supply clean contained air.
- (Inspecting face-piece for defects):
- (Checking for proper fit): Respirator should fit tightly with a seal. Beards impede the seal's effectiveness
- (Fit test agents: banana oil, saccharine, and stannic chloride): These agents are harmless but easily smelled or noticed if the respirator does not fit properly.
- (Banana oil fit test): If the respirator fits correctly, the wearer will not be able to smell the oil.
- (Stannic chloride smoke tube): Used for fit-testing, this produces an irritating smoke
- (Stannic chloride fit test): If the fit is good, the wearer should not be able to detect the smoke.

### **Other Comments:**

OSHA regulations require all respirator wearers be fit-tested and have adequate respirator training before using respirators. It is highly recommended that this course include a fit test for students. If it does not, be sure that students are aware they must undergo such a test before using respirators.

## Guidance for the Instructor: Monitoring Instrumentation

### **Additional Suggested Activities:**

- Hands-on work with equipment is invaluable. Obtain an OVA, oxygen meter, HNu, CGI and other pieces of equipment, divide students into teams, and allow them to practice using equipment on some spiked samples of air and soil. You will probably want to allow one half day for this.

### **Visuals:**

In addition to the word slides shown in this chapter, the following graphic slides are applicable:

#### Slides

- (Oxygen meter): Used to measure oxygen levels. Readings are most useful when paired with CGI readings
- (Hydrogen sulfide meter): Detects hydrogen sulfide, a concern mainly in sewers
- (Combustible gas indicator): Used to determine the concentration of flammable gasses
- (MSA explosimeter and explosimeter/oxygen meter combination): a combination of two functions sometimes makes transport easier.
- (Industrial Safety Explosion/Oxygen meter):
- (AIM 3000 Explosion/oxygen/Organic Vapor/Carbon monoxide detector): Having a number of functions in one piece of equipment minimizes the number of things to carry around.
- (Man checking tank with CGI):
- (Drager pump and tube): Can be used as a screening method, but it is not very accurate
- (Pumping): a hand held pump draws air through the tube
- (Drager tube):
- (Colorimetric tube):
- (Foxboro OVA): Detects concentration of volatile organics
- (Schematic of OVA):
- (Strip chart recorder for OVA):Used to provide a permanent record of concentrations, for the file
- (Probe extension for OVA):



- (HNU photoionization detector): Detects organic compounds
- (Schematic of HNU):
- (Instrument plate): a permanent plate affixed to the monitoring instrument indicates the instrument has an approved rating for use

**Other Comments:**

Inspectors should be thoroughly trained in and familiar with use and interpretation of all the direct reading instruments

A summary of costs for various equipment types may be of interest to certain audiences.

## **Guidance for the Instructor: Permissible Exposure Levels**

### **Additional Suggested Activities:**

Pass out copies (or photocopies) of the various exposure guides, such as the NIOSH Pocket Guide To Chemical Hazards, and practice interpreting some of the data within them. Give some concentration and/or exposure levels, and have students determine if the levels are safe.

### **Visuals:**

In addition to the word slides shown in this chapter, the following graphic slides are applicable:

#### **Slides**

- (DOT flammable liquid placard): The DOT labelling system is required by law. (NFPA and UN systems are voluntary).
- (Explanatory graphic for DOT labels): The system provides a graphic and written hazard description plus a four digit identification number
- (DOT labels): Examples
- (Full color NFPA label): Provides information on relative hazard levels for flammability, health and reactivity
- (Health diamond): Rankings range from 0 (lowest hazard) to 4 (highest hazard)
- (Flammability diamond): Rankings range from 0 (lowest hazard) to 4 (highest hazard)
- (Reactivity diamond): Rankings range from 0 (lowest hazard) to 4 (highest hazard)
- (Other info diamond)

### **Other Comments:**

You may want to discuss the 0-4 ranking criteria in greater detail if need/interest exists.



# Health and Safety Training for Underground Storage Tank Inspectors Student's Guide



### **Acknowledgment**

Earlier versions of this document were funded in part by the U.S. Environmental Protection Agency, Office Of Underground Storage Tanks, through a contract with ICF Inc. It has been subject to peer review by a number of diverse individuals, including review during its initial run as a Pilot project in Region 10 in 1990.

The Project Manager was Joan Cabreza (EPA Region 10). We wish to acknowledge the participation and assistance of a number of individuals, particularly those in the initial workgroup who spent so much time during the early phases: Maureen Doughty and Terry Bahrych (EPA Region 8); Walter Huff (Mississippi); Gerry Phillips (EPA Region 5); Dede Montgomery (EPA Region 10); Jon Walker (Region 1); Dorene Fier-Tucker (Minnesota); Jacqueline Hardee (Texas); Dave Haldeman (Nebraska); Jacques Gilbert (Connecticut); and a number of other pilot project participants, regulators, toxicologists, hygienists, and consultants too numerous to mention, who provided insightful comments.

---

ED 371-100021

## CONTENTS

<b>Chapter</b>	<b>Page</b>
<b>Section 1: Introduction</b>	<b>2</b>
Course Objectives	3
Course Organization	4
Hazards Addressed	6
Course Limitations	8
Regulatory Framework	9
<b>Section 2: Recognizing Health and Safety Hazards</b>	<b>11</b>
Petroleum Types and Characteristics	12
Objectives	13
Petroleum Product Classes	14
Important Physical Characteristics	17
Fires and Explosions	19
Objectives	20
The Fire Triangle	22
Factors Important in Combustion	24
Relationship of Flash Point and Flammability	27
Flammable Characteristics of Gasoline	29
Flammable Characteristics of Middle Distillates	31
Flammable Characteristics of Residual Fuels	33
Flammable Characteristics of Used Oils	34
Explosions	35
Working Near Explosive Vapors or Ignitable Liquids	37
Purging	38
Inerting	40
Ignition Sources	41
Spark Generation	42
Static Electricity Sources	43
Reducing Static Electricity and Sparking	44
Fire and Explosion Potential	45
Oxygen Depletion	51
Objectives	52
Causes of Oxygen Depletion	53
Hazard Areas for Oxygen Depletion	54
Physiological Effects of Oxygen Depletion	55
Confined Spaces	59
Objectives	60
Course Limitations	61
Confined Space Characteristics	62
Confined Space Hazards	65
Confined Space Entry Precautions	66
Confined Space Entry Plan	68

## CONTENTS

<b>Chapter</b>	<b>Page</b>
Confined Spaces (con.)	
Prior to Entering Confined Spaces . . . . .	69
Buddy System . . . . .	70
Continuous Monitoring . . . . .	72
Proper Tools for Confined Space Entry . . . . .	73
Rescue Procedures . . . . .	74
Emergency Procedures . . . . .	76
Heavy Equipment . . . . .	79
Objectives . . . . .	80
Commonly Used Heavy Equipment . . . . .	81
Safety Precautions Around Heavy Equipment . . . . .	82
Backhoe/Front-end Loader Hazards . . . . .	85
Drill Rigs . . . . .	86
Cranes . . . . .	87
Other General Safety Hazards . . . . .	91
Excavations . . . . .	97
Objectives . . . . .	98
Excavation Cave-ins . . . . .	99
Methods To Prevent Cave-ins . . . . .	102
Additional Excavation Hazards . . . . .	106
Excavation Hazard Prevention . . . . .	107
Toxicity . . . . .	111
Objectives . . . . .	112
Exposure Routes . . . . .	113
Types of Exposure . . . . .	115
General Symptoms of Toxic Exposure . . . . .	116
Activities Having Potential Toxic Exposure . . . . .	117
Toxicity of Gasoline Constituents . . . . .	118
Toxicity of Aromatics . . . . .	120
Toxicity of Gasoline Additives . . . . .	123
Gasoline Additives: Acute Exposure . . . . .	125
Gasoline Additives: Chronic Exposure . . . . .	126
Toxicity of Middle Distillates . . . . .	127
Middle Distillate Fuels: Symptoms of Acute Exposure . . . . .	129
Middle Distillate Fuels: Impacts of Chronic Exposure . . . . .	131
Toxicity of Residual Fuel Oils . . . . .	132
Toxicity of Used Oils . . . . .	133
Sampling . . . . .	139
Objectives . . . . .	140
Types of Sample Collection . . . . .	141
Soil Sampling: Hazards . . . . .	143
Soil Sampling: Minimum PPE . . . . .	145
Water Sampling . . . . .	146
Free Product and In-Tank Sampling . . . . .	148

## CONTENTS

<b>Chapter</b>	<b>Page</b>
<b>Section 3: Hazard Recognition, Evaluation and Control</b>	<b>151</b>
Site Safety Plans	153
Objectives	154
Safety Plan Preparation	155
Safety Plan Purpose	156
Safety Plan Contents	157
Safety Plan Hazard Assessment	158
Handling Emergencies	160
Respiratory Protection	161
Objectives	162
Respirators	163
Air Purifying Respirators	165
Use of Air Purifying Respirators	167
Air Supplying Respirators	169
Physiological and Psychological Limitations	171
Personal Protective Equipment	173
Objectives	174
Sources for Site Hazard Data	176
Types of Protective Equipment	177
Protective Clothing Limitations	178
Head Protection	180
Eye and Face Protection	181
Foot Protection	183
Hand Protection	185
Body Protection	186
Levels of Protection	187
Protection Against Biological Hazards	194
Decontamination Procedures	195
Monitoring Instrumentation	197
Objectives	198
Chemical Hazards Requiring Monitoring	199
Monitoring Instruments	200
Instrument Certification	202
Direct Reading Instruments	205
Oxygen Meter	206
Hydrogen Sulfide Meter	208
Combustible Gas Indicator	209
Detector Tubes	213
Flame Ionization Detectors	215
Photoionization Detectors	218

## CONTENTS

<b>Chapter</b>	<b>Page</b>
Permissible Exposure Levels . . . . .	221
Objectives . . . . .	222
OSHA Permissible Exposure Limits . . . . .	223
NIOSH Recommended Exposure Limits . . . . .	224
ACGIH Threshold Limit Values . . . . .	225
Establishing Exposure Limits . . . . .	227
DOT Labeling System . . . . .	229
NFPA Labeling System . . . . .	230

### **Selected References**

- Appendix A: Additional information on Respiratory Protection**
- Appendix B: Additional Information on Monitoring Instruments**
- Appendix C: Sample Safety Plan**



## **TABLES**

<b>Table</b>	<b>Page</b>
1-1 OSHA Regulations Applicable to UST Activities .....	10
2-1 Fire Hazard Properties of Petroleum Products .....	26
2-2 Trench Shoring .....	105
2-3 Summary of Toxicological Effects .....	135
3-1 Chemical Resistance of Some Protective Materials .....	179

## **EXHIBITS**

<b>Exhibit</b>	<b>Page</b>
2-1 Accidents Involving Handling and Transfer of Petroleum .....	48
2-2 Accidents During Confined Space Entry .....	78
2-3 Heavy Equipment Accidents .....	92
2-4 General Site Accidents .....	93
2-5 Excavation Accidents .....	100

## **FIGURES**

<b>Figure</b>	<b>Page</b>
2-1 Summary of the Effects of Oxygen Depletion .....	57
2-2 Trench Sloping: Approximate Angle of Repose .....	104



---

**HEALTH AND SAFETY TRAINING  
FOR  
UNDERGROUND STORAGE TANK  
INSPECTORS**

---

---

**SECTION 1**  
**INTRODUCTION**

---

## COURSE OBJECTIVES

---

- Provide basic UST Inspector training
- Highlight toxicological and physical hazards
- Recognize, evaluate, and control hazards

### COURSE OBJECTIVES

### NOTES

This course is intended to provide appropriate information to sensitize inspectors to potential health and safety hazards and to teach inspectors how to recognize, evaluate, and control these hazards. While this course was developed primarily for federal, state, and local UST inspectors, the principles obviously apply to anyone working around underground storage tanks.

At the end of this course, you will have an understanding of the specific hazards associated with UST inspections and you will know how to protect yourself from those hazards.

## COURSE ORGANIZATION

---

- **Section 1:** Course introduction
- **Section 2:** Specific hazards
- **Section 3:** Hazard recognition, evaluation, and control

### TRAINING COURSE ORGANIZATION

### NOTES

Section 1: Provides an introduction to both the objectives and content of the health and safety training course.

Section 2: Presents UST health and safety fundamentals organized into eight topic areas:

- 1) types and characteristics of petroleum;
- 2) fires and explosions; 3) oxygen depletion;
- 4) confined space entry; 5) heavy equipment;
- 6) excavation; 7) toxicity; and 8) sampling.

This section identifies potential health and safety hazards in these eight areas and relates the hazards to UST inspection activities. Particular attention is given to flammable characteristics of petroleum; entry into confined spaces; excavation cave-ins; dangers of backhoe, crane, and drill rig operation; and the effects of acute and chronic exposure to petroleum products.

Section 3: Discusses how to recognize, evaluate, and control the hazards described in Section 2. This section identifies key elements to the successful preparation of a Site Plan, emphasizes the need to wear personal protective equipment (PPE), describes the importance of using monitoring instruments to detect potential hazards, and examines the regulations and guidelines for worker exposure to hazardous substances.

All word slide materials are reproduced in this manual so you will not need to copy them. In addition, space is provided in the right column for any notes you want to take.

## **COURSE ORGANIZATION (con.)**

A list of objectives is provided at the beginning of each subsection. These are designed as a type of self test. At the end of each subsection you may wish to review these objectives to make sure you can reach them. If you can't, re-read or re-study the subsection.

HAZARDS ADDRESSED	
•	Fires and explosions
•	Confined spaces
•	Excavations
•	Oxygen Depletion
•	Heavy equipment hazards
•	Petroleum product toxicity

### **HAZARDS ADDRESSED**

### **NOTES**

During the performance of their activities, UST inspectors are faced with a variety of potential hazards ranging from exposure to toxic chemicals, asphyxiation, fires, and explosions, to hazards associated with excavations and general construction.

UST inspectors must understand the causes of these hazards in order to recognize, evaluate, and take the necessary steps to control them.

This section presents an overview of the potential hazards that an UST inspector is likely to encounter. In Section 3 you will learn to evaluate and control these hazards.



## INSPECTION ACTIVITIES COVERED IN THIS COURSE

---

- Tank and pipe installation
- Tank and pipe repair and testing
- Monitoring well installation
- In-place tank closure
- Tank and pipe removal and disposal
- Investigation and sampling

## NOTES

## COURSE LIMITATIONS

- Covers petroleum products only
- Introductory coverage only for monitoring equipment, personal protective equipment, and confined space entry
- Depending on amount of field work, up to 16 hours additional training may be needed to complete OSHA requirements

### COURSE LIMITATIONS

This course does not cover chemicals, wastes, or mixtures. It only addresses petroleum products and petroleum contaminated media (soil, water, and air).

Although over 90 percent of USTs contain petroleum hydrocarbons, it is critical to remember that a large volume and number of chemical wastes and mixtures are also stored in USTs. For example, the California UST notification data reveal that the following 10 hazardous substances are found frequently in USTs: 1) sodium hydroxide; 2) sulfuric acid; 3) toluene; 4) acetone; 5) methylethyl ketone; 6) chromium; 7) potassium hydroxide; 8) nickel; 9) xylene; and 10) methyl alcohol. These chemicals pose hazards which are significantly different from petroleum products.

The sections on monitoring equipment, personal protective equipment, and confined space entry provide only an introduction to the hazards and the methods of control. Additional formal training is needed for a working proficiency in these areas. The course covers 24 hours. Those persons needing 40 hours of training will need additional exercises or courses to meet the OSHA requirements.

### NOTES

## REGULATORY FRAMEWORK

- OSHA specifies health and safety regulations.
- EPA UST Inspectors follow OSHA provisions.
- Inspectors receive 16 to 24 hours minimum training.
- Cleanup workers receive 40 hours training.

### REGULATORY FRAMEWORK

### NOTES

UST inspectors are strongly encouraged to be aware of and abide by applicable OSHA health and safety provisions when conducting field inspections.

The key provisions in the federal OSHA regulations applicable to UST activities are listed briefly below. Table 1-1 lists these key provisions and other applicable OSHA regulations.

- 29 CFR Part 1910.106 specifies fire prevention guidelines for tank storage, design, and construction.
- 29 CFR 1910 Subpart I delineates personal protective equipment requirements, including:
  - 1910.133 Eye and face protection
  - 1910.134 Respiratory protection
  - 1910.135 Occupational head protection
  - 1910.136 Occupational foot protection
  - 1910.137 Electrical protective devices
- 29 CFR Part 1910.1000 outlines chemical specific Permissible Exposure Levels.
- 29 CFR Part 1910.1200 contains the Hazard Communication Standard, including requirements for Material Safety Data Sheets.
- 29 CFR Part 1926 includes specifications for construction and general industry standards.

**TABLE 1-1**

**Occupational Health and Safety Regulations Applicable  
to UST Activities**

**CODE OF FEDERAL REGULATIONS (CFR)**

**Citations**

<b>29 CFR 1910</b>	<b>General Industry Standards</b>
<b>29 CFR 1910.21</b>	<b>Walking Working Surfaces</b>
<b>29 CFR 1910.106</b>	<b>Flammable and Combustible Liquids/Fire Prevention Guidelines</b>
<b>29 CFR 1910.106 (b)</b>	<b>Tank Storage</b>
<b>29 CFR 1910.106 (c)</b>	<b>Piping, Valves, Fittings</b>
<b>29 CFR 1910.120</b>	<b>Hazardous Waste Operations and Emergency Response</b>
<b>29 CFR 1910.132</b>	<b>Personal Protective Equipment</b>
<b>29 CFR 1910.133</b>	<b>Eye and Face Protection</b>
<b>29 CFR 1910.134</b>	<b>Respiratory Protection</b>
<b>29 CFR 1910.135</b>	<b>Occupational Head Protection</b>
<b>29 CFR 1910.136</b>	<b>Occupational Foot Protection</b>
<b>29 CFR 1910.137</b>	<b>Electrical Protective Devices</b>
<b>29 CFR 1910.155</b>	<b>Fire Protection</b>
<b>29 CFR 1910.176</b>	<b>Materials Handling and Storage</b>
<b>29 CFR 1910.1000</b>	<b>Air Contaminants and Permissible Exposure Levels</b>
<b>29 CFR 1910.1200</b>	<b>Hazardous Communications Standards, MSDS Reporting</b>
<b>29 CFR 1926</b>	<b>Construction Standards</b>
<b>29 CFR 1926 Subpart C</b>	<b>(interim final rule December 19, 1986, 51 FR 455554 and correction on May 4, 1987, 52 FR 16241)</b>
<b>29 CFR 1960</b>	<b>Basic Program Elements for Federal Employees</b>
<b>29 CFR 1960.10</b>	<b>EPA Employee Compliance</b>
<b>29 CFR 1960.16-19 (b)</b>	<b>EPA as Employer Compliance</b>

---

## **SECTION 2**

### **RECOGNIZING HEALTH & SAFETY HAZARDS**

---

---

**PETROLEUM**

**TYPES AND CHARACTERISTICS**

---

## PETROLEUM TYPES AND CHARACTERISTICS

---

### Objectives

Participants will be able to:

- list the four major petroleum product classes and describe how they differ
- describe petroleum products' four physical characteristics of concern
- describe how petroleum products' physical characteristics vary by product type

### PETROLEUM TYPES AND CHARACTERISTICS

### NOTES

Petroleum products vary widely in composition. In order to understand the hazards associated with petroleum, it is important to learn about the basic types of petroleum products you may encounter. The physical and chemical characteristics of each product affect its behavior in the environment and determine the degree of hazard it will present to UST inspectors.

## PETROLEUM PRODUCT CLASSES

- Gasoline
- Middle distillate fuels
- Residual fuel oils
- Used oils

### PETROLEUM PRODUCT CLASSES

### NOTES

General definition of a fuel oil: Any liquid petroleum product burned in a furnace for the generation of heat, or used in an engine for the generation of power, except oils having a flash point of 100°F, and oils burned in cotton or wool-wick burners.

A variety of factors are used to classify fuel products, including flash point, pour point, percent water and sediment, distillation temperatures, carbon residue, ash, and viscosity. These are determined by the American Society of Testing and Materials (ASTM).

**Gasoline** is the petroleum product most commonly found in USTs. Gasoline is a non-uniform blend of organic liquids composed of numerous constituents from four major chemical groups including alkanes, alkenes, naphthalenes, and aromatics.

**Aliphatics** are organic compounds of hydrogen and carbon characterized by straight chains of carbon atoms. **Alkanes** are aliphatic hydrocarbons containing only single carbon-to-carbon bonds. They are also known as paraffins. **Alkenes** are aliphatic hydrocarbons containing at least one carbon-to-carbon double bond. They are also known as olefins. **Aromatics** are compounds which contain at least one benzene ring. **Naphthalenes** are chemicals comprised of two benzoid rings fused together. Automotive gasoline is composed of several hundred hydrocarbons in the C4 to C11 range. General composition as percent weight by category is 40 to 62 percent aliphatics, 1 to 11 percent olefins, 20 to 49



## CLASSIFICATION OF PETROLEUM PRODUCTS (con.)

### NOTES

percent benzene and alkylbenzenes (aromatics), and up to 1 percent naphthalenes.

In addition to the natural constituents, other chemical compounds or **additives** are used to modify the chemical/physical characteristics of the pure products. Additives exist in concentrations ranging from a few parts per million to as much as 10 percent of the product.

Additives are used to boost the performance of gasoline, or to give it a "higher octane." The higher the octane rating, the slower the fuel burns, resulting in more power and better fuel economy. (More fuel is burned as the octane rate is reduced.)

Octane was one of the first compounds discovered to slow the burning rate of hexane, which would explode violently in test engines, causing "knocking." Today, the octane ratings do not reflect actual octane content, but the burning rate of the fuel compared to a hexane-octane standard.

Many compounds have been used to slow the burning rate of gasoline, notably tri-ortho-cresyl-phosphate (TOCP) and organic lead compounds. Because of their high toxicity, these compounds have been largely replaced by methyl-tert-butyl-ether (MTBE) and ethanol. Refining processes also increase octane rating, typically by increasing the amounts of cyclic and aromatic compounds.

**Middle distillates** include kerosene, aviation fuels, diesel fuels, and Fuel Oils Nos. 1 and 2. Fuel Oil No. 1 is used for domestic heating; Fuel Oil No. 2 is used as a general purpose domestic or commercial fuel in atomizing type burners. Diesel is often referred to as Fuel Oil No. 2. These fuels are less volatile than gasoline because of the distillation process.

Kerosene is not considered a fuel oil, although it is very similar to Fuel Oil No. 1.

## CLASSIFICATION OF PETROLEUM PRODUCTS (con.)

### NOTES

Fuel Oil No. 2 is essentially the same as diesel fuel. Diesel fuel derives its name from the engine developed by Rudolph Diesel in 1897. It was supposed to run on gasoline, but did much better on Fuel Oil No. 2.

Fuel Oil No. 3 is not widely used. It is often recycled as feedstock for other fuels.

**Residual fuel oils** (Fuel Oils Nos. 4, 5, and 6) are specifically formulated for certain uses. Generally, they are defined as the product remaining after the removal of appreciable quantities of the more volatile components of crude oil. Fuel Oil No. 4 is used in commercial or industrial burners not equipped with preheating facilities; Nos. 5 and 6 are used in furnaces and boilers of utility power plants, ships, locomotives, metallurgical operations and industrial power plants. These fuels are the least volatile of the petroleum products.

**Used oils** are petroleum-derived oils which, through use, storage or handling, have become contaminated by physical and chemical impurities and are unsuitable for their original purpose. They include both automotive and industrial oils. In some cases (high ignitability or lead content), used oils may be considered hazardous waste. Used oils mixed with waste solvent are automatically classified as hazardous waste under the "Mixture Rule" in the hazardous waste regulations.

## IMPORTANT PHYSICAL CHARACTERISTICS OF PETROLEUM

---

- **SPECIFIC GRAVITY:** Most petroleum products float on water
- **VAPOR PRESSURE:** High vapor pressure = more vapors
- **VAPOR DENSITY:** Vapors are slightly heavier than air
- **VISCOSITY:** More viscous = slower flow

### IMPORTANT PHYSICAL CHARACTERISTICS

### NOTES

Four of the most important physical characteristics that determine how petroleum acts in relation to water and air are specific gravity, vapor pressure, vapor density, and viscosity.

**Specific gravity** is the ratio of the density of petroleum with respect to the density of water. The specific gravity of water equals 1.0 while the specific gravity of most petroleum products is less than 1.0 (between 0.6 and 0.9). As such, most petroleum products will float on water, although some fractions will dissolve in water. The low specific gravity simplifies identification of leaks and recovery of product from the water table.

The products with the lower specific gravities (lighter products), such as benzene, xylene, and toluene are the most soluble. These are typically the contaminants posing the greatest threat to groundwater. They also have a greater tendency to travel.

**Vapor pressure** defines the ability of a product to volatilize or to create vapors. Products having a high vapor pressure, such as gasoline and JP-4, have a potential for creating vapor problems in subsurface structures near leaking USTs.

Compounds with a high vapor pressure will evaporate readily and will typically have a low flash point, and are discussed later in more detail.

## IMPORTANT PHYSICAL CHARACTERISTICS (con.)

### NOTES

**Vapor density** is the weight of a vapor in relation to the weight of air (1.0) and determines how that vapor will "settle out" relative to other vapors. Gasoline vapors are 3-4 times as heavy as air, and tend to occupy the lowest levels in excavations, tanks, or other confined spaces. They will displace oxygen in excavations or tanks.

A rule of thumb regarding vapor density: If the material is a liquid at room temperature, it will generate vapors heavier than air.

**Viscosity** is the measure of a product's resistance to gravity flow. The lower the viscosity a petroleum product has, the faster it will flow or leak and the farther the contamination is likely to spread. In order for a product to free flow, the viscosity must be less than 30 cST (centistoke). Kinematic viscosity values can range from 1 cST for gasoline to 638 cST for No. 4 GT gas turbine fuel oil.

There are various viscosity tests, ranging from one similar to dropping a marble into a bottle of Prell shampoo, to ones requiring specialized equipment. One important point about all petroleum products, is that they will increase in viscosity (thicken) as the temperature drops. For this reason, trucks will sometimes burn Fuel Oil No. 1, rather than the heavier fuel oil No. 2, in cold weather, and the military and commercial jets will use Jet-B (JP-4), a lighter blend of jet fuel, similar to gasoline in extreme cold.

**Flammability, ignition, temperature, and flash point** are also important characteristics that determine the degree of petroleum hazard. These characteristics are discussed next under Fires and Explosions.

---

## **FIRES AND EXPLOSIONS**

---

## FIRES AND EXPLOSIONS

---

### Objectives

Participants will be able to:

- name the three parts of the fire triangle
- list three factors important in combustion
- define flash point and flammability, and discuss their significance
- contrast relative flammability of the four petroleum product classes
- describe what causes an explosion; define UEL and LEL explosivity limits

### NOTES

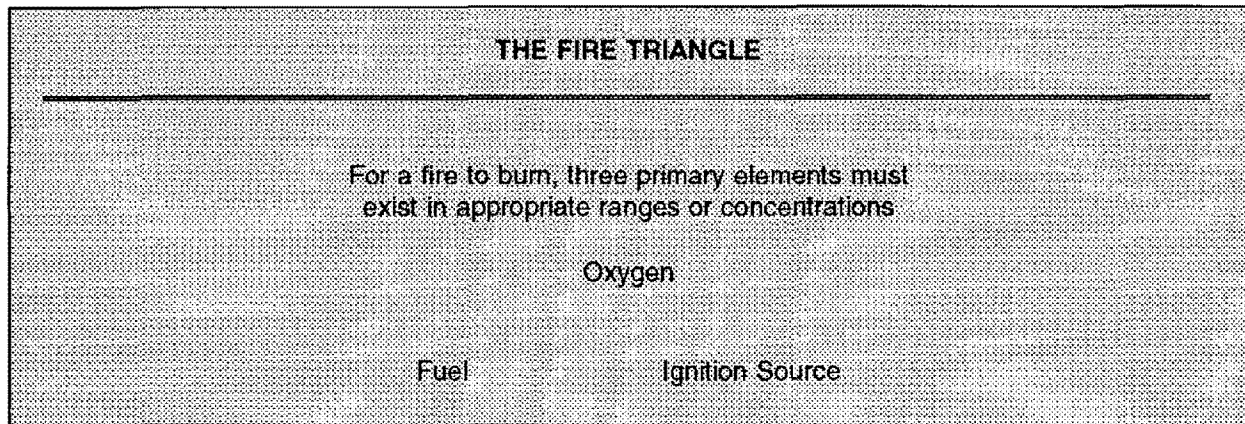
## FIRES AND EXPLOSIONS

---

### Objectives (con.):

- describe general safety measures near explosive vapors or ignitable liquids
- describe how to control the "fuel" point of the fire triangle
- identify how to control the "oxygen" point of the triangle
- name several potential ignition sources
- list ways to reduce static electricity and sparking
- list four situations where fire and explosion potential are greatest

### NOTES



## THE FIRE TRIANGLE

## NOTES

Fire is a rapid and persistent chemical reaction accompanied by the emission of heat and light. Three primary elements, represented by the fire triangle, must be present for a fire to burn: **oxygen**, **fuel**, and a **source of ignition**.

Each side of the fire triangle represents one of the necessary elements of fire. The center of the triangle represents the optimal fuel-to-oxygen ratio with enough heat to ignite the mixture. If any of the elements are removed, however, there can be no fire (this is represented by the corners of the triangle). For example, if the wood on a campfire is consumed or removed, the fuel supply is no longer sufficient to sustain combustion.

A more modern fire triangle would have these three elements: oxidizer, fuel, and energy source. Energy can be produced by chemical reaction, mechanical action or electrical discharge. All these factors may come into play at UST sites.

It is important to understand that it is not the liquid which burns. Vapors are produced, which are heated and broken into simpler compounds (such as methane) which will readily oxidize. The flame above a solid material is also the result of the burning of heated gases. Surface burning may occur after all the volatile materials are driven off, as in the case of burning charcoal. Surface burning also occurs when metals burn.



## THE FIRE TRIANGLE (con.)

### NOTES

Once started, a fire will continue until the fuel or oxygen concentration falls below a minimum value. A fire commonly results from the combination of some combustible material with oxygen, but the oxidizer does not have to be  $O_2$ . The oxygen may be part of a chemical compound such as nitric acid or ammonium perchlorate. Combustion may also occur, in some cases, without oxygen being involved; for example, break fluid can be ignited by chlorine.

Oxidation can occur with any chemical material that can easily yield oxygen, or a similar element. Similar compounds include fluorine, chlorine, and bromine. However, simply because a compound contains these elements does not make it a strong oxidizer. Carbon dioxide has two oxygens, but is not an oxidizer.

## FACTORS IMPORTANT IN COMBUSTION

- Flammability range
- Ignition temperature
- Flash point

### FACTORS IMPORTANT IN COMBUSTION

### NOTES

**Combustion** is the burning of any substance, whether gaseous, liquid, or solid.

**Flammability** is the ability of a material to generate a sufficient concentration of combustible vapors to be ignited. The **flammable range** is the range of vapor-air mixtures which will support combustion. It is bounded by the **upper flammable limit (UFL)** or the highest concentration of a product that is flammable and the **lower flammable limit (LFL)** or lowest concentration of a product that is flammable. Concentrations outside this range that are too vapor-rich or too vapor-poor, will not ignite.

Combustion and flammability have technical and regulatory definitions. It is important to understand this difference. (The technical, or scientific, definition is given here). The Department of Transportation has its own definitions for flammable and combustible. Any liquid with a flash point of 100°F or less is considered flammable. Any liquid with a flash point greater than 100°F is considered combustible. This is strictly a regulatory definition. What's the difference between material with a flash point of 99°F and one with a flash point of 102°F?

**Ignition temperature** is the minimum temperature to which a substance in air must be heated in order to initiate, or cause, self-sustained combustion independent of the heating element.

Ignition temperature is also referred to as "auto-ignition temperature." Ignition temperature is important in many applications, but not so much for determining fire hazard,

## FACTORS IMPORTANT IN COMBUSTION (con.)

### NOTES

strangely enough. For instance, gasoline is much more of a fire hazard than diesel, yet the auto-ignition temp of diesel is at least 100°F less than gasoline!

**Flash point** is the minimum temperature at which a substance produces sufficient flammable vapors to support a flame when an ignition source is present.

The availability of vapor, not the ignition temperature, is the key indicator of hazard.

Table 2-1 delineates fire hazard properties of various flammable liquids, gases, and volatile solids.

**TABLE 2-1**  
**FIRE HAZARD PROPERTIES OF PETROLEUM PRODUCTS**

Chemical	Flash point °F (°C) Lower	Ignition temperature °F (°C) Upper	Flammable limits % by vol.		Specific gravity (Water=1)	Vapor density (Air=1)	Boiling point °F (°C)
Benzene	12 (-11)	928 (498)	1.3	7.9	0.9	2.8	176 (80)
Fuel oil, No. 6	150-270 (66-132)	765 (407)			1.0		
Gasoline, <sup>1</sup> C <sub>8</sub> H <sub>12</sub> to C <sub>12</sub> H <sub>22</sub> O	-45 (-43)	536 (280)	1.4	7.6	0.8	3-4	100-400 (38-204)
Gasoline, <sup>1</sup> aviation	-50 (-46)	824 (471)	1.3	7.1			
Toluene	40 (4)	896 (480)	1.2	7.1	0.9	3.1	231 (111)
m-xylene	81 (27)	982 (527)	1.1	7.0	0.9	3.7	282 (139)

Chemical	Water solubility	Extinguishing method	Hazard Identification	
			Health	Flammability
Benzene	No <sup>2</sup>	1	2	3
Fuel oil, No. 6	No <sup>2</sup>	0	2	0
Gasoline, <sup>1</sup> C <sub>8</sub> H <sub>12</sub> to C <sub>12</sub> H <sub>22</sub> O	No <sup>2</sup>	1	1	3
Gasoline, <sup>1</sup> aviation	No <sup>2</sup>		1	3
Toluene	No <sup>2</sup>	1	2	3
m-xylene	No <sup>2</sup>	1	2	3

*Fire hazard properties of some flammable liquids, gases and volatile solids (abstracted from NFPA 325M-1984, p. 9-95, 1984).*

<sup>1</sup> Values may vary for different gasoline grades.

<sup>2</sup> Water solubilities are very low.

## FLASH POINT/FLAMMABILITY RELATIONSHIP

- **Highly Flammable** Flash point < 100°F
- **Moderately Flammable** Flash point > 100°F but < 200°F
- **Relatively Inflammable** Flash point > 200°F

### RELATIONSHIP OF FLASH POINT AND FLAMMABILITY

### NOTES

The relative flammability of a substance is based on its flash point.

**Flash point** is defined as the minimum temperature at which a substance produces sufficient flammable vapors to ignite when an ignition source is present. An ignition source could be the spark from static electricity, an electrical tool, or a wayward cigarette butt.

Note: In the case of liquids, it is not the liquid itself that burns, but the vapor above it.

Flash point is the single most important factor to look at in determining fire hazards. Flash points are determined by the National Fire Protection Association (NFPA). If the temperature of a liquid has reached the flash point, or higher it will be ignited by a spark, if the fuel/air mixture is right. There is a value called the "Fire Point." The "Fire Point" is the temperature the liquid must reach to generate enough vapors to sustain a flame. For practical purposes, however, we are only concerned with the flash point. If the liquid is at the flash point, and an ignition source is present, there will be a fire.

There are two methods of measuring flash point: open cup (o.c.) and closed cup (c.c.). The open cup method does not attempt to contain the vapors as they are generated, while the closed cup method does. The closed cup flash point is always lower than the open cup, since the concentration of vapors are not lowered by dispersion. This is important to UST inspectors, who deal with closed containers and confined areas frequently.

## FLASH POINT/FLAMMABILITY RELATION (con.)

### NOTES

Flash points do not apply to solids or gases. Finally, flash points are variable. Gasolines are different, and lab tests differ. It is not uncommon to see flash points differ 10° from one reference to the next; therefore, it is recommended that one allow a generous margin of safety.

## FLAMMABLE CHARACTERISTICS OF GASOLINE

---

- **Readily generates flammable vapors** at atmospheric temperatures (NFPA = 3)
- **Flash point:** -45°F
- **Flammability limits:** LFL = 1.4 percent; UFL = 7.6 percent

### FLAMMABLE CHARACTERISTICS OF GASOLINE

### NOTES

**Gasoline** is one of the most dangerous petroleum products because it readily generates flammable vapors at atmospheric temperatures (down to -45°F) and generates these vapors within an UST. It is this vapor, not liquid gasoline itself, that burns or explodes when mixed with air and an ignition source. In addition, gasoline has a very low flash point that means even the smallest source of ignition can cause an explosion.

The concentration of vapors in USTs storing gasoline is normally too rich to burn, that is, above the upper flammability limit (UFL). However, if the temperature of the liquid gasoline is in the -10°F to -50°F range, the concentration of vapors will be within the flammable range.

The National Fire Protection Association (NFPA) developed Standard 704M, a five step ranking system from 0 (lowest) to 4 (highest), to identify relative hazard levels. The NFPA standard addresses three categories: flammability, health, and reactivity. Gasoline is rated **3** in the NFPA category for flammability. An NFPA value of three indicates that gasoline is a liquid that readily ignites under typical ambient conditions.

## FLAMMABLE CHARACTERISTICS OF GASOLINE (con.)

NFPA Flammability		
<u>Rating</u>		Example
0	Will not burn in air when exposed to 1500° for five minutes.	Asbestos
1	Material must be preheated before it will burn.	Diesel
2	Materials that must be moderately heated before ignition can occur. "Liquids with flash points between 100°-200°F."	
3	Materials can be ignited under most ambient conditions.	Gasoline
4	Materials that rapidly disperse in air and burn readily.	Flammable gases



## FLAMMABLE CHARACTERISTICS

---

### Middle Distillate Fuels

<b>Diesels and fuel oils No. 1 and 2</b>	Relatively non-flammable (NFPA rating = 2)
<b>Kerosene grades Jet-A/A-1, JP-5/7/B</b>	Relatively non-flammable (NFPA rating = 2)
<b>Jet B, JP-4 (gasoline/kerosene blends)</b>	Greater fire hazard (NFPA rating = 3)

### FLAMMABLE CHARACTERISTICS OF MIDDLE DISTILLATES

### NOTES

Much of the nomenclature in the petroleum industry is rather vague. For instance, fuel oils can be classed as middle, heavy, or residual distillates. Jet fuel may range from kerosene-like blends, with middle distillate properties, to blends more like gasoline, a light distillate. Don't get hung up on the light-middle-heavy-residual distillate terminology. It is general. Look at the properties of the fuel or oil of concern.

**Middle distillates** are the fractions of crude oil which possess a moderate boiling point. These fractions include kerosene, aviation fuels, diesel fuels and Fuel Oil Nos. 1 and 2, and have a wide range of flammabilities.

The **diesel fuels and fuel oils** are relatively non-flammable. They require limited heating at ambient temperatures to ignite. Flammability is expressed in units (percent) by volume of the material in air. The lower flammability limit (LFL) for diesel fuel is 1.3 percent. The upper flammability limit (UFL) is 6 percent.

While diesel is not typically a flash hazard, if the fuel is spilled on hot concrete or metal, or stored in direct sunlight, the heat may be sufficient to make diesel a serious hazard.

**Aviation fuels** are divided into the kerosene grades (Jet A, A-1, JP-5, 7 and 8) and the "wide cut" blends of gasoline and kerosene (JP-4 and Jet B). Wide cuts are lighter blends

## FLAMMABLE CHARACTERISTICS OF MIDDLE DISTILLATE FUELS (con.)

### NOTES

and more closely resemble gasoline. The kerosene grades are relatively non-flammable, but the wide cut blends represent a significantly higher fire hazard.

The vapor space in a tank storing a low vapor pressure liquid, such as kerosene, contains a mixture too lean to burn, that is, below the LFL. The vapor space of UST storing materials such as JP-4 and Jet B (and other liquids of similar vapor pressure between 2 and 4 psi) presents a fire hazard because the vapors are normally in the flammable range.

## FLAMMABLE CHARACTERISTICS

---

### Residual Fuels (Fuel Oil Nos. 4, 5, 6)

#### Relatively non-flammable

- NFPA = 2

#### Flash points

- Nos. 4, 5      130°F to 335°F
- No. 6      150°F to 270°F

#### LFL

- Nos. 4, 5, 6      1.0 percent

#### UFL

- Nos. 4, 5, 6      5.0 percent

### FLAMMABLE CHARACTERISTICS OF RESIDUAL FUELS

### NOTES

**Residual fuels** (Fuel Oils Nos. 4, 5, and 6) are defined as the product remaining after the removal of appreciable quantities of the more volatile components of crude oil. They have a high flash point; ignition will not occur until the liquid reaches a temperature of 130 or higher. They are not as dangerous as gasoline, however, they do pose a threat.

## FLAMMABLE CHARACTERISTICS

---

### Used Oils

- Significant variability exists
- Solvent additions may reduce flash point
- 30 percent of 1,000 samples tested = flash point < 140°F

### FLAMMABLE CHARACTERISTICS OF USED OILS

### NOTES

**Used oils** in general are relatively non-flammable, yet they pose special dangers. The characteristics of used oils are not uniform because the oils take on additional characteristics and components during use. Thus, used oils may contain toxins or other dangerous products of which an inspector may not be aware.

For instance, the "other products" (often solvents) found in used oils can greatly reduce their flash point, making them much more flammable. Virgin lubricating oil has a flash point of 350°F. By comparison, when 1,000 samples of waste oils were tested, 30 percent of them had a flash point under 140°F.

The components of some used oils, particularly chlorinated solvents, pose a special toxicological hazard in a fire because of their ability to release toxic fumes.

All associated hazards are affected by ambient conditions. For instance, a used oil may be difficult to ignite, but if a nearby fire heats the oil it may ignite and burn fiercely.

## EXPLOSIONS

---

- Rapid chemical reactions producing large quantities of gas and heat
- Explosivity is expressed as percent by volume of material in air, with levels the same as for flammability (that is, LEL/UEL)
- Not always result of combustion; may occur when compressed vapors expand and burst a container

### EXPLOSIONS

### NOTES

**Explosions** are rapid chemical reactions that produce large quantities of gas and heat, a shock wave, and noise. **Explosivity** is expressed as a percentage of a given material in a volume of air. The lower explosivity limit (LEL) is the lowest concentration of a product that is explosive. The upper explosivity limit (UEL) is the highest concentration of a product that is explosive.

UEL and LEL, for all intents and purposes, are the same as UFL and LFL.

Generally, explosions can do serious harm much more rapidly than toxic exposure. Explosions and fires are the most immediate hazard during tank removal or closure activities, and when release investigation techniques are performed in a confined space.

Bear in mind that the difference between a fire and explosion is not a large one. It can simply be the speed of the reaction. Any material that can burn, if placed under sufficient heat, and confined as in a tank, can explode with tremendous force.

Explosions are not necessarily the result of combustion. In a closed container (such as an UST), flammable liquids expand when heated. Gasoline, for example, expands about 0.06 percent in volume for every 10°F increase in temperature. When the pressure inside the UST exceeds the designed pressure resistance, a "pressure release explosion" can occur.

## EXPLOSIONS (con.)

### NOTES

Although not directly related to standard petroleum products, **Boiling Liquid Expanding Vapor Explosions (BLEVEs)** are important due to their tremendous destructive force. BLEVEs occur when compressed gases, such as LPG, are stored as liquids at temperatures above their normal boiling points. If the vessel is exposed to a fire, the rapid buildup of pressure coupled with heat-induced weakening of the tank sides, results in a sudden and violent rupture, with the superheated liquid vaporizing and creating a fireball.

## **WORKING NEAR EXPLOSIVE VAPORS OR IGNITABLE LIQUIDS**

---

- Use only explosion-proof cameras
- Remove flash camera batteries, or do not use
- Do not smoke or use matches or lighters
- Immediately change oil-saturated clothing

### **WORKING NEAR EXPLOSIVE VAPORS OR IGNITABLE LIQUIDS**

### **NOTES**

If an inspector discovers that vapors or liquids are present in a confined structure and a rapid assessment indicates the potential for an explosion or fire, the inspector should take general safety measures at once.

- All persons should be kept away from the danger area, except those properly trained and equipped.
- The local fire department should be alerted.
- A trained operator of a combustible gas indicator should determine the concentration of vapors present. Oxygen levels must also be monitored.
- Persons in the area should not smoke, start or use vehicles or equipment with internal combustion engines, or touch electrical switches or extension cords.
- Instruments used at UST sites must not contribute to the potential for an explosion or fire. Insurance and safety organizations have developed codes for testing electrical devices used in hazardous situations, and an electrical instrument certified for use in hazardous locations will indicate this. If an instrument does not have an approved rating, it should not be used in a hazardous or potentially hazardous situation.

## PURGING

- Controls "fuel" point of fire triangle
- Replaces flammable vapors with air
- Reduces flammable vapors (<LEL)
- Assure procedure's effectiveness with monitoring equipment

### PURGING

### NOTES

**Purging** is an effective method for controlling the fuel point of the fire triangle. The goal of purging a tank is to reduce the flammable vapors in the tank well below the lower explosive limit. Purging or ventilating the tank dilutes the tank's flammable vapors with air, reducing the mixture of fuel and oxygen.

An eductor-type air mover, typically driven by compressed air, draws vapors out of the tank and forces fresh air into the tank. The fill (drop) tube should remain in place to ensure proper ventilation of the tank bottom. Discharge vapors should be dispersed 12 feet from the tank in order to ensure that flammable vapors are being vented effectively into the upper atmosphere.

Most petroleum products have a flammable range of 1 to 10 percent by volume in air, the amount of fuel vapor necessary to become flammable in the presence of oxygen and an ignition source. Below a fuel vapor level of 1 percent (the lower explosive limits or LEL), the mixture of fuel and oxygen is too small to support combustion.

Purging should not be undertaken on hot, humid, or still days because the still air will not disperse the flammable vapors. In order to maintain safe conditions, site work should be put off for a day.

Purging is a temporary procedure. Product trapped in bottom sludge and wall scale regenerates flammable vapors inside the tank. Therefore, when purging, lower the flammable



## PURGING (con.)

### NOTES

concentration to 20 percent of the accepted LEL value of the mixture. The tank should be constantly monitored to ensure that LEL value does not exceed 20 percent.

Use a Combustible Gas Indicator (CGI) to measure the reduction in the concentration of flammable vapors during purging. Periodically test the percentage LEL inside the tank, in the excavation, and any other below grade areas.

**CAUTION:** In air purging, with plenty of oxygen present, the concentration of vapors in the tank begin in the flammable range, or may go from too rich through the flammable range before a safe concentration is achieved. It is especially important to ensure all ignition sources have been removed from the area before beginning this process.

## INERTING

---

- Controls "oxygen" point of fire triangle
- Displaces oxygen with inert gas
- Reduces oxygen below the combustion level
- Common inerting materials: dry ice ( $\text{CO}_2$ ) and compressed nitrogen
- Assure procedure's effectiveness with oxygen meter

### INERTING

### NOTES

**Inerting** controls the oxygen element of the fire triangle. Inerting reduces the concentration of oxygen needed to support combustion (below 12 to 14 percent oxygen by volume) by replacing the oxygen with an inert gas.

Common inerting materials include dry ice ( $\text{CO}_2$ ) and compressed nitrogen. During the inerting process, gases should be introduced under low pressure in order to avoid producing static electricity.  $\text{CO}_2$  is best applied in solid, dry ice form, rather than as a compressed gas.

It is important to recognize that the inert gas does not "neutralize" the flammable vapors in the tank; it simply displaces the oxygen. To measure the effectiveness of the inerting procedure, test the air inside the tank with an oxygen indicator. Eight percent or less oxygen by volume is a safe and acceptable level.

## IGNITION SOURCES

---

- Static electricity
- Electrical appliances
- Open flame
- Smoking cigarettes
- Lightning
- Sparks

### IGNITION SOURCES

### NOTES

The Ignition Source is the easiest point of the fire triangle to control.

There are many possible sources of ignition during handling and transfer of petroleum products. These sources include static electricity, sparks generated by tools, monitoring equipment and engines in the area, lit cigarettes, or even electrical appliances and lightning. Any one of these ignition sources is enough to complete the fire triangle.

## SPARK GENERATION

---

Sparks can be generated by:

- Static electricity
- Striking tank with a metal instrument (hammer, backhoe)
- Striking rock with metal during excavation
- Electrical instruments (camera, drill)

### SPARK GENERATION

### NOTES

Sparks can be generated at an UST site by static electricity, striking metal on metal, such as a hammer on the tank, or striking metal on rock, as when digging with a backhoe. Sparks are also created by the ignition of electrical or combustion engines and pumps, use of non-intrinsically safe monitoring instruments, and lightning. Precautions need to be taken to eliminate the possibility of these activities causing fire and explosions.

## STATIC ELECTRICITY SOURCES

---

- Tank filling (by splashing and movement against piping surface)
- Settling of rust or sludge particles
- Motorized equipment
- Self-generation by humans
- Induction

### STATIC ELECTRICITY SOURCES

### NOTES

The primary manifestation of static electricity is the discharge or sparking of accumulated charges. Under the right conditions, these sparks can be the ignition source for a fire or explosion. Sparks can also be self-generated by humans or created through induction.

The static charge resulting from flowing liquids is of primary importance during the transfer of petroleum products. Static electricity is generated by the separation of like and unlike bodies. When liquid flows, charging occurs because absorbed ions are separated from free ions that are carried into the body of the liquid by turbulence. For example, static results from liquid dropping into a tank during product deliveries, liquid flowing through a hose when product is pumped from the tank, or compressed gas or air being released into the tank atmosphere.

During product transfer, static electricity can be generated by the flow of fuel through small holes into the tank. The movement of the fuel against the pipe also generates a static charge. Furthermore, static electricity can be generated by the settling of rust or sludge particles.

Motorized equipment used during tank installation, testing, and closure may generate static electricity. In order to minimize such risk personnel should ground all equipment during operation.

## REDUCING STATIC ELECTRICITY AND SPARKING

---

### Two effective methods

#### Bonding

- equalizes static electricity
- creates conductive connection between two entities (such as UST and tank truck)

#### Grounding

- diverts static electricity into earth
- eliminates static buildup

## **REDUCING STATIC ELECTRICITY AND SPARKING**

## **NOTES**

**Bonding** and **grounding** are effective methods to reduce the potential for electrostatic charge generation and sparking, and the subsequent chance of fires and explosions.

**Bonding** entails running a conductive line from one metal object to another. This equalizes static electricity by creating a conductive connection between two objects, reducing the likelihood of sparks jumping from metal to metal. Cargo tanks should be electrically bonded to the fill stem, piping, or steel loading rack. Also, all metal parts of the fill pipe assembly should form a continuous electrically conductive path downstream from the point of bond connection.

Bonding insures that individual components of a system do not build up charges. In essence, you slow down the charge buildup by distributing it over a bigger area. However, the entire bonded system will eventually build a significant charge. Bonded systems should also be grounded.

**Grounding** entails running a conductive line from a metal object to the ground. This will dissipate any charge on the outside surface of the tank by having it flow into the ground.

## FIRE AND EXPLOSION POTENTIAL

---

Potential greatest when handling or transferring product

Installation/Upgrades	Explosion can occur during pressure testing
Release Investigation	Spilled product or vapors
Leak Detection Testing	Presence of leaking product or vapors
Installation of Monitoring Wells/Sampling	Drilling into buried utility lines

### FIRE AND EXPLOSION POTENTIAL

### NOTES

Assuming an UST is well-maintained, the greatest fire and explosive hazard occurs during the transfer of the product to or from storage and during the cleaning and removal of USTs.

Although petroleum products have been handled and transferred safely for decades, UST inspectors should not believe that this transfer is risk- and hazard-free.

The transfer of flammable and explosive products (liquids and vapors) may occur during tank testing or repair, tank upgrades, tank closure or removal, tank re-filling or corrective actions. UST inspectors should be aware of the risks associated with these activities.

Due to the danger of violent rupture, use extreme caution when performing pipe and tank testing during tank installation. Do not pressure-test any piping or tanks that contain flammable or combustible liquids. Do not exceed internal tank pressures of 5 pounds psig during pressure testing. Install a pressure relief valve at 6 pounds psig. Use a pressure gauge with a range of 10 to 15 psig, and test

## FIRE AND EXPLOSION POTENTIAL (con.)

### Closures and removals

Product or vapors present while draining tank  
If vapors removed, product may remain trapped in sludge  
Vapors can regenerate in inert or purged tank

both the inner and outer shells of double-wall tanks. Outer wall should be filled by bleeding off pressure from the inner tank. Do not pressurize directly. Avoid standing near endcaps of an UST. The endcaps are the most vulnerable to explosion.

Whether a tank is to be removed from the ground, or closed in place, product trapped in the sludge at the bottom of the tank, absorbed in the tank walls, or trapped under the scale is a continuous source of vapor regeneration. Cleaning the tank will decrease the amount of vapor regeneration.

To make it safe for handling, after the tank is purged or inerted the sludge can be washed to one end of the tank and pumped out while the tank is still in the excavation. If the scale is stubbornly caked on, the contractor may have to enter the tank for manual cleaning. Make sure appropriate safety procedures are followed (see Confined Space Entry in Section 3), and a continuous stream of fresh air is introduced into the tank. Make sure the contractor blocks the tank to prevent any movement. If tank sludge contains sufficient lead or other substances to be considered a hazardous waste, it must be handled and disposed of consistent with the Resource Conservation and Recovery Act (RCRA), Subtitle C requirements.

Tanks should be removed from the site as promptly as possible after purging or inerting procedures have been completed, preferably the same day. If the tank remains on-site overnight or longer, additional vapor may be



## **FIRE AND EXPLOSION POTENTIAL (con.)**

### **NOTES**

regenerated from any liquid, sludge, or wall scale remaining in the tank. Regardless of when they are removed, tanks should be checked with an explosimeter to ensure that 20 percent of the lower explosivity limit (LEL) is not exceeded.

If a leak has occurred, contaminated soil and free product will also generate vapors outside of the tank. An explosimeter should be used to check explosive levels in the excavation as well as in the tank itself.

Exhibit 2-1 provides examples of actual accidents that have occurred during the handling and transfer of petroleum products.

## **EXHIBIT 2-1**

### **ACCIDENTS INVOLVING HANDLING AND TRANSFER OF PETROLEUM PRODUCTS**

Some reported accidents involving the Handling and Transfer of Petroleum Products are presented below. Notice that a large number of accidents occur during closure.

#### **Explosion in Tank "Deemed Safe" Kills One**

Georgia, 1990 - A Snellville, Georgia man dies April 17 when a 10,000-gallon underground gasoline storage tank explodes at Dry Storage of Georgia. The tank was deemed safe one-half hour before the explosion occurred. The worker was a five-year employee of Westinghouse Environmental and Geotechnical Services, a company that specializes in removing underground tanks. This is the third death in Georgia in less than a year involving a tank closure.

#### **Worker Dies in "Preventable" Accident**

Tulsa, 1990 - An underground storage tank explosion kills a worker and blows out the windows in nearby stores. The explosion occurs when two workers are attempting to cut a fill pipe from an UST containing a small amount of water and some residual fuel. The metal cutting saw they are using creates a spark that ignites the gasoline vapors. The ensuing blast blows the 5-foot end off the tank. The flying metal disk travels 20 feet and decapitates a co-worker who is returning to the job site from a convenience store located across the street. A Tulsa Fire Department spokesman characterizes the incident as "a highly preventable accident."

#### **Worker Dies from Trauma Following Explosion**

Tulsa, 1990 - An explosion in an empty gasoline storage tank kills a worker as he is dismantling it with an acetylene torch. According to authorities, the steel tank was removed from the ground the week prior to the explosion and a substance was placed in it to help ventilate fumes. The plumbing company returned to begin dismantling the tank, assuming it to be free of fumes. The 2,000-gallon steel tank explodes when the worker, employed by the plumbing contractor, applies an acetylene torch to it. The end of the tank blows out and propels the worker backwards about 25 feet, where he hits a building. The man dies, apparently from trauma suffered when thrown by the explosion. In addition, a building on the property and a truck owned by the plumbing contractor are damaged.

#### **Explosion Crushes Worker**

Indianapolis, 1990 - Employees of a company which collects empty fuel tanks and cuts them up into scrap metal are in the midst of purging vapors and cutting tanks when the accident occurs. A worker is using an acetylene torch to cut a tank when an adjacent tank explodes, pushing it 6 feet forward into the one he is working on. The worker is crushed between the tank he is working on and a wrecker parked nearby. Investigators suspect that the tank that exploded either had not yet been cleaned or had been cleaned improperly.

## **EXHIBIT 2-1 (con.)**

### **ACCIDENTS INVOLVING HANDLING AND TRANSFER OF PETROLEUM PRODUCTS**

#### **Man Killed While "Scrapping" Abandoned Underground Storage Tank**

A scrapion and metal dealer is working alone and using an acetylene torch to cut a tank into scrap when the flame from the torch ignites fumes inside the tank and touches off an explosion. The force of the blast lifts the 10,000-gallon tank into the air, sending it about 50 feet from its initial spot. A tank end is blown about 450 feet into a nearby field.

The tank, measuring 20 feet by 10 feet, was reportedly used for underground storage of residential heating oil. However, individuals at the accident scene speculated the tank actually contained gasoline or gasoline residue, and that fumes from the gasoline ignited. The victim's brother said the worker was experienced in cutting scrap metal and "knew better than to cut up a gas tank."

#### **OHIO - Sandblasting Incident**

A man retained to sandblast an underground storage tank dies when he turns on an electric vacuum cleaner as he prepares to clean sand from the tank bottom. A spark from the vacuum cleaner ignites the vapors inside the tank, causing it to explode. He dies later as a result of the burns suffered in the blast.

#### **Tank Abandonment Kills Three**

While cutting the top off an empty tank at Kerr-McGee's Cotton Valley Refinery, a piece of equipment apparently ignites vapors inside the tank. The blast kills three men inside the tank; a fourth man left the tank to get some tools and escaped unharmed.

#### **Explosion Narrowly Avoided**

1990 - Two employees breaking out the concrete inside a pump island in order to relocate the product line, instead of capping the exposed line, stuff a rag in it to keep the dirt and broken concrete out. While cleaning the island with shovels, a spark ignites the fumes coming through the rag. The rag immediately catches fire and burns until the employees smother it with dirt.

#### **Tank Worker Dies During Vapor Check**

1990 - An Oregon tank worker places a lighted rag down a fill pipe to determine if the tank contains vapors. It does, and an explosion results, killing the worker.

---

## OXYGEN DEPLETION

---

## OXYGEN DEPLETION

---

### Objectives

Participants will be able to:

- identify situations where oxygen depletion is most likely to occur
- describe physiological effects of oxygen depletion

### NOTES

## CAUSES OF OXYGEN DEPLETION

---

- Gasoline vapors displace oxygen in confined spaces.
- Oxygen is consumed through oxidation (rusting).
- Inert gas is pumped into tank.
- Other gasses displace oxygen in sewers, manholes, and tunnels.

### CAUSES OF OXYGEN DEPLETION

### NOTES

Oxygen content in the air may decrease due to biological decay, oxidation (rusting), combustion or displacement by other gases, such as methane, hydrogen sulfide, and carbon monoxide.

It is critical to keep in mind that even when oxygen concentration is deficient for human well-being, there may be enough oxygen to oxidize a combustion or explosion. For example, a 16 percent oxygen concentration could be sufficient for a fire or explosion, while being too low for humans to comfortably breathe.

Eleven percent O<sub>2</sub> is considered the theoretical lower limit for a fire. However, a reaction with a strong oxidizer could result in a flame in the total absence of oxygen.

## HAZARD AREAS FOR OXYGEN DEPLETION

---

- Tanks
- Excavations
- Basements
- Sewers
- Any confined space

### HAZARD AREAS FOR OXYGEN DEPLETION

### NOTES

Oxygen depletion can occur in any confined space, especially those typically encountered by UST inspectors. Tanks and dug-out trenches are potentially oxygen deficient; basements and sewers are other areas where oxygen may be depleted. Old USTs are particularly susceptible to oxygen depletion through oxidation.

Inspectors should always be alert to situations that could create oxygen depletion, and should never enter into such situations without first measuring the oxygen level.

EPA considers the minimum level of oxygen for a safe entry to be 19.5 percent. Below this entry into an oxygen-depleted area is absolutely necessary, inspectors must enter with an air supplying respirator. Air purifying respirators are not permitted in atmospheres containing less than 19.5 percent oxygen.

## PHYSIOLOGICAL EFFECTS OF OXYGEN DEPLETION

---

Typical air is 21 percent oxygen.

Health effects at lower oxygen levels:

16 to 21 percent	Accelerated breathing and heartbeat; impaired attention, thinking, and coordination
10 to 14 percent	Faulty judgment, poor muscular coordination; rapid fatigue, possibly permanent heart damage
6 to 10 percent	Nausea; vomiting; loss of movement; unconsciousness
< 6 percent	Death in minutes

### PHYSIOLOGICAL EFFECTS OF OXYGEN DEPLETION

### NOTES

Oxygen depletion produces a range of physiological effects that worsen as oxygen content is lowered or exposure time is increased. Generally, there are no detrimental effects above a 21 percent concentration oxygen in air, which is the general concentration of oxygen in air at sea level (it could be more or less in other geographical areas). Below this concentration, however, potential life threatening situations exist.

The first signs of depletion occur when oxygen concentration is between 16 percent and 21 percent. With this level of oxygen, a person's respiration and heartbeat accelerate. Also, attention and coordination begin to be impaired. Lower concentrations of oxygen can cause rapid fatigue, heart damage, nausea, unconsciousness and death. See Figure 2-1 for an oxygen scale illustrating the physiological effects of depletion.

Many times, O<sub>2</sub> depletion occurs in a very seductive fashion. The victim may simply become sleepy, and suddenly see nothing wrong with closing the eyes for a short nap, from which he does not wake. The impairment of judgement is drastic, but insidious. After all, it is hard to be alert to symptoms that involve loss of alertness. Plan ahead and use your



## PHYSIOLOGICAL EFFECTS OF OXYGEN DEPLETION (con.)

### NOTES

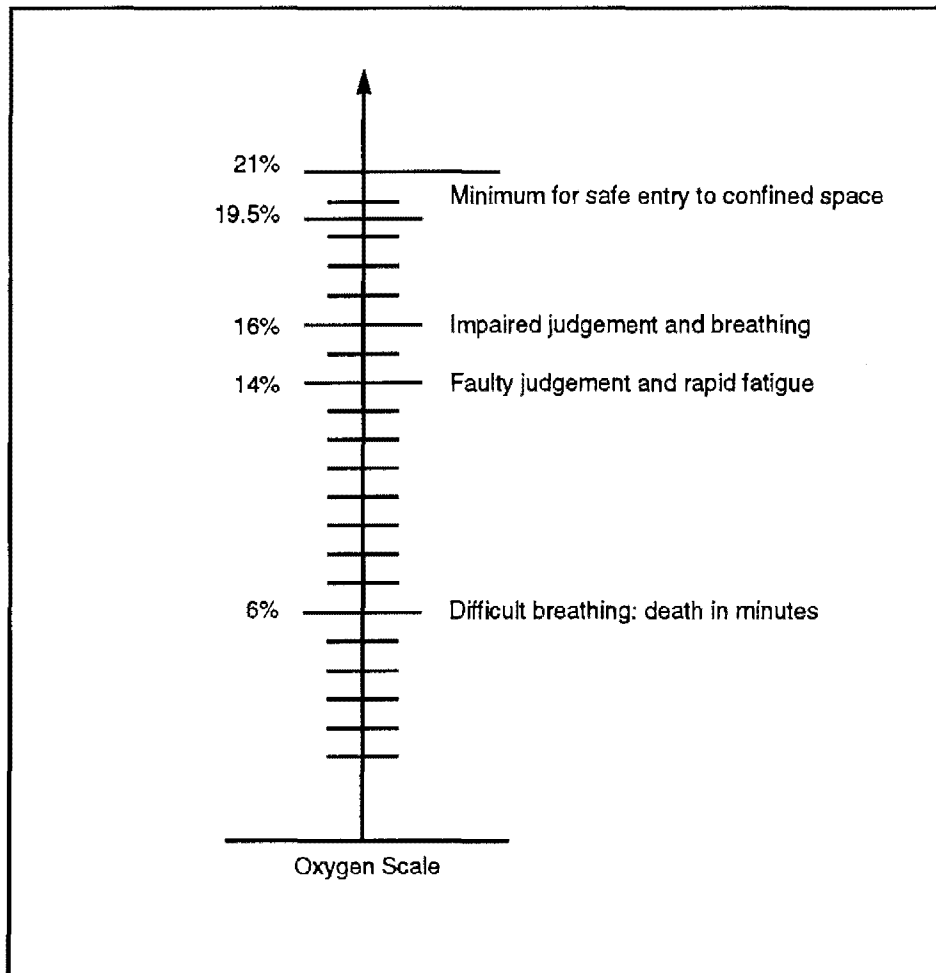
instrumentation.

When on-site, UST inspectors should be alert to the symptoms outlined in the page above. If they experience any of these symptoms in a confined space, they should immediately leave the area and seek medical attention if necessary.

Asphyxiation is most likely to occur in low-lying areas where heavier-than-air vapors accumulate. An exception to this is methane, or natural gas, which is slightly lighter than air, and may rise to higher levels. Methane is a simple asphyxiant, having no true toxic effect, but it is extremely flammable.

**FIGURE 2-1**

**SUMMARY OF THE EFFECTS OF OXYGEN DEPLETION**



## ACTIVITIES HAVING ASPHYXIATION POTENTIAL

---

### Petroleum Release Investigations

- entering sewers, basements, trenches

### Tank Removals/Repairs

- entering inerted tanks
- entering trenches

## NOTES

---

## CONFINED SPACES

---

## CONFINED SPACES

---

### Objectives

Participants will be able to:

- list 2 characteristics of confined spaces
- list 3 NIOSH confined space hazard classes
- list 4 confined space hazards
- list 5 precautions when entering confined spaces
- describe confined space emergency procedures for personnel inside and outside tanks

### NOTES

## CONFINED SPACE SAFETY: COURSE LIMITATIONS

---

- Additional training is needed before conducting confined-space entry work.
- Even with additional training, confined space entry should only be undertaken as last resort.

### COURSE LIMITATIONS

### NOTES

Before working in confined spaces, UST inspectors should have additional training in:

- use of respiratory equipment;
- use of monitoring instruments;
- confined space entry; and
- emergency rescue procedures.

Reminder: This course is not sufficient preparation to train someone in confined space entries; confined space training is required.

## CONFINED SPACE CHARACTERISTICS

---

### Confined spaces

- have limited openings for entry and exit
- may have limited ventilation
- may be life-threatening due to oxygen deficiency or toxic, flammable, or corrosive contaminants

### CONFINED SPACE CHARACTERISTICS

### NOTES

A **confined space** is defined as any space or enclosure that has limited openings for entry and exit, and may have limited ventilation. Normally this is defined as any topped space 4 feet or more in depth that is not subject to adequate ventilation. The confined space may also contain or produce life-threatening atmospheres due to oxygen deficiency, or the presence of toxic, flammable, or corrosive contaminants.

Specific confined spaces include storage tanks, sewers and manholes, basements, underground utility vaults, ventilation and exhaust ducts, silos, vats, and boilers. Under certain conditions, excavations, trenches, and natural depressions can also act as confined spaces, trapping vapors and restricting oxygen flow.

The National Institute of Occupational Safety and Health (NIOSH), in its Criteria for a Recommended Standard for Working in Confined Spaces (1979), defines confined space hazards into three classes. The NIOSH classifications roughly parallel the EPA protective equipment levels. Each class requires that specific steps be taken before entry and work within the confined space. The three classes are defined as follows:

- 1) **Class A Confined Spaces** present immediate danger to life or health (IDLH). Characteristics include oxygen deficient or

## CONFINED SPACE CHARACTERISTICS (con.)

### NOTES

enriched atmospheres ( $\leq 16$  percent or  $>25$  percent), explosive or flammable atmospheres (20 percent or greater of LFL) and/or concentrations of toxic substances (at IDLH levels).

- 2) **Class B Confined Spaces** have the potential for causing injury or illness if preventive measures are not used, BUT is not IDLH. Characteristics include  $O_2 = 16.1$  to 19.4 percent or 21.5 to 25 percent; LFL = 10 to 19 percent, toxicity between the permissible exposure level (PEL) and IDLH.
- 3) **Class C Confined Spaces** are such that potential hazard would not require any special modification of the work procedure. Characteristics include  $O_2 = 19.5$  to 21.4 percent; LFL  $\leq 10$  percent; toxicity less than PEL.

Toxicity and exposure levels are discussed later in this section.

Most UST work will involve working with excavations and basements. These will usually be class B or C confined spaces. Class C spaces may be entered and evaluated using normal precautions. Class B entries should not be performed by UST inspectors without careful planning. Class A spaces should be avoided entirely. Class A & B spaces both require equipment and personnel that the inspector is not likely to have readily available on the "average" inspection.



## EXAMPLES OF CONFINED SPACES

---

- Storage tanks
- Sewers, manholes, and tunnels
- Basements and underground utility vaults
- Silos, vats, boilers, process/reaction vessels
- Excavations and trenches
- Natural depressions/low lying areas (under certain conditions)

## NOTES

## CONFINED SPACE HAZARDS

---

Accidents are often a result of failing to recognize confined spaces are potential hazards

Until proven otherwise, assume all confined spaces have danger of:

- fire
- explosion
- poisoning
- asphyxiation
- structural failure

### CONFINED SPACE HAZARDS

### NOTES

The hazards associated with confined spaces are capable of causing bodily injury, illness, or death to the worker. Accidents occur because of failure to recognize that a confined space is a potential hazard. UST inspectors should assume that the most unfavorable situation exists in every case and that the danger of fire, explosion, poisoning, or asphyxiation is present at the onset of every entry.

Confined spaces also create problems with communications, entry and exit, noise, and structural hazards.

Each year numerous injuries and deaths occur during "confined space" work in industry. A brief illustration of the seriousness of this problem as reported in various newspapers throughout the United States is presented in Exhibit 2-4.

## CONFINED SPACE SAFETY PRECAUTIONS

---

- Develop Site Health and Safety Policy and Entry Plan
- Brief workers before entry
- Inspect space before entering
- Use the buddy system
- Ventilate hazardous atmospheres
- Use appropriate personal protective equipment
- Continuously monitor conditions
- Know proper rescue procedures/equipment

### CONFINED SPACE ENTRY PRECAUTIONS

### NOTES

UST inspectors should under no circumstances enter confined spaces unless the operation has been fully planned ahead of time and identified in the approved Site Safety Plan. Also, no person should enter a confined space until an entry plan has been completed.

Hazardous conditions must be monitored, the hazardous atmosphere must be vented, and suitable protective clothing, respiratory equipment, and other safety equipment must be worn when entering confined spaces.

Proper rescue procedures and equipment (including the buddy system) must be followed. Inspectors should make note of the nearest first-aid equipment and be certain that any exposures to health hazards are recorded. Each of these precautions are discussed in more detail on the following pages.

The most critical aspect of confined space safety is planning ahead. A "generic" Site Safety Plan should be prepared for site visits. In addition, a tailored entry plan for confined spaces should be prepared.

## **CONFINED SPACE ENTRY PRECAUTIONS (con.)**

### **NOTES**

Prior to entry, a final briefing should be given to the members of the work team. Safety checks should be redone before each entry into a confined space.

More details on the preparation of a plan are provided in Section 3. The confined space entry plan is discussed in more detail on the following pages.

## CONFINED SPACE ENTRY PLAN

---

Entry plan identifies and contains:

- confined space location and entry task description
- known and potential hazards
- isolation checklist
- safety and protective equipment requirements

### **CONFINED SPACE ENTRY PLAN**

### **NOTES**

The entry plan should be reviewed by personnel knowledgeable in site health and safety. It serves as a written approval and authorization for an entry into a specific space for a specific task.

The plan specifies that existing and potential hazards have been adequately identified and evaluated and it identifies the protective measures necessary to ensure worker safety. The plan should also specify pre-entry and continuous monitoring requirements, emergency procedures, available first aid equipment, and required training.

No confined space work in Class A or B spaces should be performed without a completed and signed entry plan.

The release signature should be that of an individual who is trained and competent to evaluate confined space hazards and determine appropriate control measures.

NIOSH has three classifications for confined spaces. These classifications are based on safety characteristics of the confined space including oxygen content, flammability, and toxicity. Class A is considered immediately dangerous to life. Class B is dangerous, but not immediately life threatening, and Class C is considered a potential hazard.

## BEFORE ENTERING CONFINED SPACES

---

- Inspect entrance for structural integrity
- Isolate physically and electrically from other systems (when possible)
- Monitor for explosive atmospheres (oxygen, hydrogen sulfide, and organic vapors)
- Use appropriate personal protective equipment

### PRIOR TO ENTERING CONFINED SPACES

### NOTES

Before entering a confined space, inspect the condition of the access steps. If it appears the steps are not sturdy, or if there are no steps, some form of ready entry and exit, such as a ladder, must be provided.

When possible, completely isolate all confined spaces from other systems by such means as the physical disconnection of all lines to the confined space.

The confined space should be monitored for explosive and oxygen deficient atmospheres and appropriate personal protective equipment (PPE) must be worn before any attempts at entry.

## BUDDY SYSTEM

- A minimum of two workers remain outside confined space
- Where space permits, involve minimum of two workers in the task
- Workers outside responsible for terminating operation if danger is apparent

### THE BUDDY SYSTEM

### NOTES

A minimum of two workers must remain outside the confined space when work is being performed within. One worker should stand directly outside the space as the designated safety person, while the other remains in visual or audio contact with both the safety person and the worker within the confined area. Where space permits more than one worker should enter the area. If visual contact is not possible, emergency motion detectors should be used. Emergency motion detectors are devices worn by the worker while in the confined space. When the worker stops moving for longer than several seconds, the device begins beeping to alert the workers that remain outside the confined space.

Clarification: OSHA regulations state that there must be a designated safety monitor called an "attendant" on Class A and B work. This person maintains communications and monitors workers inside the confined space. However, this worker never enters the confined space, even for rescue. Rescue and other entry duties must be assigned to other personnel.

A safety harness must be worn at all times when entering, working in, and exiting most confined spaces. If the access hole is less than 18 inches wide, a wrist or shoulder/belt harness must be used. A safety person should always tend the safety line (secured to a well-anchored object), especially when a worker is

## BUDDY SYSTEM (con.)

### NOTES

entering or exiting the confined space. The worker in the confined space should never be left tied off while the safety person goes for supplies or tools. Extra slack should not be allowed to form in the safety line. Finally, the safety line should be kept away from traffic and equipment with moving parts.

In the real world, if a worker is wearing a harness, a winch or pulley system is needed to extract the workers. In the movies, they may drag people up a hundred feet using hand over mighty hand, but very few people can actually haul an unconscious person even a few feet in this manner.



## CONTINUOUS MONITORING

---

- Monitor air before entering confined space.
- Repeat monitoring periodically.
- Monitor with CGI, O<sub>2</sub> meter and H<sub>2</sub>S detector, either FID or PID.

### CONTINUOUS MONITORING

### NOTES

**Absolutely no** confined space entry should be initiated without the use of appropriate air supplying respirators and dermal protection; and until appropriate initial testing has been conducted to assure a safe atmosphere. All persons entering a confined space must be aware that oxygen deficient atmospheres and "immediately dangerous to life and health" (IDLH) situations are possible and more than likely in non-routine work situations.

Combination combustible gas indicators, oxygen and hydrogen sulfide detectors, and either a flame or photoionization meter must be used to test the atmosphere for flammable vapors and oxygen before and during the operation. Monitoring should be conducted at the opening and in the space that workers shall occupy. Monitoring may also be performed in pockets, corners, and at ground level to identify the extent of hazard.

Perform monitoring slowly, giving instruments adequate time to respond.

Take reading at several different heights, as well as locations, since gases may stratify. Always attempt to perform sampling without actually entering the confined space, that is, use tools such as pumps and tubing, or attachments.

## **PROPER TOOLS FOR CONFINED SPACE SAFETY**

---

Make sure all tools and equipment are non-sparking and certified as "intrinsically safe"

See that tools and equipment are inspected for compliance with:

- OSHA 29 CFR 1910 Subpart S
- availability of guards
- bonding and grounding

### **PROPER TOOLS FOR CONFINED SPACE ENTRY**

### **NOTES**

Tools or other objects which necessitate the use of a hand should not be carried while entering or exiting a confined space. Extreme caution must be exercised to avoid banging equipment against other metal objects, which creates sparks. Also, never lower an electrical tool or light to a worker in a confined space unless it has been thoroughly checked to ensure that it is explosion proof, double-insulated, and grounded. Tools should always be clean and in good working order. Tool selection and use should meet OSHA (29 CFR 1910 Subpart S) regulations. Where vapors are present, air-activated tools must be used. Safety guards must be available to encase light bulbs. All items should be bonded and grounded where appropriate.

## RESCUE PROCEDURES

---

- Notify emergency assistance teams immediately
- Attempt no rescue without proper training and appropriate protection
- Remember that rescues require minimum of Level B protection

**Over 50 percent of deaths in confined spaces are workers attempting to rescue other workers!**

### RESCUE PROCEDURES

### NOTES

Rescuers must be trained in rescue procedures and follow those procedures when attempting to rescue coworkers. Unplanned rescues, such as when someone instinctively rushes in to help, typically result in multiple fatalities.

Use common sense: If a person wearing the same type of PPE as yourself collapses suddenly, for no apparent reason, it is a safe bet that they have been overcome by a toxic substance that penetrated their equipment. It will also breach your equipment, so do not attempt rescue. On the other hand, if a co-worker runs into an overhead obstruction and knocks himself senseless, you can probably rescue that worker safely, if you avoid the overhead obstruction. Remember though: Many chemicals impair judgement and coordination, so be alert, and be careful!

Emergency situations within confined spaces may differ according to the type of confined space. It is difficult to develop general procedures that will cover every situation. However, general emergency procedures can be formulated, and each crew and individual must anticipate a variety of specific emergencies and responses. All rescue equipment should be fully inspected at the work scene before any person enters the confined space. If a worker is stricken inside

## RESCUE PROCEDURES (con.)

### NOTES

confined space, first call for emergency assistance, then go through the proper procedures for a rescue before attempting to enter the confined space. At a minimum, rescue workers should wear Level B protection (see Section 3).

### **EMERGENCY PROCEDURES: INSIDE**

---

If you are inside a confined space when an emergency occurs:

- notify safety person
- attempt to assist incapacitated workers
- exit area, if possible

### **EMERGENCY PROCEDURES: INSIDE**

### **NOTES**

If you are inside a confined space when an emergency occurs:

- Upon detection of a hazard, immediately notify the safety person external to the space, giving all known details of the hazard;
- If a worker is incapacitated, attempt to assist the individual; this should be done only if it presents no increased risk to yourself or others;
- If possible, exit the area, proceeding to the nearest exit.

## **EMERGENCY PROCEDURES: OUTSIDE**

---

If you are outside a confined space when an emergency occurs:

- offer assistance, try to correct problem
- don't enter without a supplied air respirator
- alert emergency network
- remain outside to assist

## **EMERGENCY PROCEDURES: OUTSIDE**

## **NOTES**

If you are outside the confined space when an emergency occurs:

- Upon learning of the problem offer assistance and try to correct the problem.
- Never enter a confined space without a self-contained breathing apparatus (SCBA) or until all causes of the incapacitation have been eliminated.
- If professional assistance is necessary, send a worker to notify the established emergency network, remain available to guide emergency units.
- Remain outside of the confined space to aid with the rescue equipment and render assistance.

Remember that the person specified as the attendant may not enter for any reason.

## **EXHIBIT 2-2**

### **ACCIDENTS DURING CONFINED SPACE ENTRY**

Some accidents reported involving confined spaces are presented below. Note that most are due to explosions or asphyxiation.

#### **Two Killed in Jet-Fuel Explosion**

Newington, NH, 1981 - Two tank cleaners are killed in a powerful explosion within an empty Air Force jet fuel tank.

#### **Space Shuttle Worker Killed**

Cape Canaveral, FL, 1981 - An aerospace worker dies and four others are hospitalized following an incident which occurred when five workers, without respiratory equipment, entered the spaceship Columbia's engine compartment before it had been cleared of the pure nitrogen atmosphere used during a test.

#### **Welder Dies Before Aid Arrives**

Deer Park, TX, 1980 - Two welders and a standby worker collapse inside a vessel under repair and the welders both die before rescuers can aid them.

#### **Two Killed in Flash Fire**

Bradford, PA, 1980 - Two workers die and two others are injured when a flash fire occurs in an oil tank car during cleanup, three days after a derailment.

#### **Tank liner escapes injury.**

While relining an underground tank, during the sandblasting procedure, an employee in the tank hits a four-inch rubber Expando plug that was placed in the product line from inside the tank located directly above him. The Expando plug eventually works itself loose and falls out, causing the employee to be soaked with fuel. Fortunately, the employee is not injured.

#### **Three workers injured trying to save fourth.**

Arkansas, 1980 - One worker is killed and three others seriously injured in a sewer trench cave-in. The three injured workers jump into the trench to try to save the first man after the cave-in, but are themselves caught in a second cave-in.

---

## HEAVY EQUIPMENT

---



## HEAVY EQUIPMENT

---

### Objectives

Participant will be able to:

- list 5 major types of heavy equipment
- discuss the main hazards associated with each heavy equipment type
- describe safety precautions to avoid each hazard

### NOTES

### COMMONLY USED HEAVY EQUIPMENT

---

- Backhoes
- Front end loaders
- Dump trucks
- Cranes
- Drill rigs

#### COMMONLY USED HEAVY EQUIPMENT

#### NOTES

Installing or moving USTs requires the use of a variety of earth-moving and other heavy equipment. Examples of such equipment include backhoes, front end loaders, dump trucks, cranes, and drill rigs. Any one of these pieces of equipment can be dangerous and can cause injury or death.

Some examples of accidents associated with the use of heavy equipment are described in Exhibit 2-3.

### **SAFETY PRECAUTIONS AROUND HEAVY EQUIPMENT**

---

- Use qualified equipment operators.
- Park vehicles away from trucks and equipment.
- Avoid stacked pipes, hoisting equipment, and heavy rotating components.
- Wear appropriate protective gear.
- Avoid wearing loose or torn clothing.

### **SAFETY PRECAUTIONS AROUND HEAVY EQUIPMENT**

### **NOTES**

To avoid creating unnecessary hazards, operators of heavy equipment should be properly trained and certified to operate equipment they are using. Vehicles should be parked far enough away from other vehicles and equipment to avoid possible collisions.

Stacked pipes can pose a serious construction hazard. Personnel should avoid standing near stacked piping because a single dislodged pipe may cause the entire stack to collapse.

Individuals with long hair should have it tied back or otherwise constrained. Applicable protective gear such as hard hats, goggles, high visibility clothing, hearing protectors, and heavy boots should be worn at all times. Shirts with loose sleeves, trousers with baggy cuffs, torn clothing, and jewelry have a tendency to get caught in machinery and, therefore, should not be worn.

### ADDITIONAL GENERAL SAFETY PRECAUTIONS

---

- Do not touch moving parts.
- Know location of "Emergency Shut Off" switches.
- Do not smoke or use spark-producing equipment.
- Know location of underground and overhead utilities.
- Terminate machine operations during thunderstorms.
- Stay well away from moving equipment.

### ADDITIONAL GENERAL SAFETY PRECAUTIONS

### NOTES

Many heavy equipment accidents result when workers touch the moving parts of the machinery. Personnel must pay close attention when operating or working near machinery. Furthermore, personnel must be aware of the location of "Emergency Shut Off" switches on the machinery to avoid serious accidents.

Do not smoke or use spark-producing equipment around excavations because the use of a backhoe or a drill rig may release flammable gasses from the subsurface environment.

There is also the potential of a backhoe or drill rig coming into contact with buried gas, water, electric, sewer, or product lines and even the USTs themselves. This can cause sudden explosions, electrocution, or flooding. Therefore, all lines should be located and clearly marked prior to initiating operations. An additional electrocution hazard can occur during periods of lightning, as the lightning may be attracted to backhoes or crane booms. All operations should be stopped during a thunderstorm.

Many pieces of diesel equipment are not killed by turning off the key. There is typically a fuel shutoff knob that must be pulled, and, in some cases, held, to kill the engine. If there is a

## ADDITIONAL GENERAL SAFE PRECAUTIONS (con.)

### NOTES

high concentration of flammable vapor in the air, it may be impossible to shut off a diesel engine. (This is very rare.)

Older equipment may start while in gear. Do not stand near the equipment when it is being started.

## BACKHOES/FRONT END LOADER HAZARDS

---

Backhoes are used for excavation and soil transfer

Excavations can damage or break underground utilities or product lines, causing:

- Electrocution
- Exposure to toxic substances
- Flooding
- Power outages

Physical hazards of backhoes include swinging buckets and unstable loads

### BACKHOE/FRONT END LOADER HAZARDS

### NOTES

Earth moving equipment posing the greatest danger includes backhoes and front end loaders. These machines are generally used for excavating trenches and soil transfer during installation and removal actions. During excavation and soil transfer, backhoes and front end loaders can dig up or break utility or product lines. This can result in death due to electrocution, exposure to toxic chemicals, or flooding. Additionally, operation of this equipment creates physical hazards to those not aware of its presence or operation.

The backhoe arm travels from side to side, as well as lengthwise and up and down. Be sure to stand well away from the entire radius of the arm swing.

Backhoes are equipped with outriggers, which help stabilize it during digging. No digging or moving of earth using the arm should be performed without setting the outriggers. Backhoe/front-end loader hybrids are common. The front bucket of these hybrids is operated without the use of outriggers.

## DRILL RIGS

---

Drill rigs are used for soil borings and well installation monitoring

Three types: Mud rotary, air rotary, and plain auger flight

Hazards of drill rigs:

- high pressure air hoses can break, causing serious injury
- rotating parts can sever digits and limbs
- utility lines pose possibility of electrocution

### DRILL RIGS

### NOTES

Drill rigs may be of the mud rotary or the air rotary types. Note that using an air rotary drill will increase the likelihood of exposure via inhalation, while a mud rotary drill will increase the potential for dermal absorption of chemicals.

Mud rotary rigs may also pose a disposal problem. The muds used often contain traces of barium and other metals which are toxic. EPA has begun to view drilling muds with a critical eye.

Air rotary drills have a number of high pressure hoses that might break and cause injury. The rotating parts of either type of drill rig can sever a digit or limb. Furthermore, digging into the ground always raises the possibility of electrocution from broken utility lines.

Unless wearing the proper protective equipment (see Section 3), avoid contact with cuttings, drilling liquids, and groundwater because they may be contaminated.

## CRANES

---

Cranes are used for lifting tanks in and out of excavations

- Follow load lifting specifications.
- Never exceed recommended safe load for rigging.
- During actual lift, stay outside range of wire sling; sling can "whip" if it snaps.
- Agree on and use standard operating signals to direct operations.
- Avoid swinging loads above personnel.

## CRANES

## NOTES

Cranes are commonly used during tank installations and removals to place or remove the tank from the excavation. Lifting or moving a tank should be done in accordance with the manufacturer's specifications. The crane should not lift loads heavier than the recommended safe load. Weight loads in excess of the recommended load can pull the crane into the excavation. Also, rigging should never be loaded in excess of its recommended safe load.

During the actual lift, all personnel should remain outside the range of the wire sling. If the sling breaks during a lift, serious injury can result from the whip action of the broken wire.

Cranes come in several configurations, from the older, dragline types to the newer, mobile cranes, which are also called "cherry-pickers."

Draglines are track-mounted and extremely heavy. They can rotate 360° on their platforms. Their extreme weight provides their stability.

The cherry-pickers are more common at UST sites, because they are truck-mounted and easier to move. These units are equipped with outriggers which must be set before the lifting arm is deployed, and must remain in place until the lift arm is once more retracted and cradled.



## CRANES (con.)

### NOTES

On any crane, the lifting arm can lift the greatest weight when upright. The further the arm extends, the greater the mechanical advantage of the load, and the less weight the crane can lift.

Frayed rigging is not uncommon. While minor fraying may not necessarily affect performance significantly, more severe fraying is dangerous. The load limits of frayed cabling are unknown. Frayed cabling may also hang and snarl.

## CRANES (con.)

- Place hook directly over load being lifted.
- Major hazard; keep minimum 6 feet between boom and overhead power lines.
- When operating under power lines, safety guard installation is recommended.

## NOTES

Cranes should be operated only by trained personnel. Before daily operations start, all equipment used for hoisting, including cables, sheaves, pulleys, boom and hook stops, should be inspected.

A standard set of operating signals should be agreed upon before crane operation, and UST inspectors should become familiar with them. Only one individual should be permitted to give signals to the crane operator.

Personnel should never ride along with loads carried by the crane and crane operators should not swing a load over the heads of other workers around the construction site.

In order to reduce strain on the crane and to prevent the sliding of loads, the crane hook should be directly over the load being lifted.

Workers should use cables or rods to position suspended tanks. They should not stand underneath tanks and use their hands and bodies to adjust the tank's position, or to guide it.

## CRANES (con.)

- Personnel on ground touching the crane or attached wires have greatest electrocution danger during power line contact.

### NOTES

Another serious potential hazard involving cranes is electrocution through contact with a hanging power line. Operators should maintain a minimum distance of 6 feet between the crane's boom and power lines. In order to avoid possible electrocution, ground personnel must refrain from touching the crane if it comes in contact with a power line.

Operators in cabbed equipment should remain in the cab if they come in contact with a live power line, sit still, and avoid touching the cab controls and all metal surfaces.

Installation of a safety guard is also recommended when working beneath power lines. The safety guard, which can consist of an insulated section of the upper boom or an insulated lifting hook, will help to protect both the crane operator and ground personnel.

It should be noted that electrocution can result from more than just contact with power lines. During high humidity conditions, an electrical arc can jump several feet from a power line to a crane.

## GENERAL SAFETY HAZARDS

---

- Slips, trips, and falls due to loose materials, such as soil piles and ropes
- Cuts, punctures, and abrasions due to improper use of tools such as cutting torches and jackhammers
- Misuse of compressed gases

### OTHER GENERAL SAFETY HAZARDS

### NOTES

Besides the specific heavy equipment hazards, UST operations also pose a number of general construction hazards. The majority of general construction accidents are small ones. While not fatal, these accidents are responsible for large amounts of lost work time, personal trauma, and costly medical claims. Injuries due to falls or trips are common, as are puncture wounds, cuts, and abrasions caused by careless use of tools. UST inspectors must be aware that injuries can occur anywhere and at any time. They need to prepare for such eventualities and remain constantly alert while on the job site.

Guidance for the control of general construction hazards can be found in OSHA regulations (29 CFR 1910), which stipulate detailed requirements for the use, storage, and maintenance of equipment and tools.

Some examples of general construction type accidents are described in Exhibit 2-4.

## **EXHIBIT 2-3**

### **HEAVY EQUIPMENT ACCIDENTS**

Some examples of reported accidents involving heavy equipment are presented below.

#### **Coal Worker Accidentally Crushes Himself**

Indianapolis, IN, 1990 - A worker using a backhoe to remove four 8,000-gallon fuel tanks from the AMAX Coal Co.'s Minehaha mine leans out a broken window of the backhoe cab to remove a chain from the bucket, and accidentally strikes an operating lever. The bucket drops down and crushes him. The federal Mine Safety and Health Administration cites the company for the broken window in the cab and a broken ignition switch on the backhoe.

#### **Worker Maimed in Installation Accident**

Tulsa, OK, 1990 - A contractor and his sub-contractor are on a job site preparing to compact the backfill material around a new tank installation. The contractor's employee motions for the track hoe operator (the sub-contractor) to use the bucket to lower the tamper into the hole. The track hoe operator swings the bucket over and sets it down by the employee, who is ready to load the tamper. The employee, thinking the bucket is not moving, turns his back to the bucket to lift the tamper. The track hoe operator is still in the process of tipping the bucket when the employee turns around and catches his foot underneath the teeth of the bucket. The teeth of the bucket pinch off one of his toes and break two others.

## **EXHIBIT 2-4**

### **GENERAL SITE ACCIDENTS**

Some reported accidents caused by a violation of general safety procedures are presented below. Notice the wide variety of forms they take.

#### **Using an air compressor**

When an employee using an air compressor shuts down the unit the hose is apparently kinked. The employee grabs the hose, releasing the kink and the pressure that built up in the hose. The force tears the employee's safety glasses off and blows the contact lenses from his eyes. Luckily, he is not injured.

#### **Repairing a submersible pump**

Two mechanics called to a service station to repair a submersible pump disable it by turning off the power at the breaker box. As they pull the leak detector, someone in the store turns the breaker back on, causing gasoline to gush out on one of the technicians. He is drenched with fuel and actually swallows some. The other technician runs into the store to turn the pump off and instructs all employees not to touch the breaker panel. The fuel-covered technician loses a day of work due to chemical exposure. The lesson learned by this incident is to make certain every employee in the store is aware that the power is off and that they are not to touch the breaker panel.

#### **Working around unsecured objects**

A wooden box lid left unsecured atop the box is blown off by a strong wind and strikes an employee working in the warehouse yard. The employee is transported to the hospital by ambulance and undergoes x-rays and a CAT scan. Luckily, he escapes with a mild concussion and a minor cut on his ear, and is able to return to work the following day.

#### **Repairing a submersible pump**

A veteran serviceman is dispatched to a convenience store in response to a report that the customer can not dispense regular unleaded fuel. The serviceman suspects a problem with the submersible pump capacitor. The store operator is present and says he will turn off the power to the unit in question. Upon opening the capacitor housing, the serviceman observes that it is filled with fuel. Without checking the power (which was still on), the serviceman pulls a terminal off the capacitor. This creates a spark which ignites the fumes in the cavity. The serviceman has the presence of mind to snuff out the fire immediately. There is no physical damage or injuries caused by this incident, and all involved are very lucky to have avoided a major disaster. The serviceman points out the company procedures that he did not follow: 1) Don't rely solely upon another person to turn off power to a device. See that you agree with what has been done; 2) "Lock-Out" the breaker or switch that has been turned off by means of a sign or a mechanical device; 3) Check the device being turned off with an electrical tester before proceeding with repairs. Haste can also be faulted in this incident as it was late Friday afternoon.

## **EXHIBIT 2-4 (con.)**

### **GENERAL SITE ACCIDENTS**

#### **Breaking concrete**

A jackhammer operator breaking concrete is not paying attention to what he is doing and jackhammers his foot. Unfortunately, he is wearing tennis shoes instead of the steel-toed shoes the company requires. He lacerates his foot, breaks his toe, and loses several weeks of work.

#### **Building a wooden box**

An employee building a wooden box steps backward onto a nail which protruded from a board and loses 10 days work as a result of the puncture wound to his foot. This is the second time in the last 2 months the company experiences incidents involving foot punctures. Both accidents involve employees who were on the job six months or less.

#### **Repairing a ceiling-hung reel**

The reel is hung from a 2x4 covered by a suspended ceiling at an automobile dealership. In order to repair the reel, the service tech walks out on the 2x4 framing. As he reaches to unbolt the reel he loses his balance and falls through the ceiling. Fortunately, he is able to grab a 2x4 and pull himself back up. The alternative was a 14-foot fall to the cement.

#### **Testing pumps and dispensers**

A crew bleeds the pressure off the product lines (or so they think) at a new tank installation and begins to prepare the leak detectors for installation. They dope up the first detector and pull the two-inch plug off the submersible. Product blows out the 2-inch opening and gasoline soaks both employees working in the area. The workmen strip off the clothes they are wearing and wash under a nearby water hose. No fire or explosion results. Procedures now call for pulling the submersible pump completely to drain the product from it before installing leak detectors.

#### **Repairing a card lock system with a defective flow switch**

A mechanic called to repair a defective flow switch at a card lock system shuts off the power at the breaker panel, removes the pump panels, and barricades the area surrounding the pump. A friend of the operator comes to the station for product. He goes into the pump control room, turns on the power at the breaker, and somehow finds his way around the barricade. As he starts the pump, fuel sprays from the flow switch opening. Fortunately, the incident does not cause a fire. Procedures now call for locking the breaker out, locking the pump handle, and plugging the hole from which the flow switch is removed.

## **EXHIBIT 2-4 (con.)**

### **GENERAL SITE ACCIDENTS**

#### **Repairing a faulty petroleum pump**

A man repairing a faulty pump is working on the hydraulics and electrical components at the same time. A spark from a shorted wire ignites the vapors in the test can, causing it to explode. He dies later that evening as a result of burns suffered in the blast.

#### **Ladder accident**

A warehouse employee is standing on ladder while transferring 60-pound boxes from the top of a raised forklift to a storage shelf. One of the boxes catches on a rail at the top of the shelf. While struggling to free the box, the ladder starts to tip, causing him to lose his footing. The employee falls approximately 5 feet to the ground, landing on his left hand. He is taken to an area hospital where x-rays revealed a fracture of his left wrist. Surgery is required to repair the damaged joint. Several pins remain in the wrist for 8 weeks, and extensive physical therapy is necessary in order for the employee to regain the function of his wrist and hand. The employee is off work 16 weeks.

#### **Disconnecting equipment from a truck.**

A man disconnects a portable air compressor from a truck and forgets to lower the wheel stand on the compressor before disconnecting it from the truck bumper. As he raises the compressor and moves it away from the truck bumper, he loses his balance. The tongue of the compressor chassis drops to the ground and crushes his finger under the hitch. He is off work 5 weeks.

#### **Working inside a sump**

An employee is working inside a piping sump at a convenience store that has just been built. The manhole lid and sump cover were removed, and an orange traffic cone was placed adjacent to the hole. As a salesman drives out of the parking lot, he first drives over the traffic cone and then over the manhole where the employee was working. The salesman stops his car only because the traffic cone became wedged in the undercarriage of his vehicle. The mechanic is low enough in the sump to escape injury.

New procedures call for parking a service truck in such a way as to protect the workers from traffic, whether employees are working in an open or closed station.



---

## EXCAVATIONS

---

## EXCAVATIONS

---

### Objectives

Participants will be able to:

- list the main excavation hazards
- describe the two most effective methods for preventing cave-ins
- discuss prevention measures for the other excavation hazards

### NOTES

## EXCAVATION CAVE-INS

---

Excavation is one of the most hazardous types of construction work.

Main concern: trench or excavation cave-ins

Likelihood of cave-ins is increased by:

- freezing
- thawing
- vibrations
- surcharge loads

### EXCAVATION CAVE-INS

### NOTES

UST activities often entail excavation. The construction industry considers excavation and trenching to be two of its most hazardous jobs. Annually there are approximately 100 fatalities and 5,000 injuries at excavation sites.

Cave-ins are the primary excavation hazard to which employees may be exposed. While the number of cave-ins is small compared to the total number of accidents, cave-ins tend to be very serious in nature, frequently resulting in fatalities. Cave-ins occur when the soil forming the sides of the excavation cannot support the pressure put on it by individuals, equipment, or gravity. Surcharge loads are created by placing an extra load on the soil surrounding the excavation, for example, a vehicle. Changing environmental conditions and the process of digging can also reduce the ability of soil to resist cave-in forces. Examples of excavation accidents are illustrated in Exhibit 2-5.

## **EXHIBIT 2-5**

### **EXCAVATION ACCIDENTS**

Some examples of recorded accidents involving excavation-related activities are presented below. Note that cave-ins are a primary source of excavation accidents.

#### **Geologist Killed in Cave-in**

California, 1976 - The collapse of a trench results in the death of a geologist. The trench is 3 feet wide, 13 feet deep, and has vertical walls that were not shored. The geologist is warned that the ground is unstable, but ignores the warnings. Once inside the trench, he is quoted as saying, "This sure looks bad in here. It looks like it's going to cave in." Ten seconds later a cave-in occurs and completely covers him.

#### **Worker Crushed when Ground Gives Way**

Utah, 1981 - A worker is killed when a trench in which he is laying water pipe gives way. The victim is standing in a trench about 5 feet deep and 3 feet wide dug in sandy soil. The side of the trench caves in, crushing the man against the other side of the trench. Although his head remains above the soil, he dies almost instantly from massive internal injuries to the windpipe, lungs, and liver.

#### **Worker Killed Shoring Trench**

California, 1968 - A worker is helping to install shoring in a trench about 10 feet deep when the material caves in under the existing shoring, covering his feet and lower legs. Before he can be rescued, the whole side of the trench caves in, covering him completely.

#### **Gasoline Explosion Seriously Injures Five**

Missouri, 1980 - Employees of a water company strike and rupture a gas line while digging a trench. During an attempt to repair the break, five employees of the gas company are seriously injured when an explosion occurs, followed by a fire.

#### **Three Workers Injured Trying to Save Fourth**

Arkansas, 1980 - One worker is killed and three others seriously injured in a sewer trench cave-in. The three injured workers jumped into the trench to try to save the first man after the cave-in, but were themselves caught in a second cave-in.

## **EXHIBIT 2-5 (con.)**

### **EXCAVATION ACCIDENTS**

#### **Worker Drowns Unable to Escape Trench**

California, 1968 - A lateral trench is dug at right angles to a main trench that is 8 feet deep. Digging the lateral trench undermines supports of a 6-inch water main, causing the pipe to break. The trench quickly fills with earth and water. Fellow workers can not pull a laborer who was installing shoring from the mud which came up to his knees. He is drowned when water fills the trench. It was assumed that the water line was not closer to the trench than 5 feet because of the location of a fire hydrant above ground at that distance.

#### **Worker Dies After Cave-in Rescue Attempt**

Pennsylvania, 1981 - An employee is caught in a trench cave-in, but is not killed. During the rescue, the employee suffers deep gashes in his back when rescuers attempt to free him with the backhoe. The employee later dies from complications resulting from these injuries.

#### **Minor Injury in Excavation**

A member of an installation crew standing on a tank that was lowered into an excavation in order to check the level of the tank asks another worker to throw a 4-foot level to him. When he attempts to catch the level, it slips through his hands and strikes him in the eye. The employee is treated in the emergency room. Although the eye is not damaged, six stitches are required to close the wound on his eyelid.

## METHODS TO PREVENT CAVE-INS

---

Use sloping or shoring on all excavations over 4 feet deep

- Sloping: Angle sides to prevent downhill slide of soil
- Shoring: Brace sides to prevent cave-ins

### METHODS TO PREVENT CAVE-INS

### NOTES

Several different methods exist to protect employees from cave-ins. These include sloping or benching the sides of the excavation, placing a shield between the sides of the work area, and shoring up the sides with supports.

OSHA regulations delineate approximate angles for sloping in 29 CFR 1926.652. Exhibit 2-8 shows approximate slopes, and Exhibit 2-9 shows trench shoring requirements.

**Sloping** provides protection by removing the soil that might cave-in. At a minimum, all slopes should be excavated to the angle of repose. The determination of the angle of repose and design of an adequate support system must be based on careful evaluation of pertinent factors such as: depth of cut; possible variation in water content of the material while the excavation is open; anticipated changes in materials from exposure to air, sun, water or freezing; and vibration from equipment and traffic movement. Designing the proper slope or bench configuration for a particular situation is a complex engineering problem and should not be attempted by inexperienced personnel.

Support systems can be constructed to add another component of resistance to the forces that could cause a cave-in. **Shoring** provides support or shields to stop the soil from traveling back into the trench where workers are. Shoring and bracing materials should be carried down when initially entering the excavation. If this is not done, workers expose themselves to cave-ins when entering the excavation at full depth to install the bracing

## METHODS TO PREVENT CAVE-INS (con.)

### NOTES

and shoring. Beware: the possibility of a cave-in also exists during the installation or removal of the support system.

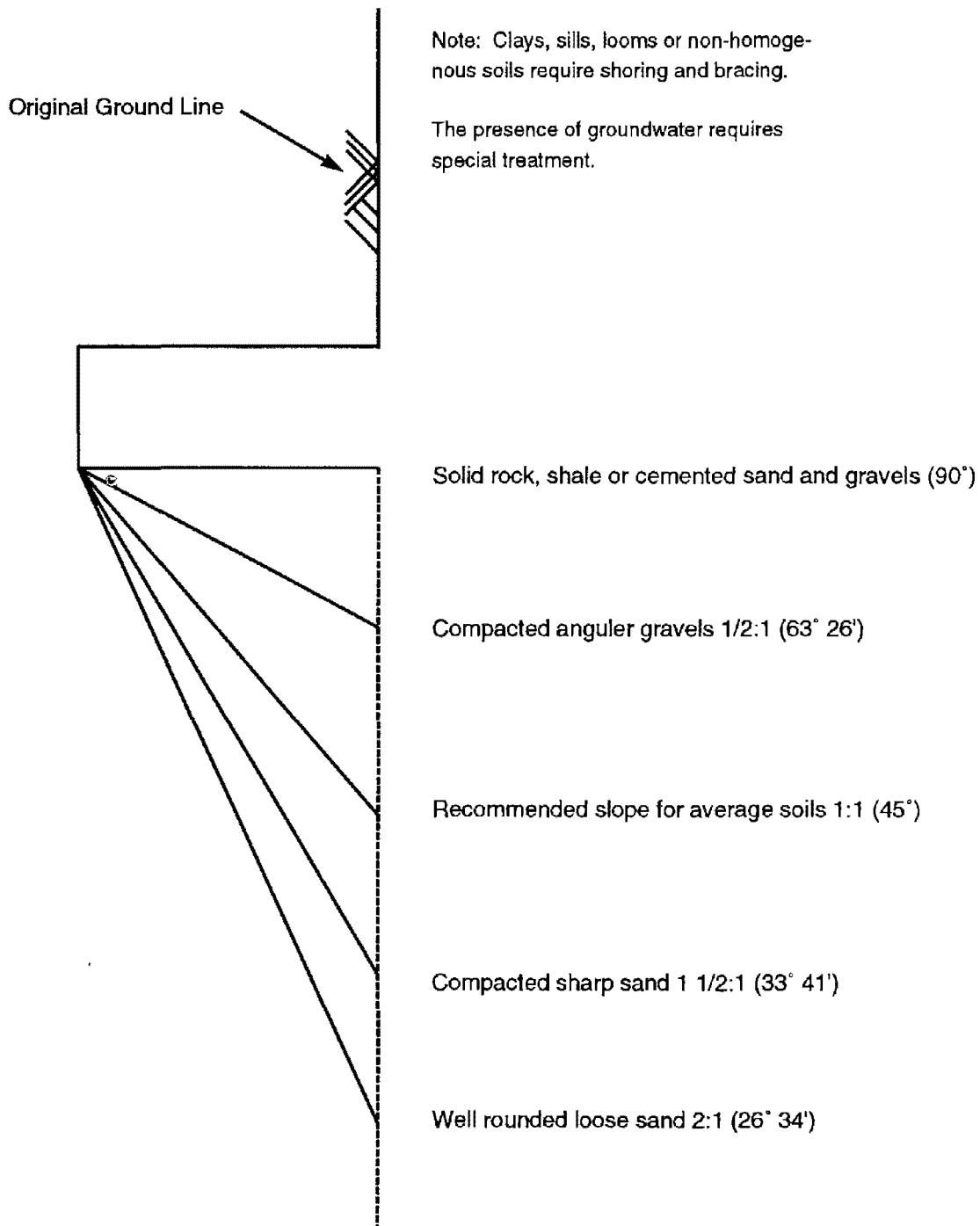
Shoring and sloping are seldom seen at many UST pulls. This does not mean that it is correct to proceed without them. However, here are a few clarifications:

- These measures are only necessary when workers enter or work in the excavation.
- Workers may stand on exposed tank tops to attach cabling or to remove, repair, or install piping. These activities do not typically require sloping or shoring, since the worker is not in danger of a cave-in.
- It is, in reality, impractical to install shoring in a tank hole. However, it may be unavoidable if working near foundations, roadbeds, or other areas where soil may be destabilized and sloping is not possible.
- Many contractors are reluctant to use sloping, because it is more work. They will use every excuse not to do it. If workers enter the excavation, they must be properly protected. Period.

Tables 2-2 and 2-3 summarize sloping and shoring requirements.

**FIGURE 2-2**

**APPROXIMATE ANGLE OF REPOSE  
FOR SLOPING SIDES OF EXCAVATIONS**





**TABLE 2-2**  
**TRENCH SHORING**

Depth of trench	Kind or condition of earth	Size and spacing of members										
		Uprights		Stringers		Cross braces <sup>1</sup> ; Width of trench				Maximum spacing		
		Minimum dimension	Maximum spacing	Minimum dimension	Maximum spacing	Up to 3 feet	3 to 6 feet	6 to 9 feet	9 to 12 feet	12 to 15 feet	Vertical	H
		Inches	Feet	Inches	Feet	Inches	Inches	Inches	Inches	Inches	Feet	
5 to 10	Hard, compact	3 x 4 or 2 x 6	6	.....	.....	2 x 6	4 x 4	4 x 6	6 x 6	6 x 8	4	
	Likely to crack	3 x 4 or 2 x 6	3	4 x 6	4	2 x 6	4 x 4	4 x 6	6 x 6	6 x 8	4	
	Soft, sandy, or filled	3 x 4 or 2 x 6	Close sheeting	4 x 6	4	4 x 4	4 x 6	6 x 6	6 x 8	8 x 8	4	
	Hydrostatic pressure	3 x 4 or 2 x 6	Close sheeting	6 x 8	4	4 x 4	4 x 6	6 x 6	6 x 8	8 x 8	4	
10 to 15	Hard	3 x 4 or 2 x 6	4	4 x 6	4	4 x 4	4 x 6	6 x 6	6 x 8	8 x 8	4	
	Likely to crack	3 x 4 or 2 x 6	2	4 x 6	4	4 x 4	4 x 6	6 x 6	6 x 8	8 x 8	.....	
	Soft, sandy, or filled	3 x 4 or 2 x 6	Close sheeting	4 x 6	4	4 x 6	6 x 6	6 x 8	8 x 8	8 x 10	4	
	Hydrostatic pressure	3 x 6	Close sheeting	8 x 10	4	4 x 6	6 x 6	6 x 8	8 x 8	8 x 10	4	
15 to 20	All kinds or conditions	3 x 6	Close sheeting	4 x 12	4	4 x 12	6 x 8	8 x 8	8 x 10	10 x 10	4	
Over 20	All kinds or conditions	3 x 6	Close sheeting	6 x 8	4	4 x 12	8 x 8	8 x 10	10 x 10	10 x 12	4	

<sup>1</sup>h jacks may be used in lieu of, or in combination with cross braces.

<sup>2</sup>is not required in solid rock, hard shale, or hard slag.

desirable, steel sheet piling and bracing of equal strength may be substituted for wood.

### ADDITIONAL EXCAVATION HAZARDS

---

- Destabilization of adjacent structures
- Contact with underground utilities
- Hazard for vehicular traffic
- Contact with overhead power lines
- Falling loads or equipment
- Possible pedestrian access/accidents
- Special entrance and exit precautions

### ADDITIONAL EXCAVATION HAZARDS

### NOTES

In addition to cave-ins, several other hazards are associated with excavations. Excavations can destabilize adjacent structures, leading to their collapse. Underground utilities (power, water, sewer, gas and telephone lines) may be encountered and damaged, exposing workers to possible fires, explosions, electrocution, rapid flooding, or chemical releases.

Increased vehicular traffic due to excavation activities, falling loads during the loading and unloading of earth, fill, and other materials, and hazards associated with entering and exiting excavations (such as falls and unstable ladders) are also possible. In addition, improper barricading of the excavation may result in pedestrian accidents (and lawsuits). It is important that all excavations are barricades or roped off, to keep people and equipment from falling in, to keep the edge clear, to help prevent cave-ins.

Excavations are also good collection points for heavier-than-air gasses, which may displace oxygen, causing an unseen hazard.

## EXCAVATION HAZARD PREVENTION

---

- Place excavated materials at least 2 feet from excavation.
- Station machinery far back from the edge.
- Prevent ground/surface water entrance or accumulation in excavation.

### EXCAVATION HAZARD PREVENTION

### NOTES

The additional weight of excavated material can lead to soil destabilization; all excavated materials should be placed a minimum of 2 feet back from the trench or excavation walls. Boulders, concrete and other debris that might slide into the excavation should also be removed or secured.

Personnel should not work or stand in the operational area of the excavating machinery, and machinery should be placed as far back from the edge of the excavation site as possible in order to avoid cave-ins. Personnel should stay out of excavation operations by standing at the back of an excavation site, not the sides.

Do not allow ground or surface water to enter or accumulate in the trench. If any water does enter the site, remove it using pumps which are incapable of causing the ignition of a mixture of flammable material.

### EXCAVATION HAZARD PREVENTION (con.)

---

- Use intrinsically safe pumps.
- Provide adequate space for working (both inside and outside of excavation).
- Consider presence of free product to be a hazardous condition.

### NOTES

During the excavation, there should be a minimum clearance between adjacent tanks and between tanks and the sides of excavation of 12 inches for steel tanks and 18 inches for fiberglass-reinforced plastic tanks.

Free product in the excavation signifies a hazardous condition. Immediately notify the local fire department of the presence of free product and make arrangements to have the contractor remove all free product from the excavation as quickly as possible.

## EXCAVATION HAZARD PREVENTION (con.)

---

- Place barricades, walkways, and lighting, and post notices at all excavation.
- Provide and use ladders to enter excavation.
- Obtain soil samples from backhoe bucket.
- Have emergency rescue equipment readily accessible.

## NOTES

Prior to beginning excavating, workers should set up necessary barricades, walkways, lighting, and signs around the perimeter of the excavation in order to protect both the public and the workers. Any excavation or trench must have at least one ladder.

Personnel should not enter any excavation until appropriate air monitoring has indicated that it is safe to do so. At the time of entrance, personnel should not ride in the backhoe bucket to gain access to the excavation. Employees should use ladders that extend from the bottom of the excavation to a height of 3 feet above the grade.

Employees should avoid entering the excavation pits or trenches whenever possible. Obtain soil samples from the backhoe bucket.

Employees should have emergency rescue equipment such as fire extinguishers, breathing apparatus, safety harness and line, and stretcher on site and ready for instant use during excavation.

The contractor performing the excavation work is responsible for having this equipment on hand.

TOXICITY

## TOXICITY

---

### Objectives

Participants will be able to:

- list the three main exposure routes
- define acute and chronic exposure
- describe symptoms of acute and chronic petroleum exposure
- list situations where toxic exposure is most likely

### NOTES

## EXPOSURE ROUTES

- Inhalation
- Skin Absorption
- Ingestion

### EXPOSURE ROUTES

### NOTES

There are a number of general symptoms which result from toxic exposure to most of the compounds found at petroleum UST sites. These symptoms include irritation of the eyes, mucous membrane and respiratory tract as well as depression or excitation of the central nervous system.

Petroleum products generally enter the body through inhalation of vapors, absorption (skin or eye contact), or ingestion. Of these three routes, inhalation is the quickest and most efficient route into the body. The adverse affects of inhalation of toxins can be almost instantaneous because the lungs quickly transfer the toxin into the bloodstream. The toxic effect will be proportional to the concentration of the toxin, its toxicity, and the individual's sensitivity to the toxin.

The symptoms of **inhalation** can be vague. Headaches, nausea, dizziness, insomnia, and tremors should **not** be overlooked.

Exposure via **ingestion** of contaminated water is generally limited, as petroleum in water can be detected by most people in levels as low as 1 ppm.

Visual and olfactory clues as well as site safety screening instruments should be used to assess exposure hazards. Visual cues include seeing stained soils, vapors, or iridescence in water.

Vapors from petroleum products can be smelled when they are at levels far below those considered toxic to humans. However, UST inspectors should not rely solely on their senses to detect toxic levels of vapors.



## EXPOSURE ROUTES (con.)

### NOTES

particularly since noses become desensitized to some odors after prolonged exposure. Olfactory sensitivity also decreases with age.

Table 2-8 summarizes the various types of petroleum products and their exposure potentials, exposure target organs and acute and chronic symptoms. Each of these areas is discussed in detail throughout this section.

## TYPES OF EXPOSURE

### Acute exposure

- short-term, high-level exposure
- effects are usually immediate

### Chronic exposure

- long-term, low-level exposure
- effects may take years to appear

## TYPES OF EXPOSURE

## NOTES

An inspector can face either chronic or acute exposure at a site. **Chronic** is defined as long-term, low-level exposure, while **acute** is defined as short-term, high-level exposure. Both are dangerous and have immediate and long-term health implications. UST-associated work can also expose workers to multiple chemicals which may have **synergistic** effects. This means that the effect of two chemicals together may be greater than the sum of their separate effects. All exposures should be kept as low as reasonably achievable.

Many materials stored in USTs are very common, and many have very low acute toxicity. However, the exposures of the UST inspector are more frequent, of longer duration, and higher than those of the average person. It is this repeated, low-level exposure that is so dangerous, as effects may not be seen for many years. Avoiding unnecessary exposure now can help you enjoy your later years, instead of combatting a chronic illness.

**Most exposure can be eliminated if common clues, such as strong odors and instrument readings, are heeded.**

## GENERAL SYMPTOMS OF TOXIC EXPOSURE

---

- Irritation of eyes, mucous membranes, and respiratory system
- Central nervous system depression and/or excitation
- Headache, nausea, drowsiness, dizziness, insomnia, confusion, tremors
- Dry and red skin upon contact

## NOTES

## ACTIVITIES HAVING TOXIC EXPOSURE POTENTIAL

---

### Release investigations/corrective actions

- petroleum product and vapors
- $H_2S$  in sewers
- asbestos and termiticides in basements

### In-place tank closure

- vapors, product, and sludges

### Tank/pipe repair/removal

- product and vapors
- "coating" chemicals and petroleum

### Leak detection testing

- product and vapors

## NOTES

## TOXICITY OF GASOLINE CONSTITUENTS

Aromatics and alkanes may be responsible for most adverse health effects

- carcinogenic properties are attributed to aromatic fractions, particularly benzene (4 to 10 percent of gasoline)
- other aromatics of concern are ethylbenzene, xylene, toluene, and naphthalene
- alkanes have relatively low toxicity
- some alkanes are associated with central nervous system depression, kidney damage (n-hexane and octane)

### TOXICITY OF GASOLINE CONSTITUENTS

### NOTES

All petroleum products share the characteristic of causing central nervous system depression. The early symptoms of acute over-exposure can include dizziness, drowsiness, impaired coordination, nausea, euphoria, convulsions, coma, and death, in high enough doses.

The primary route of exposure for these products is **inhalation**. If the products are ingested, do not induce vomiting, since the product may be aspirated into the lung easily. Activated charcoal, followed by "stomach pumping," is the preferred treatment.

**Skin contact** is not typically an immediate hazard. Prolonged contact will cause burning and blistering. Repeated exposures to skin will result in defatting and possible dermatitis.

### ALKANES

**Hexane** may be the most toxic member of the alkanes. It comprises 11 to 13 percent of gasoline by weight. **Acute exposure** to hexane occurs primarily through inhalation. Vertigo, headaches and nausea are the first symptoms of exposure to be noticed. At high concentrations, central nervous system (CNS) depression results in a narcosis-like state.

## TOXICITY: GASOLINE CONSTITUENTS (con.)

Pre-narcotic symptoms occur at vapor concentrations of 1,500 to 2,500 ppm as the central nervous system is depressed. Skin contact primarily causes fat removal and irritation. Hexane also irritates the eyes and mucous membranes with even a fairly short-term exposure, for example, 880 ppm for 15 minutes.

**Chronic exposure** to hexane vapors causes nerve damage. The first clinical sign of nerve damage is a feeling of numbness in the toes and fingers. Further exposure leads to increased numbness in the extremities and to loss of muscular stretching reflexes. Paralysis develops with varying degrees of impaired grasping and walking. In the most severe cases nerve conductivity is neutralized and cranial nerve involvement is also observed and may require several years to recover. In mild or moderate cases, recovery begins six to 12 months after exposure ceases.

**Octane**, if it is taken into the lungs, may cause rapid death due to cardiac arrest, respiratory paralysis, and asphyxia. It has a narcotic potency similar to heptane. Prolonged skin contact results in a blistering and burning effect.

## TOXICITY: AROMATICS

---

### Acute Exposure

- central nervous system effects
- may cause dermatitis, vertigo, headache, nausea, and vomiting

### Chronic Exposure

- benzene is a carcinogen, linked to leukemia
- increased risk of kidney cancer and lymphoma
- nerve damage, possible paralysis

## TOXICITY OF AROMATICS

## NOTES

It is almost impossible to assign a fuel product's acute effects to any given component, since they all have similar actions. Worrying about air concentrations of specific components is not practical. We typically look at total organics.

**Benzene** is found at concentrations up to 4 percent by weight in gasoline. Older gasolines may contain as much as 13 to 15 percent benzene. **Acute exposure** will depress the central nervous system (CNS) and may cause acute narcotic reactions. The lowest observed threshold for acute exposures is 25 ppm. Headaches, lassitude, and dizziness may become increasingly evident at exposures between 50-250 ppm. Concentrations of 3,000 to 7,500 ppm may result in toxic signs within the hour. Depending on the concentrations and duration of exposure, these effects range from mild symptoms such as headaches and light-headedness to more severe effects such as convulsions, respiratory paralysis, and death. Skin absorption is not considered to be as important a route of entry as inhalation or ingestion because skin absorption is extremely low, with the highest absorption through the palm. Direct contact with the liquid may cause redness and dermatitis.

NOTES

Benzene is a known carcinogen. Chronic exposure to benzene has been linked to leukemia and irreversible chromosome damage. At the early stages, reversible leukemia, anemia, or a decrease in the blood platelet count may occur. Continued exposure leads to severe bone marrow damage, which results in a deficiency of all cellular elements of the blood. The direct, life-threatening consequence of this is an increased susceptibility to infection and hemorrhaging. The lowest air levels of benzene capable of producing these effects are in the range of 40 to 50 ppm. Effects of high exposure levels (>100 ppm) may persist for many years after exposure has been discontinued. The most important effect resulting from chronic benzene exposure is its hematotoxicity, the targets being the cells of the bone marrow. UST workers may be exposed to as much as 10 ppm in their everyday activities.

**Toluene** is found in concentrations of up to 4 to 7 percent in gasoline. The primary hazard of acute inhalation exposure is CNS depression. Reaction times will begin to be impaired after exposures of 20 minutes at 300 ppm. Toluene will also cause eye irritation, and prolonged or repeated skin contact may cause dermatitis. As concentrations increase, symptoms can include: muscular fatigue, confusion, tingling skin, euphoria, headache, dizziness, lacrimation, dilated pupils, eye irritation, nausea, insomnia, nervousness, and impaired reaction time. Occupational exposure to toluene has been linked to a higher reported incidence of menstrual disorders. Children born to these women may experience more frequent fetal asphyxia and be underweight.

**Xylenes** are found in concentrations of 6 to 8 percent in gasoline. Short-term inhalation exposures are associated with narcotic effects on the central nervous system, and high concentrations may lead to CNS depression. Both liquids and vapors are irritating to the skin, eyes, and mucous membranes. Skin absorption of xylenes occurs readily and xylenes can also be transferred across the placenta. Incomplete brain development has been reported in the fetuses



NOTES

of mothers exposed to xylene. **Chronic**, high-level human inhalation exposure results primarily in CNS effects, lack of coordination, nausea, vomiting, and abdominal pain. There are variable effects on the liver, kidneys, and gastro-intestinal tract. Chronic effects of xylenes resemble the acute effects but are more severe. They include headache, irritability, fatigue, digestive and sleep disorders, CNS excitation followed by depression, tremors, apprehension, impaired memory, weakness, vertigo, and anorexia. Xylenes are skin irritants and prolonged contact may cause formation of blisters.

**Ethylbenzene** is known to be toxic to the liver and kidneys. It will irritate the skin, eyes, and upper respiratory tract. Inhalation of small amounts may exacerbate the symptoms of obstructive airway diseases and cause extensive fluid buildup and hemorrhaging of lung tissue. Although a tolerance to the eye and respiratory effects may develop after a few minutes, CNS effects will usually begin at this stage, leading to CNS depression.

## TOXICITY: GASOLINE ADDITIVES

---

- Tetramethyl and tetraethyl lead (TML and TEL)
- Ethylene dibromide (EDB) and ethylene dichloride (EDC)
- Tri-ortho-cresyl-phosphate (TOCP)

### TOXICITY OF ADDITIVES

### NOTES

Gasoline often contains substances that have been added to improve the fuel's performance properties. Gasoline additives of general concern for leaded gasolines are tetramethyl lead (TML) and tetraethyl lead (TEL), as well as ethylene dibromide (EDB) and ethylene dichloride (EDC). Both TML and TEL are used as anti-knock agents; EDB and EDC are used to prevent lead deposition. These compounds are present in low concentrations in gasoline (relative to benzene, toluene, and xylene), but they are quite toxic.

TML and TEL can be absorbed through the skin, ingested, or inhaled. TEL intoxication is caused by inhalation or absorption through the skin. Acute intoxication can occur through absorption of a sufficient quantity of TEL either through brief exposure at a very high rate (100 mg/m<sup>3</sup> for 1 hour) or for prolonged periods at lower concentrations. Exposure can cause acute intoxication, liver and thymus damage, and possibly death from a combination of depression of the central nervous system, respiratory irritation, and bronchiolar obstruction.

Most severe exposure to TEL and TML have resulted from sniffing gasoline. Some victims have shown the symptoms listed as well as fluid buildup in the brain, resulting in swelling and increased intracranial pressure.

## TOXICITY: GASOLINE ADDITIVES (con.)

### NOTES

The signs and symptoms of exposure are often vague and easily missed. The onset of symptoms may even be delayed up to 8 days after exposure and include weakness, fatigue, headache, nausea, vomiting, diarrhea, anorexia, insomnia, and weight loss. Symptoms peculiar to TEL exposure are the sensation of hairs in the mouth and the feeling of insects crawling on the body.

As intoxication worsens, there is confusion, delirium, manic excitement, and catatonia. Nightmares, anxiety, and anorexia are also seen. Loss of consciousness and death may follow after several days. Severe intoxication causes recurrent or continuous episodes of disorientation and intense hyperactivity which may rapidly convert to convulsions that may terminate in coma or death. TEL is likely to have adverse effects on human reproduction and embryonic development.

### GASOLINE ADDITIVES: ACUTE EXPOSURE

---

- Affects central nervous system
- Irritating to mucous membranes, eyes, and skin
- Severe respiratory tract irritation
- Vomiting, diarrhea, abdominal pain
- Delayed lung damage

### GASOLINE ADDITIVES: ACUTE EXPOSURE

### NOTES

**Acute exposure** to gasoline additives is a serious health threat. In general, brief exposure to additives (100 mg/m<sup>3</sup> for 1 hour) can cause acute intoxication and depress the central nervous system. Symptoms include insomnia, confusion, headaches, and tremors, and may be delayed for up to 8 days. Specifically, both EDB and EDC are highly toxic and identified as carcinogenic, although EDC has a much lower potency.

Acute exposure also causes vomiting, diarrhea, abdominal pain and, in some cases, lung damage. The vapor is irritating to the eyes and mucous membranes and may cause liver, kidney, and lung damage, including delayed pulmonary lesions. The liquid form is highly irritable to the skin, causing redness and blistering. Death has occurred following ingestion of 4.5 ml. Recent studies by NIOSH have shown adverse reproductive effects in men.

### **GASOLINE ADDITIVES: CHRONIC EXPOSURE**

---

- Weight loss, anemia, emotional instability, and toxic psychosis
- Adverse effects on central nervous system, peripheral nerves, and vascular system
- Adverse effects on reproductive and embryonic development
- Liver and kidney damage.

### **GASOLINE ADDITIVES: CHRONIC EXPOSURE**

### **NOTES**

**Chronic exposure** to additives has equally serious health effects. In general, chronic human exposure is associated with adverse effects on the central nervous system, peripheral nerves, kidneys, and vascular system. Adverse effects are also likely on the human reproductive system and embryonic development.

Symptoms of chronic exposure include weight loss, anemia, emotional instability, and toxic psychosis. Recovery may take months to years, and 25 to 30 percent of cases never recover.

## TOXICITY: MIDDLE DISTILLATE FUELS

---

- Kerosene, aviation fuels, diesel fuels, and Fuel Oils Nos. 1 and 2
- Oral, dermal, and inhalation exposure
- Major systemic reaction: central nervous system depression
- Skin and mucous membrane irritation
- Constituents of concern: polyaromatic hydrocarbons (PAHs), cresols, phenols

### TOXICITY OF MIDDLE DISTILLATES

### NOTES

The **middle distillates** include kerosene, aviation fuels, diesel fuels, and Fuel Oil Nos. 1 and 2. They are referred to as the middle distillates because of the similarity in their degree of volatility during the distillation process. They can be taken into the body by ingestion, absorption, or inhalation.

Kerosene has the least amount of aromatic hydrocarbons of the middle distillate fuels, with benzenes, indanes, and naphthalenes being the major aromatic components. Kerosene and related hydrocarbons are irritating to the skin and mucous membranes, and skin absorption may be significant.

Jet and aviation fuels are mixtures of distillate hydrocarbons that vary in composition from those similar to motor gasoline to kerosene-based fuels used in commercial aircraft. Jet fuels contain additives such as anti-oxidants, metal deactivators, and de-icing agents.

Diesel fuels contain high amounts of naphthalenes, acenaphthalenes, phenanthrenes, and anthracenes. Dermal exposure to diesel oil is toxic to the kidneys.

Generally, No. 2 fuel oil (heating oil) contains a higher volume percentage of benzenes and naphthalenes compared to kerosene and diesel fuels.

## TOXICITY: MIDDLE DISTILLATE FUELS (con.)

### NOTES

Polynuclear Aromatic Hydrocarbons (PAHs) are present in higher concentrations in middle distillate fuels than in gasoline, but less than in the residual fuels. Specific PAHs detected in the middle distillates include naphthalene, benzo(a)anthracene, and benzo(a)pyrene. Benzo(a)anthracene and benzo(a)pyrene are known to be very **carcinogenic** (cancer-causing). PAHs have been shown to cause cytotoxicity in rapidly proliferating cells throughout the body, apparently inhibiting DNA repair. Cytotoxicity causes changes in the cytoplasm of the cell. The vascular system, lymphoid system, and testes are frequently noted as targets of PAHs.

No information about the carcinogenicity of middle distillates in humans is available. However, several members of the middle distillate family, in particular Fuel Oil No. 2 and diesel, have been shown to be weak to moderate carcinogens in animals.

**Teratogenic** compounds affect fetal development. No teratogenic effects have been observed in animal tests using kerosene, diesel fuel, and Fuel Oil No. 2.

The chief systemic reaction to the middle distillates is depression of the central nervous system. Effects of exposure are expected to resemble those of kerosene, that is, low oral, moderate dermal, and high inhalation hazard. Symptoms include irritation to the skin and mucous membranes as well as headaches and nausea.

### MIDDLE DISTILLATE FUELS: SYMPTOMS OF ACUTE EXPOSURE

---

- Headache, nausea, mental confusion
- Irritation of respiratory tract, skin, and mucous membranes
- Hemolytic anemia
- Cardiovascular disturbances

### MIDDLE DISTILLATE FUELS: SYMPTOMS OF ACUTE EXPOSURE

### NOTES

Acute exposure to middle distillate fuels can lead to headaches, nausea, mental confusion, and irritation of the respiratory system. Further exposure can cause hemolytic anemia and cardiovascular disturbances; in some extreme cases, loss of consciousness can occur. The compounds in the middle distillate fuels that are most likely to be of toxicological concern are non-carcinogenic PAHs, such as naphthalene; the carcinogenic PAHs, benzo(a)-anthracene and benzo(a)-pyrene; and cresols and phenols.

Ingestion or inhalation of naphthalene produces nausea, vomiting and disorientation. It is irritating to the skin and eyes and may cause cataracts. Benzo(a)-anthracene and benzo(a)-pyrene have been detected in Fuel Oil No. 2 and have been classified as probable human carcinogens.

Cresols are highly irritating to the skin, mucous membranes and eyes. They can impair liver and kidney function and cause central nervous system and cardiovascular disturbances. Phenol is toxic to the liver and kidneys.

Several of the components of gasoline are also found in the middle distillate fuels. For example, toluene, xylenes, and ethylbenzene are found in the middle distillates, although in much lower concentrations than in gasoline. Octane on the other hand, is present at much higher concentrations in aviation fuels than in motor gasoline. Additionally, a number of other substances may be found in the middle fractions of petroleum derivatives. These are



## MIDDLE DISTILLATE FUELS: ACUTE EXPOSURE (con.)

### NOTES

not covered in this course due to their numbers and complexity. These include components of jet fuel as well as jet and diesel fuel additives, such as Dodecane, Methylcyclopentane, N,N-Dimethylformamide, Manganese Compounds, peroxides, and Alkyl Nitrate and Nitrate/Nitro and Nitroso compounds.

### MIDDLE DISTILLATE FUELS: IMPACTS OF CHRONIC EXPOSURE

---

- Neurological effects
- Bronchopneumonia
- Toxic to liver and kidneys
- Toxic to vascular and lymphoid systems, and testes
- Probable human carcinogens

#### MIDDLE DISTILLATE FUELS: IMPACTS OF CHRONIC EXPOSURE

#### NOTES

Chronic exposure to middle distillate fuels causes neurological effects. One study of aircraft workers consistently exposed to aviation fuel found that a majority experienced recurrent symptoms such as dizziness, headaches, and nausea. Feelings of suffocation, coughs, and palpitations were also prevalent. Inhalation of high concentrations of these vapors can lead to an acute and often fatal bronchopneumonia.

## TOXICITY: RESIDUAL FUEL OILS

---

Fuel Oil Nos. 4, 5, and 6

Cracked bunker fuel and catalytically cracked clarified oil:

- both carcinogenic in animals
- cracked clarified oil is one of the most carcinogenic materials in petroleum refining

Contain higher concentration of polyaromatic hydrocarbons (PAH) than middle distillates, gasolines

### TOXICITY OF RESIDUAL FUEL OILS

### NOTES

**Fuel Oils Nos. 4, 5, and 6** are commonly referred to as the residual fuels. They are very viscous and have low water solubilities.

Residual fuels are blends of predominately high molecular weight compounds and tend to have a higher concentration of PAHs than gasoline and middle distillates. These fuels often contain blending agents including cracked bunker fuel and catalytically cracked clarified oil. Both of these blending agents have been classified as animal carcinogens. Catalytically cracked clarified oil is recognized as one of the most carcinogenic materials in a petroleum refinery. Acute oral effects of exposure to Fuel Oil No. 6 in animals include lethargy, congestion of liver and kidneys, and intestinal irritation. The heavy metals arsenic, lead, and zinc have been detected in samples of Fuel Oil Nos. 4 and 6.

### TOXICITY: USED OILS

---

- Composition varies: may include lead, chromium, cadmium, chlorinated solvents
- PCBs detected in 18 percent of analyses
- Automotive used oils: higher concentrations of heavy metals
- Industrial used oils: higher concentration of chlorinated solvents and PCBs
- No difference in concentration of aromatic solvents or PAHs

### TOXICITY OF USED OILS

### NOTES

Used oils are the byproduct of using oil as a lubricant. Through this use, the oils pick up a number of substances, such as lead, chromium, cadmium, and chlorinated solvents which are hazardous to human health. Analysis also indicates that PCBs contaminate 18 percent of used oils.

Automotive used oils tend to have a higher concentration of heavy metals, while industrial used oils tend to have a higher concentration of chlorinated solvents and PCBs.

No differences in the concentration of aromatic solvents or PAHs were found.

## TOXICITY: USED OILS (con.)

### NOTES

#### Heavy metals typically found in used oil include:

- Lead
  - Pre-1980 stock up 20,000 ppm
  - 1980s stock 100 1,200 ppm
- Barium 50 to 500 ppm (4,000 ppm)
- Cadmium 2 to 10 ppm
- Chromium 3 to 30 ppm
- Arsenic 5 to 25 ppm
- Zinc 100 to 1,220 ppm

#### Other contaminants include:

- Toluene and xylene 500 to 10,000 ppm
- Benzene 100 to 300 ppm
- Benzo(a)pyrene and benzo(a)anthracene 50 to 1,000 ppm
- Naphthalene 100 to 1,400 ppm

#### Chlorinated solvents commonly detected in used oil include:

- Dichlorodifluoromethane <1 to 2,200 ppm
- Trichlorotrifluoroethane <20 to 550,000 ppm
- 1,1,1-Trichloroethane <1 to 110,000 ppm
- Trichloroethylene <1 to 40,000 ppm
- Tetrachloroethylene <1 to 32,000 ppm

Table 2-3  
SUMMARY OF TOXICOLOGICAL EFFECTS

	Exposure Potential	Exposure Pathway	Target Organs	Symptoms:	
				Acute	Chronic
Motor Gasoline	54.5% of U.S. Petroleum Market	Ingestion Inhalation Absorption	Lungs, Intestinal organs, Kidneys	Low Exposure: drowsiness, vertigo, vomiting. High Exposure: Unconsciousness, hemorrhaging of lungs and intestines, death	Kidney Damage Probable human carcinogen
Middle Distillate Fuels	32.7% of U.S. Petroleum Market	Ingestion Inhalation Absorption	Central Nervous System, Mucous membranes, skin, eyes, liver kidneys	Headache, nausea, mental confusion, irritation of respiratory tract, skin and mucous membranes. Hemolytic anemia, cardiovascular disturbances	Neurological effects, broncho-pneumonia, toxic effect in cells, hemotopoitic system, lymphoid system, and testes. Probable human carcinogen
Residual Oil Fuels	11.7% of U.S. Petroleum Market	Ingestion Inhalation Absorption	Liver, Kidneys, intestines	Oral effects of No. 6 fuel oil in animals include lethargy, congestion of liver and kidneys, and intestinal irritation.	N/A
Constituents: Aromatic Benzene	4% of Gasoline (by weight)	Ingestion Inhalation Absorption	Central nervous system, skin, kidneys, bone marrow	Low Exposure: dermatitis, headache, light headedness. High Exposure: dizziness, nausea, vomiting, convulsions, respiratory paralysis, death	Benzene is a known human carcinogen. Anemia, leukemia, and decrease in blood packet count. Severe bone marrow damage resulting in deficiency of all cellular elements of the blood, increased susceptibility to infection and hemorrhagic conditions. Irreversible chromosome damage
1,2-Dibenzene	4-7% of Gasoline (by weight)	Ingestion Inhalation Absorption	Central nervous system, eyes, skin	Muscular fatigue, confusion, tingling skin, euphoria, headache, dizziness, lacrimation, dilated pupils, eye irritation, nausea, insomnia, nervousness, impaired reaction time	Dermatitis Higher reported incidence of menstrual disorders, low birthweight and fetal asphyxia. Incomplete fetal brain development due to placental transfer.

Table 2-3 (con.)  
SUMMARY OF TOXICOLOGICAL EFFECTS

Exposure Potential	Exposure Pathway	Target Organs	Symptoms:	
			Acute	Chronic
ylenes	6-8% of Gasoline (by weight) Ingestion Inhalation Absorption Placental transfer	Central nervous system, skin, liver, kidneys, gastrointestinal tract, eyes, nose, throat, mucous membranes, placenta	Narcotic effects on the central nervous system, CNS depression at high concentration Irritation of the skin, eyes, nose, throat, and mucous membranes Impaired reaction time, manual coordination, and body balance Nausea, vomiting, abdominal pain, loss of appetite Placental transfer has resulted in incomplete fetal brain development	Central nervous system excitation followed by depression, tremors, apprehension, irritability, impaired memory, incoordination, fatigue, dizziness, headache, anorexia, sleep disorders Variable effects on liver and kidneys, irritant effects on gastrointestinal tract, abdominal pain, nausea, digestive disorders Prolonged skin contact may cause formation of vesicles
thylbenzene	Ingestion Inhalation Absorption	Liver, kidney, skin, eyes, upper respiratory tract, lung tissue, and central nervous system	Irritates the skin, eyes, and upper respiratory tract Inhalation of small amounts causes extensive edema and hemorrhage of lung tissues Skin contact may yield inflammation Eye irritation and lacrimation are immediate and severe at 2000 ppm, accompanied by moderate nasal irritation -- tolerance develops after several minutes; CNS effects begin at roughly six minutes At 5000 ppm irritation to eyes, nose and throat is intolerable	Known to be toxic to liver and kidneys Depresses central nervous system Irritation and damage to lung tissue may exacerbate the systems of other obstructive airway diseases
rimethylbenzenes	NA Ingestion Inhalation Absorption	Central nervous system, lungs, blood	Nervousness, tension, anxiety, asthmatic bronchitis, hypochromic anemia, and impacts on blood coagulation	Unknown

Table 2-3 (con.)  
SUMMARY OF TOXICOLOGICAL EFFECTS

Exposure Potential	Exposure Pathway	Target Organs	Symptoms:	
			Acute	Chronic
11-13% of gasoline (by weight)	Ingestion Inhalation Absorption	Central nervous system, skin, eyes, mucous membranes, (kidneys?)	Initially dizziness, headaches, nausea Pre-narcotic symptoms occur at vapor concentrations of 1500 to 2500 ppm CNS depression yields a narcosis-like state at high concentrations Skin, eye, and mucous membrane irritation observed at fairly 880 ppm for 15 minutes	Nerve damage, initially as numbness in the extremities, increasing to loss of muscular stretching reflexes, eventual paralysis in varying degrees, with neutralized nerve conductivity and cranial nerve involvement in most severe cases Recovery begins 6-12 months after exposure ceases in mild/moderate cases; severe cases may require several years to recover
	Ingestion Inhalation Absorption	Central nervous system, lungs, respiratory system, skin	Direct aspiration into the lungs may cause rapid death due to cardiac arrest, respiratory paralysis, and asphyxia Narcotic potency similar to heptane	Although narcotic effects can be expected from octane exposure, the CNS effects observed with heptane are not found with octane Prolonged dermal exposure results in blistering and burning effects
NA	Ingestion Inhalation Absorption	Central nervous system skin, eyes	Exhilaration, dizziness, headache, nausea, confusion, inability to do fine work, persistent taste of gasoline, loss of consciousness in extreme cases Inhalation of up to 500 ppm appears to have no effect in humans, higher concentrations cause irritation to skin and eyes	Repeated or prolonged skin contact will dry and defat skin resulting in irritation and dermatitis



Table 2-3 (con.)  
SUMMARY OF TOXICOLOGICAL EFFECTS

Exposure Potential	Exposure Pathway	Target Organs	Symptoms:	
			Acute	Chronic
ADDITIVES - Tetraethyl & Tetramethyl Lead	Ingestion Inhalation Absorption	Central nervous system, peripheral nerves, liver, kidney, thymus, human reproductive system, and hematopoietic system	Weakness, fatigue, headache, aprior, tremors, nausea, vomiting, diarrhea, anorexia, weight loss, insomnia, irritability, delirium Peculiar sensation of hair in the mouth, feeling of insects on skin Progressive vegetative disturbances: hypotonia, hypothermia, and bradycardia Higher intoxication: confusion, delirium, manic excitement, and catatonia	Loss of consciousness and death may follow after several days Severe intoxication: recurrent or continuous episodes of disorientation and intensive hyperactivity, rapidly converting to convulsions, terminating in coma or death Death may occur from a combination of CNS depression, respiratory irritation, and bronchiolar obstruction TEL is likely to adversely affect human reproduction and embryonic development
Ethylene Dibromide & Ethylene Dichloride	Ingestion Inhalation Absorption	Central nervous system, liver, kidneys, lungs, eyes, mucous membranes, skin, human reproductive system	Inhalation exposure causes vomiting, diarrhea, abdominal pain, delayed lung damage and CNS depression Vapor is irritating to eyes and mucous membranes Liquid forms are highly irritating to skin resulting in marked erythema and vesiculation Ingestion has led to death Exposure may result in lung, liver, and kidney damage	EDB and EDC are highly toxic Both EDB and EDC are identified as carcinogens, although EDC has a much lower potency Exposure causes liver and kidney damage and often results in delayed pulmonary lesions Recent studies by NIOSH have shown adverse male reproductive effects
Tri-ortho-cresyl Phosphate (TOCP)	Ingestion Inhalation Absorption	Spinal cord, peripheral nervous system	Nausea, vomiting, diarrhea, and abdominal pain	Acute symptoms followed by a latent period of 3 to 30 days of muscle soreness, numbness of fingers, calf muscles, and toes progressing to foot and wrist drop Recovery may take months to years; 20-25% of cases never recover

---

## SAMPLING

---

## SAMPLING

---

### Objectives

Participants will be able to:

- list four types of sample collection possible at UST sites
- discuss hazards associated with each sampling technique
- describe precautions for each type of sampling

### NOTES

## TYPES OF SAMPLE COLLECTION

---

- Saturated/unsaturated surface or subsurface soil
- Ground or surface water
- Free product
- In-tank samples

**Degree of hazard depends on degree of contamination, age, and type of product**

### TYPES OF SAMPLE COLLECTION

### NOTES

All three types of sample collection—soil, water, and product—have some inherent potential hazards. This section addresses the hazards associated with sample collection and focuses primarily on situations where contamination is suspected. Professional judgment should be used when determining the appropriate protective clothing for the sampling you will conduct.

Samples may be taken from soil or water in the excavation area or even the tank itself. UST inspectors must plan for this activity and have not only the required sampling equipment (sample bottles and shipping containers, labels, and chain of custody forms), but also the required monitoring equipment and personal protective equipment available.

## SOIL SAMPLING

---

- Involves subsurface sampling in vicinity and down-gradient of USTs
- Generally obtained by hand augering, drilling, or excavating
- Potential hazards include chemical exposure and physical injury (drilling)

### SOIL SAMPLING

### NOTES

UST inspectors may routinely take soil samples via hand augering, any use of power drills or backhoes to collect samples will probably be confined to the contractors on-site.

While the chemical hazards of the three operations are basically the same, there is an increased hazard during drilling or excavation because of the larger amounts of subsurface materials brought up during these two procedures. During drilling or excavation operations, drilling personnel should conduct air monitoring using direct reading instruments including flame or photoionization detectors and CGI/O<sub>2</sub>/H<sub>2</sub>S meters. UST inspectors should stand upwind and at least 25 feet away from drilling or excavating operations and should use care when operating hand augers.

## SOIL SAMPLING: HAZARDS

---

Chemical exposure from vapors varies depending on soil type:

- wet, compact = vapors exposure
- dry, dusty = particulate exposure (PCBs, heavy metals)

Conduct continuous air monitoring and sample screening

### SOIL SAMPLING HAZARDS

### NOTES

Based on the nature of the soils, the sample may be wet or dry, compact, sandy, or dusty. Unless the sample is dry and dusty, the major health and safety concern is toxic exposure due to inhalation of volatile vapors and direct contact. Dry and dusty samples provide an additional potential hazard for inhalation of particulates that may include PCBs, dioxins, heavy metals, and other materials. To insure accurate readings, samples should be immediately screened with direct reading instruments, visually examined to determine gross contamination as indicated by staining, then collected and preserved.

## SOIL SAMPLING: HAZARDS (con.)

---

Physical hazards associated with drilling and excavating:

- moving parts and equipment
- hot engine parts
- falling equipment (pipe stacks)
- flying projectiles
- breaking air compressor hoses, chains or ropes
- electricity hazards (overhead and buried lines)

### NOTES

The **physical hazards** involved in soil sampling include moving parts in machinery; hot/burning engine parts; falling equipment, such as pipe stacks; flying metal; the breakage of air compressor hoses, ropes or chains; and electrical hazards from hanging or buried utility lines.

Safety guidelines for working around mechanical equipment and in excavations are described in the heavy equipment section presented earlier.

## SOIL SAMPLING: MINIMUM PPE

---

- Hard hat
- Eye protection
- Steel toe/shank boots
- Cotton or treated Chem-Resist coveralls
- Surgical latex gloves
- Nitrile overgloves
- Respiratory protective equipment, if air monitoring indicates

### SOIL SAMPLING: MINIMUM PPE

### NOTES

Personal protective equipment (PPE) should always be used when taking soil samples. Appropriate PPE includes steel toe and shank boots as well as appropriate garments. Also, surgical latex gloves should be worn with nitrile overgloves. Hard hats and eye protection are mandatory. Respiratory equipment should also be worn if atmosphere monitoring equipment indicates that it is needed. More detailed information on PPE can be found in Section 3 of this manual.

Uncoated **tyveks** provide almost no protection against materials with a low surface tension, like petroleum products. They become soaked almost immediately. They also melt and burn. Tyvek is not recommended for use with petroleum products. **Nomex** is fire-resistant, but also expensive and subject to contamination. The best option is simply to use cotton or treated Chem-Resist coveralls.



## WATER SAMPLING

---

Surface water sampling: Relatively hazard free, unless floating product exists

Ground-water sampling: Possible volatile organic exposure

- use respiratory protection when opening monitoring wells
- once open, check vapor levels with flame or photoionization detector and CGI/O<sub>2</sub> meter

### WATER SAMPLING

### NOTES

**Surface water sampling** is a relatively hazard-free operation unless petroleum product is found on the surface of the water. If this is the case, inhalation, direct contact, and fire/explosion hazards are possible. Appropriate caution, monitoring, and PPE are required.

**Ground-water samples** are usually taken through established monitoring wells, via bailers or pumps. With this activity, there is an increased likelihood of exposure to volatile compounds. For this reason, intrinsically safe pumps and respiratory equipment should be used when opening the wells. Once the well is open, check vapor levels with flame photoionization detectors and CGI/O<sub>2</sub> meters.

Experience at well sampling has shown two constants:

- Volatile and semi-volatile fractions of organic contaminants tend to accumulate in the well stems.
- These organics tend to escape the well stem as a vapor once the cap is removed, and subsequently decrease in concentration rapidly over time, usually reaching background concentrations within 30 minutes. In highly contaminated areas, the concentration may not decrease.

Based on the above, the following procedures for initial well opening should be used where the potential for ground water and/or subsurface soil contamination exists:

## WATER SAMPLING (con.)

### NOTES

1. Proceed with initial well opening in Level C respiratory protection. Standing upwind when opening a well with respirator equipment on hand is an effective approach as well. Do not hang your head over the well until it has vented, and has been checked with an organic vapor detector.

Level C respiratory protection is not usually necessary because in reality a ground-water well that generates significant vapors in the breathing cone is unusual.

2. Wells should be screened with a flame or photoionization detector and CGL/O<sub>2</sub> meter. (Note that activities that disturb the water column may liberate volatiles not otherwise observable and as such, it may be desirable to "bounce" a bailer a few times).
3. If initial readings are of such magnitude to indicate a potential health hazard from a brief exposure period to monitoring personnel or to the adjacent community from the venting process, the wells should be immediately recapped and locked.
4. If positive results are obtained (but to a lesser extent than that described above), the well should be allowed to vent passively for approximately 15 to 30 minutes and monitored again.
5. If negative (that is, background) results are obtained, sampling activities can be initiated in Level D respiratory protection.
6. If positive results have not diminished in the allotted time frame, sampling should be conducted in a minimum of Level C protection.
7. Because the volatiles that are anticipated to be present at UST sites are restricted to petroleum fractions, action levels based on petroleum should be used.

### **FREE PRODUCT AND IN-TANK SAMPLING**

---

- High potential for both chemical exposure and fire hazards
- Delegated to contractor with specialized training and experience, if possible
- Respiratory protection is recommended
- Avoid in-tank sampling unless no alternative
- Level B protection recommended for in-tank sampling

### **FREE PRODUCT AND IN-TANK SAMPLING**

### **NOTES**

Of all the sampling that may be conducted by an UST inspector, product sampling is the most hazardous and should be delegated to personnel specifically trained for the operation. It may be possible to forgo tank or free product sampling if the owner/operator is able to furnish full information on the contents of the tank.

Pure product presents both toxic contamination and fire hazards. Sampling of spilled or leaked source materials, that is, pure petroleum and petroleum products, presents similar hazards to contaminated media sampling except that both toxic and fire/explosive hazards are significantly increased due to the presence of pure, undiluted product. Extreme caution and the use of respiratory equipment is recommended.

Samples may be taken by surface sampling (ponding in depressions, floating on surface water, and so on), subsurface sampling (accumulations in excavations and ground water), and in-tank sampling. Although not as dangerous as sampling from inside a tank, continuous monitoring and Level C protection is recommended during free product sampling activities.

Think smart. It is not necessary to wade and wallow in contaminated soils or water to get a sample. Use remote sampling probes (otherwise known as "sticks") to obtain samples.

## SOURCE SAMPLING: LEAKS (con.)

### NOTES

Sampling operations involving extraction of product or sludge samples of unknown composition and concentrations from an UST presents toxic exposure hazards (including inhalation and direct contact) as well as those of fire/explosivity. To the extent feasible, UST inspectors should not be performing this type of sampling. Should no other alternative exist, UST inspectors must use the maximum level of protection as assurance against exposure to unknown hazards. Level B protection is therefore recommended for this type of operation.

There are very few good reasons for an UST inspector to enter a tank.

Sticks and poles are not affected by oxygen deficiency and toxic atmospheres, and they are expendable. Use them whenever possible.

---

**SECTION 3**  
**HAZARD RECOGNITION, EVALUATION,**  
**AND CONTROL**  
**HEALTH AND SAFETY HAZARDS**

---

## ELEMENTS IN RECOGNITION, EVALUATION, AND CONTROL

---

- Planning
- Protective equipment
- Monitoring instruments
- Permissible exposure levels

## NOTES

---

**SITE HEALTH AND SAFETY PLANS**

---

## SITE HEALTH AND SAFETY PLANS

---

### Objectives

Participants will be able to:

- describe safety plan purpose
- describe major safety plan elements
- distinguish between risk and hazard

### NOTES



## SAFETY PLAN PREPARATION

---

**Planning** is the most critical element of UST investigations.

- Anticipate and prevent hazards to minimize risk to workers and the public.
- Key to successful site safety = a **site health and safety plan**.

### SAFETY PLAN PREPARATION

### NOTES

UST investigations require that all operations be planned ahead of time in order to keep problems to a minimum. Anticipating and preventing potential accidents is the best way to protect workers and the public from injury.

The major aspect of planning for any hazardous field activity is the development and implementation of a comprehensive safety plan that considers each specific phase of an operation. This plan identifies all potential hazards, and specifies methods to control these hazards; prescribes work practice, engineering controls and PPE; and defines areas of responsibility.

The plan describes the organizational structure for site operations (most appropriate for use at state-lead cleanup sites) and plans for coordination with existing response organizations including the local fire marshal, police, ambulance, and emergency care facility.

The plan should be prepared by an individual knowledgeable in health and safety and at a minimum, reviewed and approved by personnel knowledgeable in industrial hygiene and health and safety.

### **SAFETY PLAN PURPOSE**

---

- Assures systematic attention to health and safety issues
- Specifies procedures to protect on-site personnel, general public, and environment
- Eliminates memory uncertainties; provides checklist for on-site activity

### **SAFETY PLAN PURPOSE**

### **NOTES**

The purpose of a safety plan is to provide guidelines and procedures required to assure the health and safety of those personnel working at sites. While it may be impossible to eliminate all risks associated with site work, the goal is to provide state-of-the-art precautionary and responsive measures aimed at assuring the use of proper occupational health and safety procedures for the protection of on-site personnel, the general public, and the environment.

A written safety plan basically outlines the steps workers should follow when on-site, and eliminates the uncertainties of memory by providing a checklist for inspectors to use when preparing to go on site. Sample checklists are provided in the appendix.

## **SAFETY PLAN CONTENTS**

---

- Expected field activities
- Potential hazards and control guidelines
- Work practices and engineering controls
- Monitoring and protective equipment required
- Personnel roles and responsibilities
- Emergency procedures and contacts

### **SAFETY PLAN CONTENTS**

### **NOTES**

The safety plan is intended to:

- Provide a systematic consideration of health and safety issues in the preparation and execution of site work and enhance the ability of team members to use their best professional judgement in reducing hazards.
- Describe potential hazards and specify applicable guidelines, standards, and regulations, and appropriate emergency responses to such hazards.
- Prescribe work practices, engineering controls, and personal protection to protect team members.
- Prescribe monitoring equipment to detect and measure potential exposures to hazardous substances.
- Prescribe guidance for changing work practices and personal protection levels in response to changing site conditions.
- Provide a list of emergency contacts.

A sample safety plan is provided in the appendix for your information.

## SAFETY PLAN HAZARD ASSESSMENT

---

Most difficult and critical plan element

Should be conducted by knowledgeable individual

Should consider:

- chemical and physical hazards
- environmental conditions
- interplay between work activities and hazards

### SAFETY PLAN HAZARD ASSESSMENT

### NOTES

The most difficult and critical aspect of the safety plan is assessing all possible potential hazards that may arise. If possible, the plan should identify all of the potential hazards and describe methods to control them.

**Safety** is defined as the practical certainty that harm will not occur. A safety plan based on reliable information will reduce the measure of risk by preventing, or at least, minimizing human exposure to hazards. Note that exposure consists of human contact with a hazard. A **hazard** is defined as any substance, situation, or condition that is capable of doing harm to human health, property and/or the environment. Note that this definition does not say that the hazards will do harm, but merely that it has the capability to do so.

The activities required to accurately assess risks and determine their acceptability can be divided into three interacting elements:

- Recognition: Identifying the substances, situations or conditions that may be hazardous and the characteristics that determine the degree of hazard.
- Evaluation: Comparing the potential impact of the risk to acceptable levels of impact or risk.

## **SAFETY PLAN HAZARD ASSESSMENT (con.)**

### **SAFETY PLAN HAZARD ASSESSMENT**

### **NOTES**

- Control: Instituting methods to eliminate or reduce the impact of the potential hazards.

The **risk** associated with a potential hazard is defined as the probability of harm to human health, property or the environment. Inspectors need to plan for effective control of both physical and health hazards often encountered at UST facilities. Inspectors are strongly encouraged to use site-specific checklists to ensure control of potential hazards.

While on-site, hazardous conditions may be in a continuous state of flux (particularly vapor-related hazards). As new monitoring results become available, inspectors should evaluate the relative risk on-site and if necessary, make adjustments in work practices or PPE.

## **HANDLING EMERGENCIES**

---

- Identify/confirm off-site emergency services and capabilities.
- Define rapid evacuation procedures for workers (audible warning signals, etc.).
- Prepare list of emergency equipment available on-site.

### **HANDLING EMERGENCIES**

### **NOTES**

The site specific checklists in the safety plan should identify all nearby emergency services, including fire and rescue services, hospitals, ambulances, medivacs, police departments, public health departments, explosives experts, and hazardous materials response teams.

The checklists should also include a list of emergency equipment available on-site. At a minimum, the checklists should include the following:

- A list of emergency service organizations that may be needed. Arrangements for using emergency organizations should be made prior to the initiation of site activities. Evaluate their capability to handle the sort of emergencies that might occur.
- A list of emergency equipment. This list should include emergency equipment available on site, as well as transportation, fire fighting and equipment to mitigate emergencies, for example, booms and sorbents.
- A list of utility company contacts, such as power, electrical, gas, and telephone.

---

## RESPIRATORY PROTECTION

---

## RESPIRATORY PROTECTION

---

### Objectives

Participants will be able to:

- identify two main categories of respirators
- describe types of air purifying respirators and when to use them
- describe types of air supplying respirators and when to use them
- list three important physiological and psychological problems limiting respirator use

### NOTES



## RESPIRATORS

---

**This discussion should not be considered as training in the use of respiratory equipment.**

Two major categories of respirators:

- Air purifying respirators (APRs)
- Air supplying respirators (ASRs)

### RESPIRATORS

### NOTES

In some cases, a module that provides hands-on respirator training and a fitness test is added to this course. Without completion of that module, this course does not provide adequate training in the use of respiratory equipment. The effectiveness of a respirator depends on its use. The American National Standard Institute's (ANSI) Practices for Respiratory Protection (Z88.2-1980) is highly recommended as a guide to respiratory protection. Respiratory protection is regulated by 29 CFR 1910.134 and 29 CFR 1910.1000.

Inhalation is the fastest and most common way for chemicals to enter the body. Gas and vapor inhalation hazards are found in tanks, confined spaces, wet wells, poorly ventilated areas, and in outdoor areas where chemicals have been spilled or improperly used. Respirators protect the user from breathing contaminated air. The two major categories of respirators are:

- **Air purifying respirators (APRs):** clean the air by removing contaminants as they cross a purifying element. They do not add oxygen to the air.
- **Air supplying respirators (ASRs):** provide a contained source of clean air at normal oxygen concentrations (21 percent). ASRs should be used when oxygen concentration are below 19.5 percent.

## RESPIRATORS (con.)

### NOTES

It is imperative to select the appropriate respiratory device for the anticipated hazards in order to provide adequate protection. Prior to each day's usage, workers should visually inspect their respirators for damage and for fit and function.

UST inspectors must have a respirator fit-test and additional, hands-on training in the use and maintenance of respirators before attempting to use one.

## AIR PURIFYING RESPIRATORS (APRs)

- OSHA requires specific training and FIT testing.
- Beards interfere with proper fit, are therefore not allowed.
- Cartridges have finite life span.
- Breakthrough occurs when sorbents are saturated.
- APRs are used only against chemicals smelled or felt well below hazardous levels.

### AIR PURIFYING RESPIRATORS (APRs)

### NOTES

There are several different categories of air purifying respirators: disposable; quarter mask; half mask; full face; and powered air. Half-mask respirators would most likely provide adequate respiratory protection, but full-face respirators provide eye protection in addition.

The "purifying element" in the APRs is either a particulate-removing filter, or a gas- and vapor-removing cartridges and canisters. Gas- or vapor-removing cartridges are selected based the desired protection against a specific type of contaminant. OSHA requires that these cartridges be color-coded, for example, organic vapors—black cartridge; acid gas—white; ammonia gas—green.

It is important to understand the correct terminology for air contaminants when selecting respirator cartridges. Vapors are generated by evaporation from liquids, and behave exactly like gases. These contaminants are removed by sorbent cartridges.

Dusts, mists, fogs, and fumes are all solid or liquid particles. They are removed by filter cartridges.

## AIR PURIFYING RESPIRATORS (APRs) (con.)

### NOTES

Multi-purpose cartridges are readily available from all major respirator manufacturers. These cartridges will remove most vapors and particulates from the air. However, all cartridges have limitations, which are printed on the cartridge. You should be familiar with your cartridge limitations.

Breakthrough occurs when chemical sorbents are saturated. Cartridges should be replaced at the first sign of breakthrough, for example. Clues can include smell and skin irritation.

As air purifying respirators do not supply oxygen and may not filter out all contaminants, inspectors entering a confined space must be aware that oxygen deficient atmospheres or IDLH atmospheres are possible in routine work situations and be prepared to use an air supplying respirator.

## USE OF AIR PURIFYING RESPIRATORS

---

- Oxygen content of at least 19.5 percent
- Contaminant identity and concentration are known
- Contaminant concentration below IDLH
- Contaminants have adequate warning properties, such as taste or odor
- Respirator and cartridge are approved against contaminant
- Specific APR type has been fit-tested on user

### USE OF AIR PURIFYING RESPIRATORS

### NOTES

APR cartridges have finite life spans based on the saturation of the absorbent materials. The length of time a cartridge will effectively absorb the contaminants is known as its service life. The cartridge's service life is dependent on respiratory rate, contaminant concentration, cartridge efficiency, and humidity.

As a rule-of-thumb, respirator cartridges should be changed at a minimum of once a day. Cartridges that are filter-only type may be used until air flow begins to be impaired. They do not necessarily have to be changed every day, or even every week. Of course, they do not provide protection from gasoline or other vapors.

APRs should only be used when conditions exist as specified on the above and subsequent page, and there is periodic monitoring of the work area to verify that no significant changes have occurred.

All respirators have a numeric **Protection Factor** associated with them that indicates the concentration of contaminant they will protect against. For example, if a respirator has a protection factor of five, it may be used in atmospheres having concentrations of up to five times the occupational exposure standard.

## USE OF AIR PURIFYING RESPIRATORS (con.)

### NOTES

Current NIOSH Protection Factors:

- Half-face APR 10
- Full-face APR 50
- PAPR 50
- SCBA (positive pressure)  
10,000+

Individuals differ. Anyone using an air purifying respirator should undergo a **respirator fit test** before using a respirator. This helps the user to find a respirator that fits tightly and comfortably, and works well for him.

The user first fits the APR snugly and performs a positive-pressure test and a negative-pressure test to insure proper seal. During the test, various respirators are then worn in different atmospheres, to determine their effectiveness.

Fit-testing may be conducted using a variety of agents, including isoamyl acetate, saccharine solutions, or stannic chloride (smoke tubes).

If a proper seal is achieved, and the user does not smell any of substances while using the respirator, the user then undergoes a challenge atmosphere test. The wearer is placed in a vapor or smoke-filled area, and the substance is allowed to drift all around the mask, while the wearer talks, breaths, looks all around, jogs in place, and performs other movements to simulate actual work motions. If the fit is good, the mask wearer should not be able to detect the challenge atmosphere.

Ventilation smoke is preferable to the other chemicals, because it is very irritating to the eyes, nose and throat. Mask wearers are not likely to give false information regarding mask fit.

You must be tested with the same size and brand of respirator you intend to wear.

## AIR SUPPLYING RESPIRATORS (ASR)

---

ASRs should **never** be used without "hands on" training in inspection, use and limitations.

Where ASR is needed, inspectors should immediately leave the area, including if:

- oxygen levels are less than 19.5 percent
- high petroleum vapor concentration exists
- potentially high chemical vapor concentrations exist

### AIR SUPPLYING RESPIRATORS (ASRs)

### NOTES

Air supplying respirators are used when APRs cannot provide sufficient protection. Air supplying respirators are appropriate where action levels are exceeded, when confined space entries are necessary, during tank sampling, and in other situations when APRs do not provide sufficient protection. However, UST inspectors are expected to perform mainly an oversight role, and air supplying respirators should not be needed in most routine work situations.

Air supplying respirators should not be used under any circumstances unless the user has been sufficiently trained in their use and limitations.

There are four major categories of air supplying respirators:

- Oxygen generating respirators
- Hose mask respirators
- Airline respirators
- Self-contained breathing apparatus (SCBA)

The following criteria should be used for selecting SCBA's: the type and atmospheric concentration of toxic substances have been identified and require a high level of respiratory protection based on established action levels, or the type and concentrations of airborne hazards are unknown; the atmosphere

## AIR SUPPLYING RESPIRATORS (ASR) (con.)

### NOTES

contains less than 19.5 percent oxygen; and work is initiated in a confined space.

Another type of self-contained respirator is the Emergency Escape Breathing Apparatus (EEBA). The device provides air for escape from hazardous situations. An EEBA should never be used to enter a hazardous atmosphere; it is designed to be easily donned over the head and to provide breathing air for 5 to 15 minutes. Under no circumstances should an EEBA be used for general respiratory purposes.



## PHYSIOLOGICAL AND PSYCHOLOGICAL LIMITATIONS FOR RESPIRATOR WEARERS

---

- Emphysema
- Chronic obstructive pulmonary disease
- Bronchial asthma
- X-ray evidence of pneumoconiosis
- Epilepsy
- Evidence of reduced pulmonary function
- Anemia

### PHYSIOLOGICAL AND PSYCHOLOGICAL LIMITATIONS

### NOTES

A number of physiological and psychological conditions may limit the use of respirators. Several are particularly troublesome:

- Pulmonary problems
- Cardiovascular disease
- Diabetes

Persons should not be assigned to tasks requiring use of respirators unless they are physically able to perform the work and use the equipment. A local physician should determine what health and physical conditions are pertinent.

**PHYSIOLOGICAL AND PSYCHOLOGICAL LIMITATIONS  
FOR RESPIRATOR WEARERS (con.)**

---

- Coronary artery disease or cerebral blood vessel disease
- Severe or progressive hypertension
- Diabetes
- Punctured eardrum
- Breathing difficulty when wearing respirator
- Claustrophobia/anxiety when wearing respirator

**NOTES**

---

**PERSONAL PROTECTIVE EQUIPMENT  
(PPE)**

---

## PERSONAL PROTECTIVE EQUIPMENT (PPE)

---

### Objectives

Participants will be able to:

- describe main elements of head, eye/face, hand, and foot protection
- list 5 limitations of PPE
- describe the basic components of Level A-D protection and when each level is appropriate
- describe decontamination procedures

NOTES

## PERSONAL PROTECTIVE EQUIPMENT (PPE) (con.)

---

Protects inspectors from:

- toxic vapors
- corrosive substances
- fire and electrical hazards
- other physical hazards

Predominant chemical and physical hazards dictate type and degree of protection

Select PPE based on known or anticipated hazards or job functions

### PERSONAL PROTECTIVE EQUIPMENT

### NOTES

Protective clothing includes all outer garments worn for the purpose of protecting the head, eyes, ears, torso, feet, and respiratory system from the harmful effects of chemical substances and physical hazards.

The appropriate clothing will vary depending on the predominant types of chemical substance hazards to which an UST inspector may be exposed at a particular site. For example, clothing appropriate for protection against a corrosive compound is different from that which protects against toxic vapors. The level of protection assigned must match the hazard confronted. Final selection should be based on a full evaluation of the potential hazards expected during site operations.

## SOURCES FOR SITE HAZARD DATA

- Federal, state and local agencies
- Facility owner or operator
- Previous inspection records

### SOURCES FOR SITE HAZARD DATA

### NOTES

Before going onto any site, it is extremely important that an UST inspector make a full evaluation of the hazards that may be encountered. The selection of Personal Protective Equipment (PPE) is based on the best available data. As additional data become available, or as site conditions or job functions change, it may be necessary to change the level of protection. For example, if an inspector discovers unexpected problems or higher levels of contamination than expected, higher levels of protection may be needed. Or, conversely, protection may be downgraded if conditions permit.

The most important factor in selecting PPE is the type of chemicals that may be present at a site. For UST inspectors, exposure to petroleum products will be the primary concern. Inspectors should consider the levels of contaminants that may be present in the air, liquids, soils, or at the source and the degree to which they will come in contact with them.

Sometimes contamination data can be obtained from federal, state, and local sources, or the facility owner, operator, or manager. It is also important to check previous inspection records, if available.

When the type of chemicals, the concentrations, and possibility for contact are not known, the appropriate level of protection must be selected based on professional experience and judgment until the hazards can be better identified. PPE reduces the potential for contact with toxic substances, but it must be combined with safe work practices and decontamination, if necessary, for an integrated approach to health and safety.

## TYPES OF PROTECTIVE EQUIPMENT

- Hard hats
- Face shields and safety glasses
- Foot protection
- Hand protection
- Protective clothing
- Respiratory protection
- Hearing protection

### TYPES OF PROTECTIVE EQUIPMENT

### NOTES

Some PPE is regulated by the Occupational Safety and Health Administration (OSHA). standards for PPE have been developed by American National Standards Institute (ANSI). These are summarized below.

- **Hard Hats:** Regulated by 29 CFR 1910.135; specified in ANSI Z89.1, Safety Requirements for Industrial Head Protection (1969).
- **Face Shields, Safety Glasses:** Regulated by 29 CFR 1910.133(a); specified in ANSI Z87.1, Eye and Face Protection (1968). (UST inspectors should emphasize splash protection when selecting eye/face protection.)
- **Foot Protection:** Regulated by 29 CFR 1910.136; specified in ANSI Z41.1, Safety Toe Footwear (1967, as revised in 1972). (Class 75 is recommended.)
- **Respiratory Protection:** Regulated by 29 CFR 1910.134 and 29 CFR 1910.1000; specified in ANSI Z88.2, Standards for Respiratory Protection (1976). (Air purify respirator cartridges should be selected based on good protection from organic chemicals.)
- **Protective Clothing:** Not specifically regulated.

## PROTECTIVE CLOTHING LIMITATIONS

---

- Decreases dexterity and mobility
- Narrows field of vision
- Diminishes communication ability
- Increases heat stress
- Reduces reaction time

### PROTECTIVE CLOTHING LIMITATIONS

### NOTES

Protective clothing can limit the wearer in several ways. Higher levels of protection limit mobility, vision, hearing, and communication with others. Be aware of the particular limitations of your clothing ahead of time; if possible, practice wearing clothing before going on site.

Also be aware of the limits of your protective garments. There is no "universal" protective material; all will decompose, be permeated or otherwise fail to protect under given circumstances. Most protective garment manufacturers provide guidelines on their products' degradation rates. Consult these guidelines whenever possible. Be sure to note which chemical substances will permeate the protective garment you are using.

Table 3-1 delineates the type of protective material that should be used when working with various petroleum compounds.



**TABLE 3-1**  
**CHEMICAL RESISTANCES OF SOME PROTECTIVE MATERIALS**

Chemical	Butyl rubber (IIR)	Natural rubber (NR)	Neoprene (CR)	Nitrile rubber (NBR)	Polyethylene (PE)	Polyvinyl alc. (aVAL)	Polyvinyl chlor. (PVC)	Teflon (PTFE)	Viton (FPM)	Saranax (PVDC/PE)	PE/Ethylene vin. alc. (PE/EVAL)
cyclohexane	X	X	X	>8	X	*	X	O	>8	N/R	O
cyclopentane	X	X	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
diesel fuel	X	X	N/R	>8	N/R	N/R	N/R	N/R	N/R	N/R	N/R
heptane	X	X	X	>8	N/R	N/R	X	N/R	>8	N/A	N/R
n-Hexane	X	X	X	>8	X	>8	X	>8	>8	X	N/R
octane	X	X	?	>8	N/R	N/R	X	N/R	O	N/R	N/R
jet fuel 3% aromatics	X	X	N/R	O	N/R	N/R	X	N/R	O	*	N/R
kerosene	X	X	X	>8	N/R	>8	N/R	N/R	N/R	N/R	N/R
naphtha 3% aromatics	X	X	?	>8	X	N/R	X	N/R	N/R	O	N/R
naphtha 5-20% aromatics	X	X	?	>8	X	O	N/R	N/R	O	O	O
naphtha VMP 30% aromatics	X	X	X	O	N/R	O	X	N/R	O	N/R	N/R
octane	X	X	?	O	N/R	N/R	X	N/R	O	N/R	N/R
pentane	X	X	X	O	X	O	X	N/R	>8	N/R	N/R
petroleum ethers (10-110°C)	X	X	X	O	N/R	N/R	N/R	O	N/R	N/R	O
benzene	X	X	X	X	X	>8	X	O	*	X	O
ethyl benzene	X	X	X	X	N/R	X	X	N/R	>8	N/R	N/R
gasoline (5-55% aromatics)	X	X	X	>8	N/R	N/R	X	>8	>8	N/R	O
gasoline (unleaded)	X	X	X	O	N/R	O	X	N/R	N/R	N/R	N/R
toluene	X	X	X	X	X	>8	X	>8	>8	X	O
xylene	X	X	X	X	X	>8	X	N/R	>8	N/R	O
naphthalene	X	X	X	N/R	N/R	N/R	X	>8	N/R	N/R	N/R
3-Butadiene	>8	X	X	N/R	N/R	N/R	X	N/R	>8	N/R	N/R

EY

X = not recommended >1 h and/or degradation  
 >8 = recommended >8h  
 O = recommended >4h

? = questionable 1-4h  
 N/R = no recommendation  
 \* = <10 mg/m<sup>2</sup> per minute

*Chemical resistances of some protective materials (from Forsberg and Mansdorf, p. 44 and 45, 1989).*

## HEAD PROTECTION

---

Recommended: hard hat at all times

- provides protection from impact, splashes
- protects against flying particles, electric shock

ANSI hard hats classification:

- CLASS A: Limited voltage resistance for general service
- CLASS B: High voltage resistance
- CLASS C: No voltage protection
- CLASS D: Limited protection for fire-fighting

### HEAD PROTECTION

### NOTES

UST inspectors should always wear a hard hat when on-site to protect from falling/flying objects, liquid splashes, and electric shock. If possible, this hard hat should be "Class B," which protects against accidental contact with high-voltage lines.

Depending on noise levels at a site, hearing protection may also be used. Exposure to loud noises can cause temporary or permanent loss of hearing. Some manufacturers have adapted hard hats so that ear protection, faceshields, liners for cold weather, and chin straps may be easily attached.

There is little difference in the protection provided by properly fitted ear muff and ear plugs. Personal preference is the deciding factor.

Ear protection should provide at least 20 dB of noise reduction.

## EYE AND FACE PROTECTION

---

Recommended: cushion-fitted goggles and face shields (directly attached to hard hats)

Wear when potential for splashing exists.

Do not wear contact lenses at an UST site:

- hard lenses may aggravate chemical splash injuries
- soft lenses may absorb vapors
- with both types of lenses, certain chemicals can "fuse" lenses to eye

### EYE AND FACE PROTECTION

### NOTES

Eye and face protection should be worn during all UST operations where potential for splashing exists. Eye protection is available in several styles.

- **Spectacles** with impact-resistant lenses resemble conventional eyeglasses. Clip-on side shields are available for side protection. These do not provide protection against fumes.
- **Flexible or cushion-fitted goggles** protect against dust, fumes, liquids, splashes, mists, and sprays.
- **Eyecup goggles** provide the same protection as flexible or cushion-fitted goggles. Cushion-fitted goggles tend to be more comfortable than other goggles and provide protection over a larger area of the face.
- **Face shields** are designed to protect the face from flying particles and sprays of liquids and to provide antiglare protection, when needed. Face shields are not acceptable for protection against heavy flying objects, for welding and cutting, or for shielding against intense radiant energy.

## EYE AND FACE PROTECTION (con.)

### NOTES

OSHA prohibits wearing contact lenses under any respiratory equipment. However, even if UST inspectors are not wearing respirators, it is strongly recommended that contact lenses not be worn on-site. Certain chemicals can fuse hard or soft lenses to the eye, and soft lenses may absorb chemical vapors.

## FOOT PROTECTION

---

Recommended: Class 75 steel toe/shank safety shoe

- 6 percent of recordable work injuries are foot injuries
- Incidents most likely to occur from heavy objects falling and/or rolling over feet
- Where chemical hazards exist, use a Neoprene, PVC, or other chemical-resistant boot

### FOOT PROTECTION

### NOTES

Approximately 6 percent of all recordable work injuries are foot injuries—about 130,000 per year. Therefore, foot protection is a very important safety precaution.

ANSI classifies shoes into three groups according to their ability to withstand various degrees of force.

- Class 75 shoes: Withstand the impact of 75 foot-pounds and compressions of 2,500 pounds.
- Class 50 shoes: Withstand the impact of 50 foot-pounds and compressions of 1,750 pounds.
- Class 30 shoes: Withstand the impact of 30 foot-pounds and compressions of 1,000 pounds.

There is a big difference between **impact** and **compression stress**.

Steel-shank boots can be pierced by nails. The steel shank is only a narrow piece of metal in the heel area of the boot. Some soles are also degraded and leather may be ruined by petroleum products. For messy sites, steel-toe and shank neoprene boots should be used.

Shoes may have other "customized" features such as conductive soles to drain off static charges, reinforced soles to protect from nails and sharp objects, and wood soles for work in hot or wet areas. UST inspectors expected to work in cold weather should purchase footwear with high insulation ratings.

## FOOT PROTECTION (con.)

### NOTES

A good practice is to tape sleeves and pant legs over (not inside) boots to prevent liquids from draining into them. Safety shoes only protect the toe area of the foot. For protection further up the foot, additional footguards may be used.

## HAND PROTECTION

---

Recommended: neoprene, nitrile and/or viton gloves

- Use gloves resistant to chemicals, punctures, and tears.
- Thicker and longer gloves = better protection.
- Wear two pairs of gloves for maximal protection.
- Tape jacket/coverall cuffs over (not inside) glove.

### HAND PROTECTION

### NOTES

Gloves worn on-site should be strong enough to resist puncturing and tearing, and should provide the necessary chemical resistance.

Penetration of glove materials is time-dependant. For a quick soil sample, almost any glove will do; for longer, more intense work, the less permeable gloves should be used, such as nitrile gloves.

The thicker and longer the glove, the greater the protection. However, the material should not be so thick that it interferes with dexterity. For greater protection, wear two pairs of gloves; for instance, heavy leather work gloves over nitrile gloves. If leather gloves become contaminated while on-site they should be discarded because leather is difficult to decontaminate.

Viton gloves, at about \$50 per pair, are too expensive to be used frequently.

There are also lightweight laminate gloves available which provide excellent protection from a broad variety of compounds.

Taping jacket cuffs over glove cuffs will prevent liquids from spilling into gloves.

## BODY PROTECTION

- Cloth (cotton or nomex) suits generally adequate
- As hazard level increases, protective material should increase
- Heat stress: a major problem when wearing protective clothing

### BODY PROTECTION

### NOTES

Several materials are available for protective clothing

- **Cellulose or paper**
- **Nomex:** A non-flammable and fire-retardant fiber used to make coveralls.
- **Tyvek:** The melting/fire hazard of uncoated tyvek, coupled with the fact that it does not block petroleum products, should preclude its selection for these applications.

As hazard level increases, protective material should increase. For example in particularly hazardous conditions, the UST inspectors should wear a suit constructed of neoprene, saran, coated tyvek or PVC rather than the standard tyvek or nomex suits.

A major problem with wearing protective clothing is that the body is shielded from the normal circulation of air. Perspiration does not evaporate, making the person susceptible to heat stress and, in some cases, heat stroke. These heat-related problems are very common when temperatures rise above 75°F.

Typical field apparel should be worn under protective clothing, including long pants. Long-sleeved shirts are highly recommended.



## LEVELS OF PROTECTION

---

Four basic levels of protection

Level D:

- used when no respiratory or skin hazards exist
- generally not used for sampling, or when chemical hazards exist
- usually sufficient if not performing hands-on activities

Level C:

- air purifying respirators used
- higher levels of skin protection may also be added

Level B:

- used when highest degree of respiratory protection, but lesser degree of skin protection needed

Level A:

- used when highest level of respiratory, skin, and eye protection is required

### LEVELS OF PROTECTION

### NOTES

There are four categories of personal protective equipment, based upon the degree of protection afforded. The level chosen should depend on the level of respiratory and chemical hazards expected to be encountered on the site.

- **Level D Protection:** Should be worn only as a work uniform and not during sampling or other intrusive activities, nor when the potential for chemical contamination exists.
- **Level C Protection:** Should be worn when criteria for air purifying respirators are met, and when additional skin protection is needed.

## LEVELS OF PROTECTION

### LEVEL A AND B PROTECTION

### NOTES

- **Level B Protection:** Should be worn when highest level of respiratory protection is required, but a lesser degree of skin protection is needed.
- **Level A Protection:** Should be worn when highest level of respiratory, skin, and eye protection is required.

## LEVEL D PROTECTION

---

- One piece coverall, preferable cotton
- Steel toe/shank leather or neoprene boots
- Hard hat with face shield attachment
- Safety glasses or chemical splash goggles
- Work gloves

### LEVEL D PROTECTION

### NOTES

It should be understood that Level D protection is primarily a work uniform. It should be worn in areas where there is no possibility of contact with contamination, and when work functions preclude splashes, immersion, or potential for unexpected inhalation of any chemicals. Containment levels should be within established exposure limits, and oxygen levels should be between 19 and 25 percent.

UST inspectors should have respirators available for emergencies while wearing level D protection.

- Air purifying respirator
- Emergency escape breathing apparatus (Escape Pack or EEBA)

## LEVEL D PROTECTION

---

When using Level D, UST inspectors should:

- avoid hands-on sampling or intrusive activities
- function in oversight or supervisory role only

### LEVEL D PROTECTION

### NOTES

In Level D protection, UST inspectors should not undertake any work activity with the potential for exposure, either by direct contact or inhalation. As much as possible, inspectors should stand upwind of site activities and a minimum of 25 feet away. When wearing Level D protection, proceed cautiously to get a closer look at site activities.

### LEVEL C PROTECTION

---

Level D protection, plus:

- additional skin protection, such as saranx coveralls, latex/neoprene gloves
- air purifying respirator

### LEVEL C PROTECTION

### NOTES

When using Level C protection, job functions should not require air supplying respirator.

## LEVEL B PROTECTION

---

Level D protection, plus:

- supplied air respiratory equipment
- chemical resistant coveralls, such as saranax, PVC

## LEVEL B PROTECTION

## NOTES

Level B protection includes supplied air, via a self contained breathing apparatus (SCBA).

## LEVEL A PROTECTION

---

Level D protection, plus

- supplied air respiratory equipment
- fully encapsulating chemical-resistant suit

### LEVEL A PROTECTION

### NOTES

Level A protection not only provides an air supply, but full skin protection as well. It does, however, severely limit mobility, vision and communication.

The air supply system has a bell inside to alert others when you are short on air, because it is not possible to get out of the suit without help.

These levels of protection are guidelines only, and may be modified as necessary. For example, it may be appropriate to wear gloves without protective coveralls, or occasionally to wear respirators without other protective clothing.

## PROTECTION AGAINST BIOLOGICAL HAZARDS

---

- Snakebites: heavy work boots, chaps, and gloves
- Fire ants: heavy work boots (tape pant cuffs)
- Insects: coveralls, gloves
- Swarming insects: face netting

### PROTECTION AGAINST BIOLOGICAL HAZARDS

### NOTES

In addition to the chemical injury and physical worksite hazards, inspectors should be alert for common biological hazards, such as snakes or insects.



## DECONTAMINATION PROCEDURES

---

- Drop contaminated tools and equipment into plastic containers
- Remove contaminated clothing, gloves, and boots
- Take a shower or wash face and hands

### DECONTAMINATION PROCEDURES

### NOTES

An UST inspector returning from field work is expected to be only minimally contaminated, if at all. The inspector should follow simple steps for decontamination. Do not wear contaminated clothing again until cleaned.

- Any tool or other equipment contaminated by contact with toxic or corrosive materials should be dropped separately in plastic containers or on plastic drop cloths.
- Remove protective clothing, gloves, boots, and deposit in a plastic container or on a drop cloth. Ask for help in removing PPE, if necessary. Wash items with decontamination solution or detergent/water as many times as necessary. Rinse thoroughly. Wash inner gloves with solution that will not harm the skin.
- Take a shower or wash face and hands. If there is a possibility that inner clothing has been contaminated, do not wear off-site.



---

## MONITORING INSTRUMENTATION

---

## MONITORING INSTRUMENTATION

---

### Objectives

Participants will be able to:

- identify hazards requiring monitoring
- list two main categories of monitoring instruments
- describe function, purpose, conditions for use, and limitation(s) of O<sub>2</sub> meter, H<sub>2</sub>S meter, Detector tubes, CGI, FID, PID

### NOTES

## CHEMICAL HAZARDS REQUIRING MONITORING

---

- Airborne toxics (during product handling, transfer, product release)
- Oxygen-deficient atmospheres (in confined spaces)
- Combustible vapors (in confined spaces, product handling, product release)
- Hydrogen Sulfide/Methane (entering sewers)

### CHEMICAL HAZARDS REQUIRING MONITORING

### NOTES

As stated earlier, toxic substances enter the body via the skin, ingestion or inhalation. Of these three routes, inhalation is the quickest and most efficient route into the body. The adverse effects produced by inhalation of a toxic substance can be almost instantaneous because the lungs efficiently and rapidly transfer the inhaled substances to the bloodstream, which distributes it to all parts of the body. The toxic effect will be proportional to the concentration of the toxin in the air, its toxicity, and an individual's sensitivity to the toxin. More detailed information on specific toxicity hazards may be found in the section on toxicity in this manual.

The objective of this section is to introduce various monitoring instruments which can warn inspectors of some of the major chemical hazards they might face such as airborne toxic substances, oxygen deficient atmospheres, combustible gases/vapors, and hydrogen sulfide. These can appear during product handling, transfer or release, or while working in confined spaces.

## MONITORING INSTRUMENTS

---

Hazards can be measured by:

- Direct Reading Instruments (DRIs)
- Compound-Specific Detectors

DRIs effectively detect:

- organic and inorganic vapors
- oxygen deficient atmospheres
- explosive atmospheres
- specific compounds, such as H<sub>2</sub>S

### MONITORING INSTRUMENTS

### NOTES

The major chemical hazards faced by UST inspectors can be measured by **Direct Reading Instruments (DRIs)** or **Compound Specific Detectors**. The most commonly used instruments are Direct Reading Instruments which can effectively detect both inorganic and organic vapors, oxygen deficient atmospheres, explosive atmospheres, and specific compounds such as hydrogen sulfides.

Most DRIs respond to many different substances. This characteristic is desirable because it allows for fast identification of dangerous situations, yet information about specific substances often cannot be determined directly. All DRIs have inherent constraints in their ability to detect hazards:

- They usually detect and/or measure only specific classes of chemicals.
- They are generally not designed to measure and/or detect airborne concentrations below the 1 ppm level.
- Many of the DRIs that have been designed to detect one particular substance also detect other substances (that is, they are prone to interferences) and may give false readings.

## MONITORING INSTRUMENTS (con.)

### NOTES

For example, some hydrogen cyanide gas DRIs, if installed backwards will change color in the presence of acetic acid.

## INSTRUMENT CERTIFICATION

---

All instruments should be certified safe in explosive atmospheres.

Certified instruments permanently carry plate showing testing by:

- Underwriters Labs.
- Factory Mutual; or
- Mine Health and Safety Administration.

### INSTRUMENT CERTIFICATION

### NOTES

Explosion hazards are a major concern at UST sites; instruments used by UST inspectors must not contribute to the hazard by being potential sources of ignition.

A number of engineering, insurance, and safety organizations have established definitions and developed codes for testing electrical devices used in hazardous situations. The National Fire Protection Association publishes the National Electrical Code (NEC) every three years. Underwriters Laboratories, Factory Mutual, and the Mine Health and Safety Administration conduct tests to certify that monitoring instruments meet the minimum standards of acceptance set by the NEC.

An electrical instrument certified for use in hazardous locations under one of these test methods, will carry a permanently affixed plate. This plate will show the logo of the laboratory that granted the certification and the Class(es), Division(s), and Group(s) the instrument was tested against. If an instrument does not have an approved rating, it should not be used in a hazardous or potentially hazardous situation.



## INSTRUMENT CERTIFICATION (con.)

---

### Instruments certified by Class, Division, and Group

- CLASS I Potentially flammable gas/vapor
- CLASS II Potentially explosive dust
- DIVISION 1 Explosive conditions exist routinely
- DIVISION 2 Explosive conditions exist only after unintentional release

## NOTES

The instrument certification categories included are divided into classes, divisions, and groups. There are two classes covering "potentially flammable gas/vapor" and "potentially explosive dust." There are two divisions including "explosive conditions exist routinely" and "explosive conditions exist only after an unintentional release." And finally, there are six groups divided according to specific compounds such as acetylene, hydrogen and similar gases, and others. The categories of instruments most likely to be encountered at UST sites are approved for Class 1, Division 1, Groups A, B, C, and D.

## INSTRUMENT CERTIFICATION (con.)

---

GROUP A	Acetylene
GROUP B	Hydrogen and similar gases
GROUP C	Ethyl ether, cyclopropane, carbon disulfide
GROUP D	Methane, butane and most solvents
GROUP E-F	Explosive dusts

### NOTES

Because of the wide variability of compounds that can be encountered at an UST site, instruments are more typically certified for multigroups of substances. This affords the widest applicability possible.

## DIRECT READING INSTRUMENTS

---

- Oxygen meter
- Hydrogen sulfide meter
- Detector tubes
- Combustible gas indicator (CGI)
- Flame ionization detector (FID)
- Photoionization detector (PID)

### DIRECT READING INSTRUMENTS

### NOTES

This course discusses six instrument types, all of which are Direct Reading Instruments. These include oxygen meters, hydrogen sulfide meters, combustible gas indicators, detector tubes, flame ionization detectors, and photoionization detectors. **UST inspectors should be thoroughly trained in and familiar with the use and interpretation of all of these instruments.**

## OXYGEN METER

---

Function: Detect oxygen percentage in air

- most models detect 0 to 25 percent range
- a few models detect 0 to 10 percent or 1 to 100 percent

How they work: electrochemical sensor

- air pumped into meter diffuses onto semipermeable membrane
- reaction between oxygen and electrodes produces minute current
- current moves the needle indicator

### OXYGEN METER

### NOTES

The **oxygen meter** has three principal components: the air flow system, the oxygen sensing element, and the microamp meter. Air is drawn into the detector with an aspirator bulb or pump. The detector uses an electrochemical sensor to determine the oxygen concentration. The sensor consists of two electrodes (a sensing and a counting electrode), a housing containing the basic electrolytic solution, and a semipermeable teflon membrane.

Oxygen molecules diffuse through the membrane into the solution. Reactions between the oxygen and the electrodes produce a minute electric current which is directly proportional to the sensor's oxygen content. The current passes through the electronic circuit and the resulting signal is shown as a needle deflection on a meter.

Oxygen measurements are most informative when paired with combustible gas measurement. Together they provide quick and reliable hazard data. A lower oxygen reading will show a lower combustible gas reading; while a higher oxygen reading will show a higher combustible gas reading. In general, oxygen measurements should be taken before combustible gas indicator readings.

## OXYGEN METER LIMITATIONS

---

- Altitudes changes skew calibrations
- Best when paired with CGI measurements (take oxygen readings first)
- Oxidants (such as ozone) affect readings
- CO<sub>2</sub> interferes with the detector

### OXYGEN METER LIMITATIONS

### NOTES

The use of an oxygen meter has limitations, since its operation depends on absolute atmospheric pressure. An oxygen meter calibrated at sea level and operated at an altitude of several thousand feet will falsely indicate an oxygen-deficient atmosphere. Furthermore, oxidants, such as ozone and interfere with detectors. Chlorine, FI, Br, and acid gases are all potent oxidants (oxidizers). An oxygen measurement should be paired with a combustible gas measurement in order to ensure reliability.

## HYDROGEN SULFIDE INDICATOR

- Function: detect hydrogen sulfide levels in air
- How it works: similar to oxygen meter
- Limitations: cross sensitivity (for example, HCN)

### HYDROGEN SULFIDE INDICATOR

### NOTES

**Hydrogen sulfide indicators** range from simple color change devices to sophisticated electronic meters. With the electronic versions, sample air is introduced to the sensor by passive diffusion or active pumps through a gas-porous semipermeable membrane. The cell electro-oxidizes the gas in proportion to the gas partial pressure in the sample. The resulting electrical signal is then amplified to run the meter.

Hydrogen sulfide gas can be fatal if inhaled in sufficiently high concentrations. UST inspectors would be most likely to encounter  $H_2S$  in sewers. The gas has a strong "rotten egg" odor. UST inspectors should never rely on their olfactory senses as a means of determining concentrations of  $H_2S$ , since the gas "deadens" the sense of smell (i.e., the olfactory nerves will adjust to and tolerate concentrations of  $H_2S$ ).

Also, some individuals are congenitally unable to smell  $H_2S$ .

No hydrogen sulfide meters are sensitive at less than 1 ppm. In addition, they are cross sensitive to hydrogen cyanide, therefore, they can, in certain instances, give misleading readings.

## COMBUSTIBLE GAS INDICATOR (CGI)

---

Function: measures flammable vapor concentrations in air

- results shown as percentage of lower flammable limit
- measure O<sub>2</sub> percentage before using CGI

How it works: operates on "hot wire" principle

- combustion chamber with platinum filament
- gas combustion raises filament temperature
- increased temperature causes resistor circuit "imbalance"

### COMBUSTIBLE GAS INDICATOR

### NOTES

The **Combustible Gas Indicator (CGI)** or explosimeter is one of the first instruments that should be used when surveying a site. It measures the concentrations of flammable vapors or gases in air and indicates the results as a percentage of the lower explosive limit (LEL) of the calibration gas. Before using a CGI, however, the percentage of oxygen should be measured with an oxygen meter.

The LEL of a combustible gas is the lowest concentration by volume in air which will explode, ignite, or burn when there is an ignition source. The UEL is the maximum concentration of a gas or vapor which will ignite. Above the UEL, there is insufficient oxygen for the fuel level to support combustion. Below the LEL there is insufficient fuel to support ignition.

Most CGIs operate on the "hot wire principle." In the combustion chamber there is a platinum filament that is heated. This filament is an integral part of a balanced resistor circuit called the Wheatstone Bridge. The hot filament combusts the gas(es) on the immediate surface of the element, thus raising the temperature of the filament. Any single gas, or mixture of combustible gases, will cause the meter to react; the effect of this trait must be understood by the CGI operator.

NOTES

As the temperature of the filament increases so does the 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 of the combustible gas used to calibrate the CGI. If a concentration greater than the LEL and less than the UEL is present, the meter needle will stay beyond the 1.0 (100 percent) level of the meter. This indicates that the ambient atmosphere is readily combustible. When the atmosphere has a gas concentration above the UEL, the meter will rise above the 1.0 mark and then return to zero. This occurs because the gas mixture in the combustion cell is too rich to burn. This permits the filament to conduct a current as if the atmosphere contained no combustibles at all. For this reason, it is critical to always watch the meter, since this rapid deflection may go undetected.

This is not a problem with most of the newer meters equipped with an audible alarm.

There is a relatively new detector system for flammables on the market now. Some detectors are using a tin oxide sensor. The tin oxide coating on the surface of the sensor has only a limited number of electrons available for conduction of electricity. Oxygen, which is highly electronegative, tends to gain electrons. Normal oxygen content will pull most of the electrons away from the tin oxide, reducing its ability to conduct electricity (high resistance). As concentrations of a flammable gas increase, oxygen "turns away" from the tin oxide to interact with the flammable compounds. The newly freed electrons can now flow, and resistance drops. The resistance changes are calibrated to be proportional to a specific flammable gas. This technology can also be used to detect non-flammable vapors as well.

Pros and cons of this technology are not yet fully field-tested, but it is reasonable to assume that varying oxygen concentrations can cause ambiguous readings, and that cross-sensitivities exist. The sensor is reported to be poisoned by halogenated gases.



## COMBUSTIBLE GAS INDICATOR LIMITATIONS

---

Limitations: must watch needle continuously

- when concentrations above UEL but below LEL, meter needle stays beyond 1.0 (100 percent) mark
- when concentrations above LEL, meter rises above 1.0 mark and quickly returns to zero

Always use with oxygen meter

Do not use in oxygen enriched or deficient areas

Leaded gasoline may "poison" internal filament

Gives accurate readings for the "calibration gas" only

### COMBUSTIBLE GAS INDICATOR LIMITATIONS

### NOTES

There are limitations to the use of a combustible gas indicator. As mentioned previously, the needle of the indicator must be watched continuously because a reading above LEL will return to zero. For a more accurate measure of combustible gases, readings should be taken at ground, waist, and overhead positions to insure detection of vapors whose densities are greater or less than air.

The following substances may "poison" the detection filaments: fuming acids, leaded gasolines, silicones, silicates and other silicon containing compounds. When it is suspected that these substances have been aspirated, the CGI should be checked with a calibration kit; if leaded gasolines are anticipated, additional filaments should be on hand. There are also catalytic filters available for use with leaded gasolines. The instrument should not be switched On/Off unless it is known that you are in a combustion free environment. The CGI reads only from 0 to 100 percent of the calibration gas, often either methane or propane. Therefore, when another combustible gas is detected, the exact meter reading is not correct and cannot be relied

## CGI LIMITATIONS (con.)

### NOTES

upon. To provide additional safety factors, field crews should discontinue operations where combustible gas is measured above 25 percent of the LEL for a methane or propane calibrated CGI.

## DETECTOR TUBES

---

Function: measure levels of petroleum, other gases

How It Works: "Detecting chemicals" change color

- air is drawn through tube
- color change intensity shows gas concentrations

Limitations

- accuracy only within 25 percent of concentration
- interfering gases can affect readings
- slow and tedious
- subjective results determination

## DETECTOR TUBES

## NOTES

**Detector tubes** (also known as calorimetric and indicator tubes) measure levels of petroleum and other gases. They are small glass tubes filled with a solid absorbent and impregnated with detecting chemicals. Air is drawn through the tube at a controlled rate, and airborne contaminants will change the color of the detecting chemicals. The intensity of the color change is taken as an index of the contaminant concentration. Because specific tubes exist for the detection of hydrocarbons and other petroleum product constituents, they can be effectively used at UST sites as a screening tool, but they are not very accurate.

There are two basic types of detector tubes:

- Stain length
- Color density

Stain length tubes are graduated, and the length of the color change is proportional to concentration. Stain length tubes are more convenient.

## DETECTOR TUBES (con.)

### NOTES

One limitation of detector tubes is that their accuracy is limited to within 25 percent of the true concentration of the contaminant. Furthermore, some gases can interfere with the reading. It is a relatively slower and more tedious approach to measuring contaminants than some other instruments. The color or stain must be evaluated immediately, as many colors fade rapidly. Finally, with some tubes, the air flow must be in one direction only; this is typically indicated by an arrow or a dot. This type of tube usually contains a drying agent or a precleaning layer ahead of the indicating chemical, to remove interfering gases or vapors, or an oxidizing layer which releases a certain part of the vapor test molecule which reacts with the indicating chemical.

## FLAME IONIZATION DETECTOR (OVA)

---

Function: two modes

- survey mode detects volatile organic concentrations
- Gas Chromatograph Mode separates and measures individual components

How It Works:

- sample drawn into hydrogen flame
- sample burns, ions produce current, read by meter

### FLAME IONIZATION DETECTOR

### NOTES

#### **Flame Ionization Detectors (FIDs)**

(sometimes called organic vapor analyzers or OVAs) are used to detect concentrations of volatile organics. An OVA consists of two major parts: (1) a 9-pound package containing the sampling pump, battery pack, support electronics, flame ionization detector, and hydrogen gas cylinder; and (2) a hand held meter/sampling probe assembly. When the sample reaches the hydrogen flame it burns and the resulting ions carry an electric current. The current is then amplified and displayed on the probe's meter. The measurement equals the total concentration of organic compounds relative to the calibration standard.

The FID can operate in two different modes. In the **survey mode**, it can determine the approximate concentration of all detectable volatile organic chemicals in the air. The **gas chromatograph (GC) mode** separates and measures individual components. This is done by drawing a sample into the FID's probe which is then carried to the detector by an internal pump.

## FLAME IONIZATION DETECTOR (OVA) (con.)

---

### Limitations:

- manufacturer internally calibrates to methane; for other compounds, adjustments and/or calibration charts needed
- only detects organic compounds
- requires high quality hydrogen (transport regulated by DOT)
- lead acid battery loses power in cold weather, affecting readings

## NOTES

In the GC mode, a small sample of ambient air is injected into a chromatographic column and carried through the column by a stream of hydrogen gas. Contaminants with different chemical structures are retained on the column for different lengths of time (known as retention times) and, hence, are detected separately by the flame ionization detector. A strip chart recorder can be used to record the retention times and peaks (concentrations), which are then compared to the retention times of a standard with known chemical constituents.

Limitations of the OVA include the fact that it is internally calibrated by the manufacturer (usually to methane), and therefore, does not give an exact reading for other compounds. The OVA can only detect organic compounds, however, since petroleum products are organic compounds, this poses no major problem.

The OVA needs high-quality hydrogen to operate. Hydrogen transport is regulated by the U.S. Department of Transportation. If the OVA's hydrogen tank is empty, it can be shipped without restriction. Once on-site, however, plans have to be made for the acquisition of high quality hydrogen.

## FLAME IONIZATION DETECTOR (OVA) (con.)

### NOTES

Lead-acid batteries are used by the OVA and they tend to lose power in cold weather which could cause problems with on-site usage.

Finally, OVA's do not detect compounds less than 1 ppm in concentration.

## PHOTOIONIZATION DETECTOR (HNU)

---

Function: detects total organic and some inorganic gases

How it works:

- sample subjected to ultraviolet radiation
- ions produced, meter reads resulting current
- easier to use than the OVA
- calibrated to benzene equivalent (isobutylene)

### PHOTOIONIZATION DETECTOR

### NOTES

**Photoionization Detectors (PIDs)** are one way to detect organic vapors. The HNU system portable photoionizer detects concentrations of organic gases and a few inorganic gases. The basis for detection is the photoionization of gaseous species. The incoming gas molecules are subjected to ultraviolet radiation which ionizes a number of gaseous compounds. Each particle is changed into charged-ion pairs creating a current between two electrodes which can be read by a meter. The HNU measures the total concentration of those organic (and some inorganic) vapors in air that have an ionization potential less than or equal to the energy of the probe.

The HNU consists of two modules connected via a signal-power cord; a readout unit consisting of a meter, a battery, and electronics; and a sensor unit consisting of a light source, a pump, and an ionization chamber.

The photoionization detector is easier to use than the OVA and it has a lower detection limit. The system is usually calibrated to a benzene substitute such as isobutylene and reads benzene directly.



## PHOTOIONIZATION DETECTOR (HNU) (con.)

### NOTES

Two other photoionization detector models are the TIP manufactured by photovac and the OVM manufactured by Envirotherm. These two models, unlike the HNU, have the ability to retain readings in memory which can then be down loaded into the computer at a later date.

## PHOTOIONIZATION DETECTION (HNU) (con.)

---

### Limitations:

- radio frequency interference may skew readings
- high humidity, temperature differentials "cloud" UV lamp window, depressing readings
- lead acid battery loses power in cold weather, affecting readings

The HNU system does have a number of limitations. It can be susceptible to radio frequency interference from power lines, transformers, high voltage equipment, and radio transmissions. Also, the window of the UV lamp must be cleaned on a regular basis to insure that airborne contaminants are ionized. Finally, the HNU system also uses a lead-acid battery. These batteries lose power in cold weather and can be unreliable. Once the batteries have been severely discharged, they may no longer accept a charge and will need to be replaced. For these reasons, the unit should be placed on the battery charger after every use. The HNU charge circuit has a protector that prevents overcharging.

---

## PERMISSIBLE EXPOSURE LEVELS

---

## PERMISSIBLE EXPOSURE LEVELS

---

### Objectives

Participants will be able to:

- distinguish between PELs, RELs, and TLVs
- list order of consideration for PELs, RELs, and TLVs when establishing permissible exposure limits
- describe different approaches for establishing permissible exposure limits for known/unknown airborne contaminants
- list three major labelling systems to identify hazardous substances/limitations

### NOTES

### OSHA PERMISSIBLE EXPOSURE LIMITS (PELs)

---

- PELs established for over 600 substances
- Generally focus on exposure by inhalation
- Because of legal standards, consider PELs first when setting exposure limits

### OSHA PERMISSIBLE EXPOSURE LIMITS

### NOTES

Regulatory agencies, trade associations and professional organizations have developed regulations and guidelines for worker exposure to hazardous substances. They are used to evaluate potential exposure hazards during safety planning and site inspections. The guidelines should also be used in planning for the appropriate personal protective equipment (PPE) if it will be necessary to conduct activities in areas where exposure is likely.

The exposure limits normally focus on exposure by inhalation because the other routes of exposure—injection, ingestion and dermal absorption—are normally controlled by work practices and personal hygiene. In addition, it is difficult to establish exposure limits for these routes. The Occupational Health and Safety Administration (OSHA) has established **Permissible Exposure Limits (PELs)** for over 600 substances. These standards are codified as 20 CFR 1910.1000 (amended 1/19/89). The PEL for a substance is the 8-hour "ceiling concentration" above which employees may not be exposed. PELs are legally enforceable standards and apply to private and government sector employees. They should be considered first when setting exposure limits.

### NIOSH RECOMMENDED EXPOSURE LIMITS (RELs)

---

- NIOSH develops, recommends standards to OSHA
- Publishes IDLH concentrations
- Publishes RELs
- Consider RELs second when establishing exposure limits

#### NIOSH RECOMMENDED EXPOSURE LIMITS

#### NOTES

The National Institute for Occupational Safety and Health (NIOSH) is a division of the U.S. Department of Health and Human Services. NIOSH is responsible for researching, developing, and recommending health and safety standards for OSHA. NIOSH researches information for use in developing OSHA PEL standards, although many recommended exposure limits have not been adopted. These are called the **Recommended Exposure Limits (RELs)**. For each REL, NIOSH publishes a criteria document that is the basis for their recommendation. RELs are not enforceable.

Approximately 150 chemicals have been assigned RELs. In accordance with OSHA 1910.120, RELs are considered second when establishing a specific exposure limit.

NIOSH has also developed the **Immediately Dangerous to Life and Health (IDLH)** concentrations which can be used as a reference in selecting a respirator. The IDLH concentrations represent the maximum concentrations from which one could escape within 30 minutes without symptoms of impairment or irreversible health effects. RELs and IDLH values are listed in the NIOSH/OSHA Pocket Guide to Chemical Hazards, NIOSH/OSHA, DHHS Publication #85-114, February 1987.

## ACGIH THRESHOLD LIMIT VALUES (TLVs)

---

ACGIH establishes TLVs for about 600 substances

Three separate TLV levels:

- TLV-TWA (time weighted average)
- TLV-STEL (short-term exposure limit)
- TLV-C (ceiling value)

Consider TLVs third when establishing exposure limits

### ACGIH THRESHOLD LIMIT VALUES

### NOTES

The American Conference of Governmental Industrial Hygienists (ACGIH) establishes exposure limits called **Threshold Limit Values (TLVs)** and publishes a listing in its booklet, Threshold Limit Values and Biological Exposure Indices. The booklet lists approximately 600 substances and is revised annually. The TLVs refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse health effects. According to OSHA 29 CFR 1910.120, the PEL is considered first when establishing an exposure limit, followed by the REL and TLV values.

There are three separate levels of TLVs. The **TLV-TWA** (time weighted average) is the average concentration of a chemical to which most chemical workers can be exposed over a 40-hour week and a normal 8-hour work day without showing any adverse effects. The TLV-TWA permits exposure to concentrations above the limit; however, elevated concentrations must be compensated by periods of exposure below the limit. The **TLV-STEL** (short-term exposure limit) is a 15-minute, time weighted exposure.

## THRESHOLD LIMIT VALUES (con.)

### NOTES

Excursions above the TLV-STEL should be at least 60 minutes apart, no longer than 15 minutes in duration, and should not be repeated more than four times per day. Because the excursions are calculated into the 8-hour, time weighted average, exposure during the rest of the day must be lower to compensate. Finally, the TLV-C represents a ceiling value that should not be breached even instantaneously. These three values should be considered third when establishing exposure limits.

TLV-C is typically used for substances that are fast-acting, and dangerous in even short exposures.

It is good practice to select the lowest of these three values as the action limit.



## ESTABLISHING EXPOSURE LIMITS

For specific chemicals and compounds (gasoline) use PELs, RELs, or TLVs

If specific contaminants unknown, use total atmospheric concentrations following EPA emergency response team action levels:

- |                          |         |
|--------------------------|---------|
| • Background             | Level D |
| • 5 ppm above background | Level C |
| • 5 to 500 ppm           | Level B |
| • >500 ppm               | Level A |

### ESTABLISHING EXPOSURE LIMITS

### NOTES

When the identities and concentrations of airborne contaminants are known, the PEL, REL, and TLV can be used to establish the permissible exposure limit. In unknown situations, such as may exist at an abandoned UST site, total atmospheric concentrations (with a number of conservative restrictions) can be used to establish limits until the airborne contaminants can be identified and quantified. In these instances, it may be appropriate to use the EPA Emergency Response Team (EPA-ERT) action levels (listed above).

The EPA-ERT action levels are guidelines only. Obviously, for some contaminants they would be inadequate, for others, far too stringent. However, when used with some common sense, they are good, general protection levels for unknown contaminants.

Action levels were developed by EPA to provide basic guidelines for decision-making in unknown situations. They address the four major site hazards: oxygen deficiency, explosive atmospheres, radioactive environments, and toxic atmospheres. If any of these hazards is suspected, monitoring with site screening instruments should be conducted prior to site entry.

## **CLASSIFICATION, LABELING SYSTEMS**

---

### **Three major hazardous substances labeling systems:**

- DOT Hazard Identification System
- NFPA Standard
- UN Hazard Classification System (not discussed)

DOT system required by law

NFPA and UN systems are voluntary

### **CLASSIFICATION, LABELING SYSTEMS**

### **NOTES**

Use of the DOT system, as outlined in 49 CFR DOT Regulations, is required by law. Use of the NFPA and UN systems are voluntary. The NFPA system is typically used as a means of in-plant communications, while the UN and DOT systems are usually used for shipments.

## DOT LABELING SYSTEM

---

Diamond with hazard illustration on top; one- or two-word hazard description in center

Four-digit UN ID numbers located in diamond's center

Common numbers:

- Gasoline: 1203
- Kerosene: 1223
- Fuel oil: 1993
- Flammable Liquid: 1993
- Aviation fuel: 1863

Vehicle placarding requirements similar to DOT warning label requirements

### DOT LABELING SYSTEM

### NOTES

The DOT requires warning labels to contain a graphic illustration of the hazards at the top of the diamond and a one- or two-word description of the hazard in the center of the diamond. **Placarding requirements** (49 CFR 172 Subpart F) mandate the placement of placards on motor vehicles, rail cars, and freight containers carrying hazardous materials. Four-digit UN identification numbers (adopted by DOT) are placed in the center of the diamond. The hazard identification number may be shown on placards by placing the identification number over the one- or two-word description, and the hazard class at the bottom of the diamond.

## NFPA LABELING SYSTEM

---

Diamond symbol provides relative hazard level for:

- flammability
- health
- reactivity

Five-step ranking system: 0 (lowest) to 4 (highest)

Identifies only level and hazard type, not exact chemical

### NFPA LABELING SYSTEM

### NOTES

The National Fire Protection Association (NFPA) Standard 704M was developed to quickly transmit the relative level of hazard in three specific categories:

- Flammability
- Health
- Reactivity

Note that the NFPA system is not intended to tell the viewer the exact chemical in the container. Rather, it is intended to convey the levels and types of hazards presented by the chemical.

In the NFPA label, each "subdiamond" (that is, category) in the diamond-shaped symbol is ranked from 0 (lowest) to 4 (highest). Although the ranking criteria differ according to each category, numerical ranking itself is consistent across all categories.

## SELECTED REFERENCES

### Suggested Additional Reading and Resources

*The Common Sense Approach to Hazardous Materials*, Frank L. Fire, Fire Engineering

*Guide to Occupational Exposure Values*, Published Yearly, American Conference of Governmental Industrial Hygienists

*Handbook of Compressed Gases*, third edition, Compressed Gas Association, Inc. (703) 979-4341

*Hawley's Condensed Chemical Dictionary*, 11th edition, N. Irving Sax and Richard Lewis, Van Nostrand Reinhold

MEDLARS Online Database, National Library of Medicine, (800) 638-8480

*Shreve's Chemical Process Industries*, 5th Edition, George T. Austin, McGraw-Hill

TOMES Plus, Micromedex Inc. (CD-ROM Software (800-525-9083)

*Casarett and Doull's, Toxicology*, Doull Klassen and Amdur, editors, McMillan

*The Merck Index*, an Encyclopedia of Chemicals and Drugs, Marth Windholz et al., Merck and Co.

**APPENDIX A.**

**RESPIRATORY PROTECTION**

## A.1 INTRODUCTION

Respiratory protection is of primary importance since inhalation is one of the major routes of exposure to toxicants. Respiratory protective devices (respirators) consist of a facepiece connected to either an air source or an air purifying device which protects the wearer from airborne hazardous materials.

Respirators with an air source (atmosphere-supplying respirators) consist of two types:

- \* Self-contained breathing apparatus (SCBA) which supply air from a source carried by the user.
- \* Supplied-air respirators (SAR) which supply air from a source connected to the user by an air-line hose. SARs may also be called an air-line respirator.

Respirators without a separate air source, but which utilize ambient air which is "purified" through a filtering element (canister or cartridges) prior to inhalation, are termed air-purifying respirators (APR).

SCBAs, SARs, and APRs can be further differentiated by the type of airflow which is supplied to the facepiece.

- \* Positive pressure respirators (PPRs) maintain a positive pressure in the facepiece during both inhalation and exhalation. This positive pressure may be a pressure demand or continuous flow system. If a leak develops in a pressure demand respirator, the regulator sends a continuous flow of clean air into the mask to prevent penetration by contaminated ambient air. Continuous flow respirators (SARs and powered APRs) send a continuous flow of air into the mask at all times. Negative pressure may be created at maximal breathing rates when using the powered APRs (PAPR).
- \* Demand respirators draw air into the mask via the negative pressure created by user inhalation. If any leak develops in this system (ill-fitting mask facepiece), the user will draw contaminated air into the respiratory area during inhalation.

Federal regulations require the use of respirators that have been tested and approved by the Mine Safety and Health Administration (MSHA) and NIOSH (National Institute for Occupational Safety and Health).

Under 29 CFR 1910.134, the employer is required to provide a suitable approved respirator and to establish a respiratory protection program.

As part of this program, the employer must:

1. Provide standard operating procedures for the use of respiratory protective equipment;
2. Train the employee in how to select a respirator based on potential hazard;
3. Train the employee in uses and limitations of respirators;
4. Provide instruction on general maintenance and cleaning;
5. Train employees in pre- and post-use inspection procedures;
6. Train employees to monitor for adverse conditions and worker stress;
7. Determine the employee's medical fitness;
8. Train the employee in storage procedures for respiratory equipment; and
9. Use MSHA/NIOSH approved respirators.

It is the employee's responsibility to:

1. Use respirator provided;
2. Guard against damage to respirator;
3. Report problems or malfunctions; and
4. Use as a system with only approved parts.

Respiratory protection will vary with field conditions. General rules for respiratory protection are:

Level A: SCBA with encapsulating suit

Level B: SCBA

Level C: Full face air purifying respirator/powered air purifying respirator, with escape mask readily available.

Level D: No respiratory protection, but escape mask should be available.

The appropriate level of protection for field activities is determined based on an evaluation of the hazards present at a given site.



### Legal Requirements:

- 1) The Occupational Safety and Health Act of 1970 established standards which state that "approved respirators shall be used when they are available."
- 2) 29 CFR 1910.134 outlines the legal requirements for selection and use of respiratory equipment as promulgated by OSHA and based on ANSI Z88.2.
- 3) (NIOSH) - 30 CFR, Part II, "Respiratory Protective Devices; Tests for Permissibility; Fees" gave jurisdiction for joint approval of respirators to NIOSH and MSHA in May of 1972.
- 4) Mine Safety and Health Administration (MSHA) - has jurisdiction over the approval of respirators for mining. The Federal Mine Safety and Health Act of 1977 transferred authority of MESA (Mining Enforcement and Safety Administration) to MSHA.
- 5) ANSI Z88.2 contains a wealth of information on practices for respiratory protection.

## **A.2 AIR PURIFYING RESPIRATORS (APR)**

### Types Of APRs Used

- 1) Single use (disposable). Example: filtration mask for painting.
- 2) Quarter mask (covers mouth and nose). Example: a dust respirator.
- 3) Half mask (covers chin, mouth and nose). Example: asbestos inspection.
- 4) Full-face mask (covers entire face and affords eye protection against irritating chemicals).
- 5) Gas masks:
  - Full-face mask – chin mounted canister
  - Full-face mask – belt mounted canister and breathing hose
- 6) Half mask. Belt-mounted cartridges and breathing hose (may be used with welders faceshield).
- 7) Powered air - purify respirator (positive pressure unit).

### Protection Factors For Respirators (PF)

Single Use (disposable)	5
Quarter Mask	10
Half Mask	10
Full-Face Mask	50
Gas Mask	100
Powered Air Purifying Respirator	100-1000
	(depending on filter type)
Full-Face Positive-Pressure SCBA	10,000+

How is the protection factor used?

Example: We want to use an APR in an atmosphere that has 50 ppm benzene. Benzene has a TLV value of 10 ppm. We attain a Maximum Use Concentration (MUC) by multiplying our PF x TLV = MUC.

$$50 \times 10 \text{ ppm} = 500 \text{ ppm on the APR mask}$$

We now know that we can use our APR in an environment measuring 50 ppm benzene depending on whether or not our cartridge covers this particular maximum use concentration.

**NOTE:** OSHA Permissible Exposure Limit (PEL) may be less than the Threshold Limit Value (TLV) value issued by the American Conference of Governmental Industrial Hygienists, so the MUC may change.

Example: Benzene measured at 50 ppm

OSHA PEL = 1 ppm

APR PF is 50

$$50 \times 1 \text{ ppm} = 50 \text{ ppm}$$

APRs may only be worn in an environment containing 50 ppm or less benzene to insure that OSHA standards are abided by.

## **Advantages and Disadvantages of Full Mask APRs and PAPRs**

### **Advantages**

- \* Enhanced mobility.
- \* Light in weight. Generally two pounds or less.
- \* PAPRs offer enhanced protection over general APRs.
- \* Provides adequate protection for Level C environments depending on cartridge needed.

### **Disadvantages**

- \* Can't be used in IDLH environment or an oxygen deficient atmosphere (less than 19.5% oxygen at sea level).
- \* Limited duration of protection.
- \* Level and type of contaminant must be known.
- \* Can only be used against gas and vapor contaminants with adequate warning properties.
- \* Requires physical effort to breath through cartridges or filters
- \* Potential leakage around the face seal (negative pressure). Only fits 60% of population.
- \* Distorts speech when wearing.
- \* Limited use in high humidity or rainfall.
- \* Facial hair, dental work, weight loss or gain may affect fit of APR.

### **Principle Of Operation (APRs)**

1. Ambient air is passed through a filter and/or sorbent bed (cartridge) and the contaminants are removed.
2. The clean air passes on through the inhalation valve (one-way check valve) to the facepiece where air is received by the wearer.
3. Exhaled air passes out the exhalation valve (one-way check valve) back to the atmosphere.

### Selection Of Cartridges/Filters/Canisters For APRs

The APR is a system. Use only cartridges manufactured by the manufacturer of your APR. If you use cartridges/canisters/filters produced by a different manufacturer you are breaking certification for your APR, and voiding all legal and functional guarantees of respiratory protection.

Always check cartridge shelf life or expiration date.

### **MSHA APPROVED CANISTERS FOR HYDROGEN SULFIDE, HYDROGEN CYANIDE, PHOSPHINE AND OTHER COMPOUNDS**

Mine Safety Health Administration (MSHA) approved respirator canister/ cartridges for protection against hydrogen sulfide, hydrogen cyanide, and phosphine may not be used for purposes other than emergency escape. These canisters were originally approved by the Bureau of Mines for concentrations far above their respective Immediately Dangerous to Life or Health (IDLH) values. None of these compounds, nor those listed below, have adequate odor warning properties for the respirator wearer to detect excessive facepiece leakage or sorbent breakthrough.

Additional compounds for which MSHA canisters are not appropriate, include, but are not limited to:

Acrolein	Methylene chloride
Aniline	Nickel carbonyl
Arsine	Nitro compounds:
Bromine	Nitrobenzene
Carbon monoxide	Nitrogen oxides
Dimethylaniline	Nitroglycerin
Dimethyl sulfate	Nitromethane
Formaldehyde	Ozone
Hydrogen cyanide	Phosgene
Hydrogen fluoride	Phosphine
Hydrogen selenide	Phosphorous trichloride
Hydrogen sulfide	Stibine
Methanol	Sulfur Chloride
Methyl bromide	Toluene Diisocyanate
Methyl chloride	Vinyl Chloride

## SELECTION OF PROPER CARTRIDGES FOR PESTICIDE SITES

Only GMP or GMA-H cartridges are to be used in the Ultra-Twin APR when entering sites where pesticides are the only known chemical present, and Level C protection is deemed appropriate. GMC-H cartridges are not NIOSH/MSHA approved and may suffer a reduced service life in pesticide environments.

A general description of the cartridges in question, and their appropriate use is presented below. The attachment to the Safety Alert is an excerpt for MSA Data Sheet 10-00-03 "Twin-Cartridge Respirators," which provides more detail about respirator and filter/cartridge use.

CARTRIDGE TYPE	COMPONENTS	RESPIRATORY HAZARDS
GMP	Activated carbon and metal fume filter	Aerosols from liquid pesticides and as noted on the attached MSA Data Sheet.
GMA-H	Activated carbon with a HEPA filter	Pesticides bound to soil particulates and as noted on the attached MSA Data Sheet.
GMC-H	Whethlerized carbon (Trade name for carbon impregnated with certain metallic salts) and a HEPA filter.	Organic vapors and as noted on the attached MSA Data Sheet.

## Filters/Cartridges

Respiratory hazards	Protection type
(1) Dust and mists having a Time Weighted Average (TWA) not less than $0.05 \text{ mg/m}^3$ or 2 million particles per cubic foot. (1,5)	Type F
(1) Dust, fumes and mists having a TWA not less than $0.05 \text{ mg/m}^3$ or 2 million particles per cubic foot and (2) radon daughters attached to dust, fumes and mists described above. (1,5)	Type S
(1) Dust, fumes and mists having a TWA less than $0.05 \text{ mg/m}^3$ , (2) asbestos-containing dusts and mists and (3) radionuclides. (1)	Type H
(1) Dust, fumes and mists having a TWA less than $0.05 \text{ mg/m}^3$ , (2) asbestos-containing dusts and mists and (3) radionuclides. (1)	Sparkfoe Type H
(1) Not more than one-tenth (0.1) percent organic vapors by volume and (2) dusts and mists having a TWA not less than $0.05 \text{ mg/m}^3$ or 2 million particles per cubic foot. (2,3,4,5)	GMA
(1) Not more than 10 ppm chlorine, 30 ppm formaldehyde, 50 ppm hydrogen chloride or 50 ppm sulfur dioxide and (2) dusts and mists having a TWA not less than $0.05 \text{ mg/m}^3$ or 2 million particles per cubic foot. (2,4,5)	GMB
(1) Not more than 1,000 ppm organic vapors, 10 ppm chlorine, 30 ppm formaldehyde or 50 ppm hydrogen chloride or 50 ppm sulfur dioxide and (2) dusts and mists having a TWA not less than $0.05 \text{ mg/m}^3$ or 2 million particles per cubic foot. (2,3,4,5)	GMC
(1) Not more than 300 ppm ammonia or 100 ppm methylamine and (2) dusts and mists having a TWA not less than $0.05 \text{ mg/m}^3$ or 2 million particles per cubic foot. (2,3,4,5)	GMD
(1) Metallic mercury vapors	Mesorb
(1) Not more than 1,000 ppm organic vapors and (2) dusts and mists with a TWA not less than $0.05 \text{ mg/m}^3$ or 2 million particles per cubic foot. (2,3,5)	GMA-F

### NOTES

- Do not use in atmospheres containing less than 19.5 percent oxygen, in atmospheres containing toxic gases or vapors, or in atmospheres immediately dangerous to life and health.
- Do not use in atmospheres immediately dangerous to life or health, or in atmospheres containing less than 19.5 percent oxygen.
- Do not wear for protection against organic vapors with poor warning properties of those which generate high heats or reaction with the sorbent material in the cartridge.
- Protection extended to dusts and mists only by adding Type F filters and filter covers.
- This filter is no longer NIOSH approved for respiratory protection against asbestos-containing dusts and mists.

## Filters/Cartridges

Respiratory hazards	Protection type
(1) Not more than 1,000 ppm organic vapors, (2) dusts, fumes and mists with TWA less than 0.05 mg/m <sup>3</sup> , (3) asbestos-containing dusts and mists and (4) radionuclides. (2,3)	GMA-H
(1) not more than 10 ppm chloring, 30 ppm formaldehyde, 50 ppm hydrogen chloride, 50 ppm sulfur dioxide, (2) dusts, mists and fumes with a TWA less than 0.05 mg/m <sup>3</sup> , (3) asbestos-containing dusts and mists and (4) radionuclides. (3)	GMB-H
(1) Not more than 1,000 ppm organic vapors, 10 ppm chloride, 30 ppm formaldehyde, 50 ppm hydrogen chloride and 50 ppm sulfur dioxide, (2) dusts, fumes and mists with a TWA less than 0.05mg/m <sup>3</sup> , (3) asbestos-containing dusts and mists and (4) radionuclides. (2,3)	GMC-H
(1) Not more than 1,000 ppm organic vapors, 10 ppm chlorine, 30 ppm formaldehyde, 50 ppm sulfur dioxide, 50 ppm hydrogen chloride, (2) dusts, fumes and mists with a TWA not less than 0.05 mg/m <sup>3</sup> or 2 million particles per cubic foot and (3) radon daughters attached to dusts, fumes and mists described above. (2,3,5)	GMC-S
(1) Not more than 300 ppm ammonia, 100 ppm methylamine, (2) dust, fumes and mists with a TWA less than 0.05 mg/m <sup>3</sup> , (3) asbestos-containing dusts and mists and (4) radionuclides. (2,3)	GMD-H
(1) Not more than 1,000 ppm organic vapors (2) dusts, fumes and mists with a TWA less than 0.05 mg/m <sup>3</sup> , (3) asbestos-containing dusts and mists and (4) radionuclides. (2,3) Also effective against iodine vapor.	GMI-H
(1) Pesticides, not approved for fumigants. (2,3,5)	GMP
(1) Mists of paints, laquers and enamels, (2) not more than 1,000 ppm organic vapors or (3) any combination thereof. Also approved against dusts and mists having a TWA not less than 0.05 mg/m <sup>3</sup> or 2 million particles per cubic foot. Not for use with urethane or other diisocyanate containing paints. (2,3)	Paint

### Changing Of Cartridge

1. Whenever the individual begins to smell the material or notices increased resistance to breathing.
2. After each work shift (8 hour day). One must be careful not to use a bent, distorted or wet cartridge.
3. Know limitations of cartridge and never use if a given situation approaches the limitations of a cartridge. May upgrade protection.

### Inspection Checklist Prior To Field Use

1. Exhalation Valve - Pull off plastic cover and check valve for debris or for tears in the neoprene valve (which could cause leakage).
2. Inhalation Valves (two) - Remove cartridges and visually inspect neoprene valves for tears. Make sure that the inhalation valves and cartridge receptacle gaskets are in place.
3. Make sure a protective cover lens is attached to the lens.
4. Make sure you have the right cartridge.
5. Make sure that the facepiece harness is not damaged. The serrated portion of the harness can fragment which will prevent proper face seal adjustment.
6. Make sure the speaking diaphragm retainer ring is hand tight.

### Ultra Twin Donning Procedure

1. Loosen harness strap adjustments.
2. Put chin in facepiece and draw back on adjustment straps evenly (i.e., top two straps, then bottom two straps, and center top strap last).
  - \* Do not tighten straps too tight, you may get a headache if you do.
  - \* Do not drink heavily the night before prolonged use.
  - a) Harness union should be centered on the back of your head.
  - b) Unevenly adjusted straps will create a leak. They are also very uncomfortable.
  - c) Straps should be drawn back no more than necessary.
3. Check for leaks and/or proper facial seal.
  - a) Cover cartridge air ports with palm of hands and attempt to pull air through the inhalation ports. Mask should collapse slightly on face.
  - b) Count to eight while holding your breath. Pressure inside of facepiece should be



maintained for duration of the count.

- c) If pressure is not maintained, check and/or adjust straps.

(NOTE: Make sure that palms are blocking all of the cartridge airports. This could be the source of leakage).

- d) Check exhalation valve by exhausting air through the valve.

(NOTE: Should detect some resistance but facial seal should not be broken).

### **A.3 RESPIRATOR FIT TESTING**

1. OSHA regulations (29 CFR Part 1910.134) require that each person who wears a respirator shall have it properly fitted, test the facepiece for face seal, and wear it in a test atmosphere. In order to wear a respirator, the person must go through a fit test to determine whether the person can obtain a satisfactory fit with a "negative pressure" air-purifying respirator. The results of the fit test will be used to select the specific type, make, and model of "negative pressure" air-purifying respirator for use by the wearer.

The following policies should be adhered to in the fitting and use of the respirators:

- A. A person must have passed the fit test in order to use any NIOSH/MSHA approved respirators.
  - B. If it is found that a person cannot obtain a good respirator-to-face seal because of facial or medical characteristics, the person should not use and/or enter an atmosphere that will require the use of a respirator.
  - C. Facial hair such as beards, sideburns, or certain mustaches which may interfere with the fit test are not allowable.
  - D. Persons requiring corrective lenses shall be provided with specially mounted lenses inside the full-face mask. Under no circumstances will contact lenses and/or glasses be worn while using full-face respirators.
  - E. Although fit testing for positive pressure SCBAs is not required as described in ANSI Z88.2 (1980), a less than acceptable respirator-to-face seal will increase the use of air via leakage and therefore reduce effective breathing time. Such leaks may pose a hazard to the user if sufficient air supply is not available to reach an uncontaminated air supply.
  - F. A person may only use the specific make(s) and model(s) of full-face, air-purifying respirators for which the person has obtained a satisfactory fit via the qualitative fit-testing procedures. Under no circumstances shall a person be allowed to use any make or model respirator not previously fit tested or having failed a fit-test period.
2. Fit-testing by use of a two-stage, cross-checking procedure provides the necessary quality assurance that the user of an air-purifying, cartridge/canister respirator is properly fitted and has a good facepiece-to-face seal.

## **A. Stage I**

### **1) Negative Pressure-Sealing Checks for Air-Purifying Respirators**

The wearer can perform this test by himself or herself in the field or office after donning the air-purifying respirator. It consists of closing off the inlet of the cartridge(s) to prevent the passage of air. This test is performed by closing off the inlet opening of the respiratory cartridge(s) by covering with the palm of the hand(s) so that it will not allow the passage of air, inhaling gently, and holding the breath for at least ten seconds. If a facepiece collapses slightly and no inward leakage of air into the facepiece is detected, it can be reasonably assumed that the fit of the respirator to the wearer is satisfactory.

This test is made only as a gross determination of fit when the respirator is to be used in relatively toxic atmospheres. Nonetheless, this test shall be used just prior to entering any toxic atmosphere.

### **2) Positive Pressure-Sealing Check for Air-Purifying Respirators**

This test is very much like the negative pressure-sealing check. This test is preferred after donning the air-purifying respirator which contains an exhalation and inhalation valve. The test is conducted by closing off the exhalation valve and exhaling gently. The fit of a respirator equipped with a facepiece is considered to be satisfactory if a slight positive pressure can be built up inside the facepiece for at least ten seconds without detection of any outward leakage of air between the sealing surface of the facepiece and the respirator wearer's face.

This test is also to be used only as a gross determination of fit when the respirator is to be used in relatively toxic atmospheres. This test shall be used just prior to entering any toxic atmosphere.

**NOTE:** Both the positive and negative pressure-sealing checks can be used on the MSA Model 401 air mask to determine the gross fit characteristics.

## **B. Stage II**

A person wearing an air-purifying respirator will be exposed to two test agents: isoamyl acetate (an odorous vapor) and stannic chloride (an irritant smoke). The air-purifying respirator will be equipped with an air-purifying cartridge which effectively removes the test agents from respired air. If the respirator wearer is unable to detect penetration of the test agent into the respirator, he has achieved a satisfactory fit.

### **1) Procedures for the Isoamyl Acetate Test**

Isoamyl acetate or banana oil is a chemical which produces a pleasant banana-smelling organic vapor. It is an easily detectable odor. The isoamyl acetate fit test will be conducted by using a plastic garbage bag as a test hood hung from the ceiling over a coat hanger suspended by twine. Inside the plastic bag, a piece of cloth saturated with isoamyl acetate is to be attached to the top portion of the bag. This procedure will produce a rough concentration of approximately 100 ppm in the test atmosphere.

inside the plastic bag. Most people can detect isoamyl acetate at 1-10 ppm. The permissible exposure is 100 ppm.

The isoamyl acetate fit test will be performed as follows:

- \* The wearer puts on the respirator in a normal manner. If it is an air-purifying device, it must be equipped with a cartridge(s) specifically designed for protection against organic vapors.
- \* The wearer enters the test enclosure, so that the head and shoulders are well inside the bag.
- \* If the wearer smells banana oil, he returns to clean air and readjusts the facepiece and/or adjusts the headstraps without unduly tightening them.
- \* The wearer repeats the second step. If he does not smell banana oil, he is assumed to have obtained a satisfactory fit. If he smells the vapor, an attempt should be made to find the leakage point. If the leak cannot be located, another respirator of the same type and brand should be tried. If this leaks, another brand of respirator with a facepiece of the same type should be tried.
- \* After a satisfactory fit is obtained, if the respirator is an air-purifying device, it must be equipped with the correct filter(s), cartridge(s), or canister for the anticipated hazard.

**NOTE:** During the test, the subject should make movements that approximate a normal working situation. These may include, but not necessarily be limited to, the following:

- \* Normal breathing.
- \* Deep breathing, as during heavy exertion. This should not be done long enough to cause hyperventilation.
- \* Side-to-side and up-and-down head movements. These movements should be exaggerated, but should approximate those that take place on the job.
- \* Talking. This is most easily accomplished by reading a prepared text and/or reciting the alphabet loudly enough to be understood by someone standing nearby.
- \* Other exercises may be added depending on the situation. For example, if the wearer is going to spend a significant part of his time bent over at some task, it may be desirable to include an exercise approximating this bending.

The major drawback of the isoamyl acetate test is that the odor threshold varies widely among individuals. Furthermore, the sense of smell is easily dulled and may deteriorate during the test so that the wearer can detect only high-vapor concentrations. Another disadvantage is that isoamyl acetate smells pleasant, even in high concentrations. Therefore, a wearer may say that the respirator fits although it has a large leak. Therefore check out these test results carefully and move on to the next atmosphere.

## 2) Procedures for the Irritant Smoke (Stannic Chloride) Test.

This qualitative test is similar to the isoamyl test in concept. It involves exposing the respirator wearer to an irritating smoke produced by commercially available smoke tubes. These are sealed glass tubes, approximately 12 cm long by 1 cm in diameter, filled with pumice impregnated with stannic chloride. When the tube ends are broken and air is passed through it, the material inside reacts with the moisture in the air to produce a dense, highly irritating smoke.

As a qualitative means of determining respirator fit, this test has a distinct advantage in that the wearer usually reacts involuntarily to leakage by coughing or sneezing. The likelihood of his giving a false indication of proper fit is reduced.

The irritant smoke test will be conducted by using a plastic garbage bag as a test hood. The bag will be hung from the ceiling over a coat hanger suspended by twine. A small hole is made in the top portion of the bag so that the irritant smoke can be dispensed into the bag when the test subject has entered the bag.

The irritant smoke fit test will be performed as follows:

- \* The wearer puts on the respirator normally, taking care not to tighten the headstraps uncomfortably. Once the respirator is on, the subject is to enter the suspended bag so that the head and shoulders are well inside the bag hood.
- \* Once the subject is inside the bag, the tester will begin to add the irritant smoke in small quantities at first, pausing between puffs from the applicator, listening for a reaction.
- \* If the wearer detects no leakage, the tester may increase the smoke density, still remaining alert to his reactions.
- \* At this point, if no leakage has been detected, the wearer may cautiously begin the head movements and exercises mentioned in the isoamyl acetate test. The tester should remain especially alert and be prepared to stop producing smoke immediately and remove the subject from the bag.
- \* If a leakage is detected at any time, the tester should stop the smoke and let the wearer out of the bag to readjust the facepiece or headstrap tension. The tester should then start the test at the second step.
- \* If at the end of all movements and exercise the wearer is unable to detect penetration of the irritant smoke into the respirator, the respirator wearer has a satisfactory fit.
- \* Remove the subject from the test atmosphere.

### **A.4 SELF CONTAINED BREATHING APPARATUS (SCBA)**

The SCBA is an atmosphere-supplying breathing apparatus. The SCBA is a positive pressure demand unit that can be used in an IDLH environment or in O<sub>2</sub>-deficient environments. The SCBA unit is an integral part of Level B and Level A protective ensembles.

## **Advantages And Disadvantages Of SCBA**

### **Advantages**

1. Operated in a positive pressure mode and can be an open circuit system which prevents ambient air breakthrough.
2. System is self-contained and mobile.
3. Chance of contaminant breakthrough is eliminated since filters or cartridges are not used.
4. If a leak occurs during use, the system vents outwardly regardless of leak location.
5. Warning alarm signals when 20-25% of the air supply remains.
6. Fogging problem in facepiece is reduced as compared to an APR.
7. Can work in an IDLH environment with an SCBA on.

### **Disadvantages**

1. Relatively short operating time (30 to 60 minutes), depending on cylinder capacity and wearer.
2. The SCBA unit weighs approximately 20 to 30 pounds fully charged.
3. Less mobile and more awkward in comparison to an APR.
4. Facepiece will fog up on occasion.
5. Distorted speech.
6. Reduction of worker efficiency due to weight.

### **Respirator Fit**

The Respirator facepiece will fit only 60% of the working population, but chances of contaminant breakthrough are minimized since the unit prevents any inflow of ambient air into the facepiece. If any leaks around the facial seal occur during use, the system vents outwardly, regardless of leak location, due to positive pressure demand.

Facial hair (beards, sideburns) is prohibited while wearing an SCBA because of the adverse effect on mask fit. Facial hair is prohibited by the Occupational Safety and Health Act of 1970.

Weight loss or gain and dental work may also affect fit of SCBA respirator masks.

### Mode Of Operation

#### A. Demand Unit - Positive Pressure Is Not Maintained At All Times

1. Negative pressure created by inhalation opens demand valves to draw clean air into the facepiece.
2. Due to negative pressure, contaminated air will be drawn in along the facepiece seal. Leakage may occur.
3. Air-conserving mode.

#### B. Positive Pressure Demand Unit

1. Demand valve is spring loaded to keep valve open.
2. Exhalation valve is spring loaded at a pressure slightly greater than the demand valve.
3. If leaks occur around the facepiece seal, the demand valve remains open, and the unit will vent continuously.
4. If leaks occur around the facepiece during inhalation, contaminants will be unable to enter the facepiece since a positive pressure is maintained in facepiece area.

#### C. Closed Circuit Unit - uses oxygen rebreathing. Air is recirculated and CO<sub>2</sub> is purified (scrubbed by alkaline scrubber) and oxygen from liquid or gaseous source replenishes the previously consumed oxygen.

#### D. Open Circuit Unit - supplies clean air to the wearer from an air cylinder and wearer exhales air directly into the environment.

### SCBA Air Quality And Testing Requirements

#### A. Cylinder air must be grade D or E.

<u>Limiting Characteristics</u>	<u>Grade D</u>	<u>Grade E</u>
O <sub>2</sub>	19.5-23%	19.5-23%
Hydrocarbons	5 ppm	5 ppm
Carbon Monoxide	20 ppm	10 ppm
Odor	None Pronounced	None Pronounced
Carbon Dioxide	1,000 ppm	500 ppm

#### B. Testing of cylinder air: Need to test every sixth cylinder or take a composite sample.

1. Oxygen Test - Use O<sub>2</sub> detector. Insert probe into a small plastic bag. Bleed cylinder air into a bag, sealing and/or tying off open end. Take reading.
2. Hydrocarbon Test - No condensed hydrocarbons should be apparent. Bleed cylinder air into a bag at room temperature and insert a small mirror into the bag for five minutes. Seal or tie off the bag and examine the mirror for condensed (vapor) droplets.
3. Carbon Monoxide Test - Insert Draeger tube for carbon monoxide into an air bag. Seal lid and take reading.
4. Odor - Air always has a slight odor, but no pronounced odor should be detectable.
5. Carbon Dioxide - Use Draeger tube as described in carbon monoxide test.

**NOTE:** Care must be taken when charging air cylinders with a compressor. Most compressors use a piston-type motor which requires oil to support compression. The oil can degrade air quality. Also, if compressors are used the ambient air must be of good quality. Use of cascading air system is preferred for cylinder refill.

#### Cylinder Test And Markings

##### A. Tests

Cylinder must be hydrostatically tested at 5/3 of the rated pressure every three years. Tank is usually checked internally and externally. Internal test is performed in a water jacket or by the use of an expansion gauge that is accurate to one percent of the tank expansion. Pressure in the tank must be maintained for 30 seconds.

##### B. Markings On Cylinders

1. DOT - E 7277 - 2216

DOT = Department of Transportation  
E 7277 = Exemption Number  
2216 = Charged Pressure

2. ALT 59 - 27/889 - a manufacturer's serial number.
3. Elastic Expansion = 96-106 ml in water jacket.
4. Hydrostatic Test Date = 9/79
5. SCI - Name of Cylinder Manufacturer
6. A - Hydrostatic Test Company Licensed by DOT
7. MSA Part #460320 - Part Number

## SCBA Components And Parts

### A. Regulator

1. Main Line Valve - regulates air as needed
2. Bypass Valve - allows air to flow continuously when open
3. Breathing Tube Connection - runs from regulator to facepiece

### B. Composite Cylinder

1. Pressure gauge
2. Rupture disk
3. Hand wheel and lock

### C. Audi-Larm

1. High pressure hose
2. Bell alarm - rings when 20 to 25% of air is left in cylinder

### D. Facepiece Breathing Tube

1. Valves
2. Gaskets and "O" rings
3. Nose cup

### E. Backpack and Harness Assembly

1. Cam key assembly
2. Straps and belt
3. Backplate
4. Clamp and spring

## Check Out Procedures

### A. General

- \* Inspect SCBA
  - before and after each use
  - at least monthly when in storage
  - every time they are cleaned
- \* Check all connections for tightness
- \* Check material conditions for:
  - signs of pliability
  - signs of deterioration
  - signs of distortion



3. Detailed checkout procedures

The high pressure hose connector should be tight on cylinder fitting.

The bypass valve should be closed.

The mainline valve should be closed.

There should be no cover or obstruction on regulator outlet.

The cylinder should be fully charged.

- \* If you encounter any regulator problem, set the unit aside until repair by an MSA technician can be made.

1. Straps

- a) Visually inspect for complete set.
- b) Visually inspect for frayed straps that may break during use.

2. Buckles

- a) Visually inspect for mating ends.
- b) Check locking function.

3. Backplate and Cylinder Lock

- a) Visually inspect backplate for cracks and for missing rivets or screws.
- b) Visually inspect cylinder hold-down strap and physically check strap tightener and lock to insure that it is fully engaged.

4. Cylinder and Cylinder Valve Assembly

- a) Physically check cylinder to insure that it is tightly fastened to back plate.
- b) Check hydrostatic test date to insure that it is current.
- c) Visually inspect cylinder for dents.

5. Head and Valve Assembly

- a) Visually inspect cylinder valve lock.
- b) Visually inspect cylinder gauge for condition of face, needle, and lens.
- c) Open cylinder valve and listen or feel for leakage around packing gland. (If leakage is noted, do not use until repaired.) Note function of valve lock.

6. High Pressure Hose and Connector

- a) Listen or feel for leakage in hose or at hose-to-cylinder connector. (Bubble in outer hose covering may be caused by seepage through hose when stored under pressure. This does not necessarily mean a faulty hose.)
- b) Check for presence and condition of O ring.

7. Regulator and Low Pressure Alarm Check Out

- a) Cover outlet of regulator with palm of hand. Open mainline valve and read regulator gauge (must read at least 1800 psi and no more than rated cylinder pressure).
- b) Close cylinder valve and slowly move hand from regulator outlet to allow slow flow of air. Gauge should begin to show immediate loss of pressure as air flows. Low pressure alarm should sound at about 500 psi down to 100 psi. Remove hand completely from outlet and close mainline valve.
- c) Place mouth onto or over regulator outlet and blow. A positive pressure should be created and maintained for 5 to 10 seconds without any loss of air. Next suck a slight negative pressure on regulator and hold for 5 to 10 seconds. Vacuum should remain constant. This tests the integrity of the diaphragm. Any loss of pressure or vacuum during this test indicates a leak in the apparatus.
- d) Open cylinder valve.
- e) Place hand over regulator outlet and open mainline valve. Remove hand from outlet and replace in rapid movement. Repeat twice. Air should escape each time hand is removed, indicating a positive pressure in chamber. Close mainline valve and remove hand from outlet.
- f) Ascertain that no obstruction in or over the regulator outlet. Open and close bypass valve momentarily to insure flow of air through bypass system.
- g) Check deflection and angle of aspirator control plate.

8. Facepiece and Corrugated Breathing Tube

- a) Visually inspect head harness for damaged serrations and deteriorated rubber. Visually inspect rubber facepiece body for signs of deterioration or extreme distortion.
- b) Visually inspect lens for proper seal in rubber facepiece, body for signs of deterioration or extreme distortion.
- c) Visually inspect exhalation valve for visible deterioration or foreign materials build-up.
- d) Check for protective lens cover.

9. Breathing Tube and Connector

- a) Stretch breathing tube and visually inspect for deterioration and holes.
- b) Visually inspect connector for good condition of threads and for presences and proper condition of the rubber gaskets.

**NOTE:** Final test of facepiece would involve a negative pressure test for overall seal and check for exhalation valve. If monthly inspection, mask must now be placed against face and following tests performed. If preparing for use, don backpack, then don facepiece and use following procedure.

10. Negative Pressure Test On Facepiece

With facepiece held tightly to face or facepiece properly donned, stretch breathing tube to open corrugations and place thumb or hand over end of connector. Inhale. Negative

pressure should be created inside mask, causing it to pull tightly to face. This negative pressure should be maintained for 5 to 10 seconds. If not, the facepiece assembly is not adequate and should not be worn.

#### Storage of Units

- 1) Cylinder refilled as necessary and unit cleaned and inspected.
- 2) Cylinder valve closed.
- 3) High pressure hose connector tight on cylinder.
- 4) Pressure bled off high pressure hose and regulator.
- 5) Bypass valve closed.
- 6) Mainline valve closed.
- 7) All straps completely loosened and laid straight.
- 8) Facepiece properly stored to protect against dust, sunlight, heat, extreme cold, excessive moisture, and damaging chemicals.

#### Donning Procedures

- A. Over-the-back method.
- B. Bypass valve operation.
- C. Tank Changing using buddy method.

#### SCBA Adjustments

##### A. High Pressure Air Line Hose

To adjust hose rotate the cylinder and the high pressure connector flywheel. This will prevent hose contact to the hip which can cause bruises.

##### B. Back Pad Adjustments

Adjust tension in the back pad to prevent contact of the back from the backplate. This prevents potential injury to the lower back from the backplate.

##### C. Audi-Larm Adjustment

Adjust Audi-Larm spring to proper tension.

##### D. Handwheel Spring Adjustment

This should be flush with the valve stem. Overtightening will overcompress the spring and cause leakage.

##### E. Packing Gland Adjustment

If the valves leak, tighten the hex nuts just enough to stop leakage. No more than one-quarter of a turn should be necessary.

#### F. Diaphragm Cap Adjustment

If the cap should come loose, retighten it by hand.

### A.5 MSA 401 OPERATIONAL SPECIFICATIONS

#### 1. GENERAL

Normal breathing rate = 6 liters/minute 12 breaths/minute (or 500 cc/breath x 12 breaths/minute = 6,000 cc/minute)

#### 2. CYLINDER

air supply time = average of 30 minutes

cylinder capacity = 45 cubic feet of air at 2216 psi = 1273.5 liters

cylinder rupture disk vents at = 3360 psi

#### 3. FACEPIECE

exhalation valve = calibrated at 1.5 inches H<sub>2</sub>O pressure over atmospheric

#### 4. AUDI-LARM

sounds at = about 500 psi down to 100 psi  
(= about 20% of cylinder volume)

#### 5. REGULATOR

positive pressure = 1 Inch H<sub>2</sub>O pressure over atmospheric

atmospheric pressure = 760 mm Hg - 29.9 inches HG - 14.6 psi

air delivery capacity = up to 400 liters/minute

low pressure relief valve = vents at 30-35 psi

high pressure release valve = vents at 105-125 psi

low side operating pressure = 25 psi

high side operating pressure = between 85-90 psi

### A.6 CLEANING AND SANITIZING OF RESPIRATOR FACEPIECE

- A. Facepiece and breathing tube should be cleaned and sanitized after each field use. This insures decontamination even if the unit is not dirty. Uses MSA cleaner solutions and follow procedures as outlined by directions which are printed on the cleaner package.

B. Disassembly of facepiece for cleaning.

1. Use MSA Cleaner-Sanitizer (Part #34337)

(NOTE: Do not use bleach or any cleaner-sanitizer other than a quaternary ammonium salt solution (50 ppm), hypochlorite solution (50 ppm), or iodine solution (50 ppm). The MSA-recommended cleaner should be used.)

2. Empty contents of package into a gallon of warm water at about 120° F.
3. Completely disassemble facepiece removing cartridges, inhalation and exhalation valves cartridge receptacle retainers, gaskets, and speaking diaphragm assembly.

(NOTE: Facepiece lens and speaking diaphragm clamp should not be removed. Overtightening of the clamp can cause leaking and damage the mask.)

4. Completely submerge disassembled facepiece in cleaner solution for about two minutes. Then scrub mask with a soft brush or sponge prior to rinsing with warm water. Allow mask to drip dry off if necessary, blow dry with electric dryer.
5. Reassemble mask.

**APPENDIX B.**

**MONITORING INSTRUMENTS**



## **B.1            INTRODUCTION**

In the course of field work, several different types of field instruments may be utilized. What follows is a description of several field instruments commonly utilized, and while for illustrative purposes some specific manufacturers and models are referred to, this is not a recommendation of a particular product or manufacturer.



## PHOTOIONIZER ANALYZER MODEL PI-101

### HNU SYSTEMS INC.

#### B.2 HNU

##### Capabilities:

Detects total concentration of many organic and some inorganic gases and vapors. Easy to use and has a rapid response (90% of actual concentration in three seconds for benzene). It has a useful range of 0-2000 ppm and a lower limit of detection of 0.1 ppm (benzene).

##### Theory:

Ambient air is drawn into the probe which contains an ultraviolet (UV) source. Since every molecule has a characteristic ionization potential, those molecules that are present with an ionization potential less than the probe energy are ionized. The ion pairs formed cause a current to flow between two electrodes. A readout of this current, which is proportional to the concentration of the ion pairs, is displayed on a meter. Probes of 9.5, 10.2 and 11.7 ev are available, but the 10.2 ev probe is the most useful. Although the 11.7 ev probe can detect more compounds than the other two probes, it has a useful life of only 12 hours, making it cost-prohibitive to use on a regular basis. Obviously if the presence of compounds that can be detected only by the 11.7 probe it will be used, instead of the 10.2 probe.

##### Limitations:

Materials with an ionization potential greater than the probe energy will not be measured. For instance, with a 10.2 ev probe, the following substances are among those which will not be detected:

Methane (12.98 ev)  
Hydrogen Sulfide (10.46 ev)  
Hydrogen Cyanide (13.91 ev)  
Carbon Dioxide (13.79 ev)

At the end of this section is a list of selected compounds and their responsiveness to various probes. For information and additional compounds, consult the NIOSH "Pocket Guide to Chemical Hazards," or other chemical reference books.

The repeatability of the meter reading is  $\pm 1\%$  of the full scale deflection (e.g., on the 0-20 ppm scale the uncertainty is  $\pm 0.2$  ppm). Therefore, at low concentrations near the detection limit the error could be quite large.

##### Pre Field Prep:

Make sure the batteries are fully charged and run through the calibration procedure to check instrument operation.

#### Calibration:

1. Attach the probe to the instrument, turn the unit on and leave the instrument in the standby position.
2. Allow five minutes for the instrument to warm up.
3. Zero the meter while still in the standby mode.
4. Set the switch to the appropriate range (0-200 ppm) for the calibration gas, and set the span as required for the probe used (span 9.8 for the 10.2 ev probe).
5. Attach regulator to calibration gas cylinder, and probe extension to the probe. Connect probe extension to calibration gas cylinder with plastic tubing. Turn on calibration gas regulator and wait about a minute for calibration gas to flow into probe. Then read the meter on the 0-200 ppm scale, and enter the meter reading and the actual concentration (read off the calibration gas cylinder) into the instrument logbook. The meter reading should be within 10% of the concentration given on the calibration gas cylinder. If the reading is off by more than 10% a trained operator should clean the lamp window (Refer to the operating manual).
6. It should be noted that this calibration gas cannot be carried on board passenger aircraft, therefore unless the team drives to the site the calibration gas has to be shipped in advance as dangerous goods via Federal Express.

#### Field Use:

After calibration is performed, detach the calibration gas cylinder and allow the instrument to purge for a few minutes. Then obtain a background reading on the 0-20 ppm scale in a clean area away from vehicles. Record this background in the field notebook, and then proceed with the survey of the anticipated work areas. It must be noted that the concentration readout is for benzene only, since the calibration gas is benzene or an equivalent. The instrument response to different compounds is relative to the calibration setting. See Table 2, for factors to convert benzene concentrations to concentrations for other compounds. The actual concentration of total contaminants can be higher or lower than the instrument readings. In addition, the response is not linear over the detection range (e.g., if the concentration increases by 10%, the meter will not necessarily rise by 10%). Figure 1 illustrates a typical calibration curve.

#### Tips:

The batteries are gel cells and it is not possible to overcharge them. Since the instrument has to be recalibrated every time it's turned off, it should be left in the standby mode after calibration, when not being used to take readings. The batteries should be charged overnight by first plugging the mini-phone jack from the charger into the instrument and then plugging the charger into the 120V mains. After charging is complete the charger should be removed from the 120V line before being unplugged from the instrument.

#### Troubleshooting:

If the reading is zero or negative, there is condensation present on the lamp. Move the instrument to a drier area so that the air drawn into the probe will remove the condensation by evaporation.

**PORTABLE ORGANIC VAPOR ANALYZER  
MODEL OVA-128  
CENTURY SYSTEMS**

**B.3            "OVA"**

Capabilities:

Responds to many organic gases and vapors. In the survey mode it detects total concentration of gases and vapors, while in the GC mode it identifies and measures specific compounds. The GC mode is not normally used for FIT work. The OVA is more sensitive and can detect more organic materials than the HNU. This is due to the fact that it uses a hydrogen flame for ionization and is, therefore, capable of ionizing compounds of higher ionization potentials than is possible with a UV lamp. The useful range is 0-1000 ppm with a lower limit of detection of 0.1 ppm (methane).

Theory:

Ambient air is drawn into the instrument by a pump where it is ionized in a hydrogen flame. Any compound that will ionize at a temperature below that of the flame (2000° F) will form ion pairs, which are drawn to electrodes causing a current flow that is proportional to the concentration of ion pairs.

Limitations:

Does not respond to inorganic gases or vapors, most importantly hydrogen cyanide. Also, any organic gas or vapor which requires a temperature higher than 2000° F for ionization will not be detected. The OVA should not be used below 40° because gases can condense within the pump.

Pre Field Prep:

Make sure the batteries are fully charged. Since they are gel cells there is no problem with overcharging. Also, check the hydrogen gas supply. It should be noted that due to this compressed hydrogen supply the instrument cannot be carried on board passenger aircraft and unless the team drives to the site has to be shipped as dangerous goods.

Calibration:

For use in the survey mode the OVA is internally calibrated to methane at the factory. Therefore, the instrument indicates the true concentration of methane in air; for all other organic compounds the instrument reading may be higher or lower than the true concentrations. Calibration charts can be made up to relate the instrument readings to the true concentrations or the instrument can be adjusted to directly read other specific compounds correctly.

Field Use:

The OVA is a fairly complex instrument and the operating manual should be consulted for detailed operating procedures. However, the basic operating procedure is presented below:

A. Start Up

1. Move the PUMP switch to the ON position.
2. Move the INSTR switch to the BATT position to check the condition of the battery.
3. Move the INSTR switch to ON and allow the instrument to warm up for at least five minutes.
4. Set the Alarm Level Adjust Knob on the back of the readout assembly so that the alarm comes on at the desired concentrations.
5. Set the CALIBRATE switch to the X10 position and then use the CALIBRATE knob to set the meter to zero.
6. Move the PUMP switch to the ON position and then place the instrument panel in a vertical position and check to ensure that the SAMPLE FLOW RATE INDICATOR reads about 2.
7. Open the H<sub>2</sub> tank valve and the H<sub>2</sub> supply valve.
8. Depress the ignite button until the burner lights (you will hear a "pop"); do not depress the igniter button for more than six seconds. If the burner does not ignite, let the instrument run for several minutes before reattempting ignition.
9. In a clean area use the CALIBRATE knob to zero out ambient background. For maximum sensitivity below 10 ppm set the CALIBRATE switch to x1 and readjust zero on the meter to 1 ppm. The zero is set at 1 ppm when using the x1 setting to avoid a false flame-out alarm; therefore, 1 ppm should be subtracted from any reading obtained down range (i.e., a 7 ppm reading is actually 6 ppm).

B. Shut Down

1. Close the H<sub>2</sub> supply valve H<sub>2</sub> tank valve.
2. Move the INSTR switch and PUMP switch to off.

Tips

Refer to the instrument operating manual.

Trouble Shooting

Refer to the instrument operating manual.

## B.4

## EXPLOSIMETER

### MODEL 2A COMBUSTIBLE GAS INDICATOR

#### Capabilities:

This instrument determines the level of flammable vapor and gas present in an atmosphere as a percent of the lower explosive limit (% LEL). A suction bulb is used to draw ambient air into the instrument through a built-in filter chamber that usually contains a cotton filter. The cotton filter removes any dust or moisture present in the sample. An activated charcoal filter can also be used which allows only methane to penetrate and then, obviously, the instrument reading is a measure of methane alone. (The working range of the instrument is 0 - 20,000 ppm). It should also be noted that the uncertainty of the explosimeter reading is  $\pm 40\%$ . The instrument can be fitted with extensions so it can sample air in recessed areas.

#### Theory:

The instrument contains a balanced electrical circuit (wheatstone bridge), one component of which is a coated filament. When a volume of ambient air is aspirated into the instrument, flammable materials present react exo-thermically with the filament. This increases the electrical resistance of the filament and unbalances the wheatstone bridge, and causes a current flow. This current is proportional to the concentration of the flammable materials in the sample, and is displayed on the meter as a % LEL. The lower explosive limit (LEL) is the minimum concentration of a flammable in air required to form an explosive mixture. The upper explosive limit (UEL) is the maximum concentration of the flammable substance that would form an explosive mixture. In other words, below the LEL the mixture is too lean to explode and above the UEL it is too rich to explode.

#### Limitations:

The instrument does not indicate what specific material is being detected. The meter reading is just the % LEL. Some chemicals can react with the filament and ruin it. Examples are fuming acids, leaded gasoline or any compounds containing silicon. The instrument will also not register above the UEL due to overloading of the bonding sites on the coated filament. The instrument is also not capable of measuring the explosive potential of atmospheres containing suspended dust particles such as coal dust or mists and sprays such as lubricating oil. Since the response of the instrument is due to the temperature change of the filament wire, rapid fluctuations in ambient temperatures will lead to incorrect readings. As the instrument is operated, the bonding sites on the coated filament are used up and the response of the instrument changes. Also, the instrument will not function correctly in an oxygen deficient (< 19.5%) or oxygen rich (> 25%) atmosphere. Therefore, the explosimeter should always be used in conjunction with an oxygen meter. When the explosimeter is used, the relative humidity must be between 10-90%.

#### Pre Field Prep:

Turn the instrument on and go through the calibration check procedure in order to ensure that the instrument is operating correctly. Six extra D-cells should be taken with the instrument.

#### Calibration:

The calibration check gas, which is 2% methane, should read 50-60% LEL. This calibration gas is not accurate enough for actual calibration but is useful for checking the operation of the instrument.

If the instrument reads low, the filament and inlet filter should be replaced (refer to the instruction manual).

#### Field Use:

Lift the lever on the switch and turn the knob one quarter turn clockwise. In an area free of flammable gas or vapor, pump the bulb five times to purge the instrument with fresh air (the bulb should be pumped two more times for every extension). The zero can now be set. The explosimeter is then taken to the area that needs to be tested. Five pumps on the bulb is usually enough to obtain a maximum meter deflection (with two additional pumps for every extension).

Action Levels: 0-10% LEL continue with work  
10-25% LEL, continue work with constant monitoring  
> 25% LEL, leave the site

#### Tips:

If the meter needle moves rapidly to the extreme right and upon continued aspiration to the left of the scale, the ambient atmosphere might be above the UEL. Under such conditions the meter deflection occurs very rapidly and drops back down. Thus, if the operator was not watching the scale continuously the deflection could be missed completely. Move the instrument to a clean area and rezero it after pumping the bulb five times to purge it of all flammable vapor or gas. At all times, when zeroing, avoid turning the knob so that the meter needle moves much above zero since this allows a larger current to flow through the filament, thus shortening its life. After each use do not turn the instrument off until it is purged well with clean air. The life of the filament also depends on how long it remains in contact with flammable gas or vapor, so the instrument should be flushed as soon as possible after each use.

#### Troubleshooting:

If the reading drifts, it is an indication that the batteries are running down. If the needle remains below zero and cannot be brought back up to zero even with the control knob turned to its extreme clockwise position, it means that the batteries are dead. Remove the bottom of the instrument by turning the two slotted screws that hold it in place. The cells operate in parallel so they should be installed with their positive terminals toward the top of the battery compartment. If the meter needle moves to the extreme right when the instrument is turned on and cannot be adjusted to zero, the filament may be burned out. A replacement is included in the case of the instrument below the top panel. Three screws holding the panel down have to be removed first. Refer to the instrument manual for the correct procedure to replace the filament detector.

### **B.5 OXYGEN METER**

#### **MSA MODEL 245R.**

#### Capabilities:

Measures oxygen content of air to determine if a suitable atmosphere is available on site (i.e., > 19.5% to < 25% O<sub>2</sub>). All personnel working in an oxygen deficient atmosphere (< 19.5% O<sub>2</sub>) will have to use approved positive pressure SCBA. In an oxygen rich atmosphere (> 25% O<sub>2</sub>), aside

from the hazard due to the reactivity of such high concentrations of oxygen, it should also be noted that the explosimeter cannot be used. The oxygen meter automatically compensates for temperatures between 32° F and 104° F.

#### Theory:

The instrument consists of a probe connected to a box containing electronics and a meter display. The probe consists of two electrodes in contact with an electrolyte which is separated from the test atmosphere by a gas permeable membrane. Oxygen diffuses through this membrane at a rate proportional to the difference in partial pressure across the membrane, which in turn is proportional to the concentration of oxygen in the test atmosphere. Due to the oxygen diffusion into the electrolyte, a current flows between the electrodes, and is displayed on the meter as percent oxygen.

#### Limitations:

A log should be kept on Sensor Replacement since their operational life is approximately one year. The probe should not be allowed to get wet or be used under conditions where moisture could condense on the probe membrane since this will cause the reading to be lower than the true value. High concentrations (> 5000 ppm) of chlorine, fluorine, ozone and acid mists will yield erroneously high readings. Atmospheres with > 10% CO<sub>2</sub> reduce the life of the sensor.

#### Pre Field Prep:

Check the instrument response and calibration to ensure that it is operating properly.

#### Calibration:

Press and hold down the red button on the side of the case while exposing the probe to fresh air offsite. After the reading stabilizes, set the meter at 20.8 (if at sea level) using the adjustment screw.

If the meter is going to be used outside the 32° F to 104° F range, then it has to be calibrated according to the manufacturer's instructions.

#### Field Use:

After calibration in fresh air the probe is placed in the atmosphere to be tested. The red button is pressed and held down. Then the percent oxygen can be read off the scale.

#### Tips:

Make sure an extra 9V battery is taken along with the instrument. Also, it should be noted that the instrument cannot be used below 0° F or above 125° F

#### Troubleshooting:

If the response is getting slow, the sensor is probably approaching the end of its useful life. In addition, if the instrument cannot be adjusted as necessary (e.g., to 20.8% O<sub>2</sub> for fresh air at sea level) either the probe or battery needs to be replaced.

## B.6

### DRAEGER PUMP AND TUBE

The Draeger Tube Air Grab Sampler consists of a bellows pump for drawing air and species-dependent detector tubes. A color change indicates the presence of the gas and the length of the color change is proportional to the concentration of the gas.

#### Capabilities:

Although a semi-quantative method at best, detector tubes are available for gases which are not detected by the OVA and HNU, and which would poison the filament of the explosimeter and oxygen indicator. Some examples would be hydrogen sulfide, sulfur dioxide, sulfur trioxide, hydrogen chloride, hydrogen cyanide and chloride.

#### Limitations:

1. Because the tubes contain silica gel, high humidity may affect results.
2. Many types of tubes have cross sensitivities to the substances and will, therefore, give incorrect readings in atmospheres containing substances other than the gas being measured. The instructions that come with the tubes list these cross sensitivities.
3. Draeger tubes must be used in a Draeger pump. Pumps and detector tubes supplied by different manufacturers are not interchangeable.
4. The shelf life of most Draeger tubes is two years when stored at room temperature. Exposure to sunlight and to temperatures in excess of 30° C will rapidly deteriorate tube performance.
5. Contaminants and the identity and approximate amount of contaminants in the atmosphere must be known in order to evaluate cross-sensitivities of the reagent and to ensure a sensitive enough detection limit of the selected tube.
6. The tube response time is relatively slow. If ten pumps are required before a color change is noted, then 1.5 to 6.5 minutes may have passed.

This time factor could seriously compromise health and safety, if the air on site is severely contaminated.

#### Prefield Prep:

Check the pump for leaks.

##### Test #1:

Insert an unopened Draeger tube and completely compress the bellows. The pump is sufficiently air-tight if the bellows has not expanded again completely after 10 minutes, i.e., the limit chain is not taut.

##### Test #2:

Compress the bellows without inserting a detector tube. The bellows should open suddenly



after releasing the pressure.

If pump fails either Test #1 or Test #2, maintenance work is necessary.

#### Field Use:

- A. Break off both tips of the Draeger tube in the break-off eyelet or in the break-off hush.
- B. Insert the tube tightly into the pump head with the arrow pointing toward the pump.
- C. Fully compress the bellows.
- D. Straighten the fingers. The suction process takes place automatically and is completed when the limit chain is taut. (The bellows is calibrated to draw in 100 cm<sup>3</sup> of air per stroke. Since the suction of the pump is caused only by the relaxation of the springs, any subjective influence is excluded.)
- E. Repeat the suction process as often as specified in the Tube Operating Instructions. The resistance to the air coming through the tube, varies with the type of Tube Packing and the "opening time" of the bellows is therefore affected. This time ranges from 3-40 seconds. Read the color change in the tube according to the tube operating instructions, to derive a concentration value.
- F. Remove the spent tube and dispose of it on site.
- G. Before putting the bellows pump away, flush it out with air, making a few strokes without a detector tube in a clean environment.

#### Maintenance:

##### Eliminating Leaks:

Any leaks can usually be eliminated by cleaning the valve. To do this, remove the front plate and unscrew the valve using the special spanner. Raise the valve disc to prevent it from being damaged by the spanner. Clean the valve by blowing it through with air or by rinsing it with water. Dry it after cleaning.

If the rubber of the valve disc is sticky, brittle, hard or cracked, it must be replaced. Remove the pin from the valve seat stem and push in the pin of the new valve seat. It is best to moisten the pin a little first. When fitting the cover plate, ensure that the limit chain is not twisted and that the fixing hook lies in the longitudinal direction of the pump, so that it fits satisfactorily in the slot of the cover plate.

##### Cleaning of the Metal Screen:

After prolonged use of the bellows pump, the wire mesh sieve under the rubber bung in the pump head may become blocked. The sieve must, therefore, be cleaned from time to time, about every four weeks when the pump is used frequently. Loosen the two-hole nut with the special spanner and remove the rubber bung. Take out the sieve and clean it with a brush under running water. When re-inserting the two-hole nut, tighten it only until the rubber bung is just under stress and the Draeger Tube can be inserted easily, but tightly.

#### Flushing the Pump with Air:

During testing, certain tube types give off vapors which pass into the interior of the bellows pump (e.g., sulfuric acid mist). To prevent corrosion, flush out the pump with air by making a few strokes without a detector tube every time it has been used.

#### Tips:

1. Be familiar with the specific detector tube prior to field use. For example, some tubes require breaking an ampule prior to pumping, or require a color comparison tube. Estimate the response time based on the sensitivity of the detector tube and the anticipated gas concentration.
2. A Draeger detection tube has a typed designation. This defines the smallest concentration which can be exactly measured with the tube (ppm or mg/l). A letter after this number is changed when changes in the construction or properties of the tube occur:

e.g., Draeger tube H<sub>2</sub>S1/C

The number "1" means that the minimum amount of hydrogen sulfide measured by this tube is 1 ppm (with the number of strokes of the gas detector pump specified for the tube). The letter "C" indicates that an "a" and a "b" tube for H<sub>2</sub>S have been manufactured, but have different construction or different minimum detection level.

---

## SITE HEALTH AND SAFETY PLAN FOR UNDERGROUND STORAGE TANK INSPECTIONS

---

The following is a generic site health and safety plan for underground storage tank inspections. As indicated throughout the plan, selected sections should only be filled out by people with technical expertise in health and safety issues. In addition, State organizations using this plan should set up a system to ensure that: (1) the plan is used properly and (2) staff follow proper safety procedures.

### PART I

Part I (Sections I-IV) should be completed by the UST inspector prior to the site visit.

---

#### SECTION I. GENERAL SITE INFORMATION

---

SITE NAME AND ADDRESS:

CONTACT PERSON AND PHONE NUMBER:

SITE IDENTIFICATION NUMBER:

PROPOSED DATE(S) OF SITE WORK:

---

#### SECTION II. DESCRIPTION OF INSPECTION ACTIVITY

---

PURPOSE OF ACTIVITY:

New Tank Installation	( )
Tank Closure	( )
Tank/Pipe Removal	( )
Tank/Pipe Disposal	( )
Petroleum Release Investigation	( )
Tank/Pipe Repair	( )
Leak Detection Testing	( )
Installation of Monitor Wells/Sampling	( )

---

---

PROVIDE A BRIEF NARRATIVE DESCRIPTION OF THE PROPOSED INSPECTION ACTIVITIES:

---

**SECTION III. SPECIFIC SITE INFORMATION**

---

SPECIFIC TANK SYSTEM INFORMATION:

Age/Size/Capacity of Tanks and Piping:

Contents of Tank:

Other (Specify):

---

TYPE OF SITE

CHECK ALL APPROPRIATE:

<input type="checkbox"/> Active	<input type="checkbox"/> TSDF
<input type="checkbox"/> Inactive	<input type="checkbox"/> R & D Facility
<input type="checkbox"/> Industrial facility	<input type="checkbox"/> Military base
<input type="checkbox"/> Gas station	<input type="checkbox"/> Other (Specify)

---

RELEASE HISTORY

No evidence of leaks or soil contamination ( )

Suspected or known leaks and soil contamination ( )

Known groundwater contamination ( )

---

BACKGROUND AND DESCRIPTION OF ANY PREVIOUS INVESTIGATIONS OR INCIDENCE:

---

BACKGROUND INFORMATION STATUS: ( ) COMPLETE ( ) INCOMPLETE

---

**SECTION IV. POTENTIAL HEALTH AND SAFETY HAZARDS**

---

ANTICIPATED PHYSICAL HAZARDS OF CONCERN: (CHECK ALL THAT APPLY AND DESCRIBE)

☐ Heat (high ambient temp.)  
☐ Cold  
☐ Noise  
☐ Oxygen depletion  
☐ Asphyxiation

☐ Heavy equipment  
☐ Physical injury and trauma resulting  
from moving machinery

☐ Excavation  
☐ Cave-ins  
☐ Falls, trips, slipping

☐ General construction  
☐ Physical injury and trauma  
☐ Electrical Hazards

☐ Handling and transfer of petroleum  
products  
☐ Fire  
☐ Explosions

☐ Confined space entry  
☐ Explosions  
☐ Other (Specify)

---

ANTICIPATED BIOLOGICAL HAZARDS: (LIST BELOW)

☐ Snakes ☐ Poisonous plants  
☐ Insects ☐ Other  
☐ Rodents

---

NARRATIVE: (Provide all information which could impact Health and Safety -- e.g., power lines, integrity of dikes, terrain, etc.)

---

ANTICIPATED CHEMICAL HAZARDS: (LIST BELOW ALL CHEMICALS PRESENT ON SITE; ATTACH MATERIAL SAFETY DATA SHEETS-MSDS)

---

- 1.
  - 2.
  - 3.
  - 4.
  - 5.
  - 6.
  - 7.
  - 8.
  - 9.
  - 10.
-

---

## PART II

Section V should only be completed by persons with technical expertise in health and safety.

---

### SECTION V. EVALUATION OF POTENTIAL HAZARDS

#### CHEMICALS OF CONCERN

<u>Chemical</u>	Highest Observable Concentration (media)	PEL/ TLV	<u>IDLH</u>	Symptoms/ Effects of Acute Exposure
-----------------	--	-------------	-------------	---

---

### PART III

---

Sections VI and VII should be completed by the UST inspector prior to the site visit.

### SECTION VI. METHODS TO CONTROL POTENTIAL HEALTH AND SAFETY HAZARDS

---

MONITORING INSTRUMENTATION: (NOTE: MONITORING INSTRUMENTS MUST BE USED FOR ALL OPERATIONS UNLESS APPROPRIATE RATIONALE OR RESTRICTIONS ARE PROVIDED).

- ☐ Organic Vapor Analyzer
  - ☐ Photoionization Detector
  - ☐ Combustible Gas Indicator (CGI)
  - ☐ Oxygen Meter
  - ☐ Hydrogen Sulfide Meter
  - ☐ Detector Tubes (specify)
  - ☐ Other, specify (toxic gas, air sampling pumps, etc.)
- 

IF MONITORING INSTRUMENTS ARE NOT USED, SPECIFY RATIONALE OR JUSTIFICATION OR ACTIVITY/AREA RESTRICTIONS.

---

#### ACTION LEVELS (breathing zone):

---

##### Combustible Gas Indicator

- |         |     |   |
|---------|-----|---|
| 0 - 10% | LEL | No Explosion Hazard   |
| 10 -25% | LEL | Potential Explosion Hazard; Notify Site Health and Safety Officer |
| >25%    | LEL | Explosion Hazard; Interrupt Task/Evacuate                         |



**ACTION LEVELS (breathing zone): continued**

**Oxygen Meter**

<21.0%	O <sub>2</sub>	Oxygen Normal
<21.0%	O <sub>2</sub>	Oxygen Deficient; Notify Site Health and Safety Officer
<19.5%	O <sub>2</sub>	Oxygen Deficient; Interrupt Task/Evacuate

---

**Photolionization  
Detector**

Specify:

( )	11.7 ev
( )	10.2 ev
( )	9.8 ev

Type:

---

**Flame Ionization  
Detector**

Specify:

Type:

---

**Detector Tubes**

Specify:

Type

Type

Type

---

**PERSONAL PROTECTIVE EQUIPMENT:** List all applicable items

Minimum personal protective equipment:

1. Hardhat
2. Safety glasses/goggles
3. Steel toed/shank shoes or boots
4. Flame retardant coveralls
5. Hearing protection (muffs or ear plugs)

Is additional PPE required?

YES / NO

PERSONAL PROTECTIVE EQUIPMENT continued

Check all additional necessary items:

- |  |  |
|--|--|
| <input type="checkbox"/> Uncoated tyvek coveralls                  | <input type="checkbox"/> Full face respirators |
| <input type="checkbox"/> Saranex tyvek coveralls                   | type of cartridge: <input type="checkbox"/>    |
| <input type="checkbox"/> Rubber boots                              | <input type="checkbox"/> SCBA / SAR            |
| <input type="checkbox"/> Overboots                                 | <input type="checkbox"/> ELSAs                 |
| <input type="checkbox"/> Surgical (inner) gloves                   | <input type="checkbox"/> Other (specify):      |
| <input type="checkbox"/> Butyl/neoprene/viton/nitrile outer gloves |  |

---

**VII. EMERGENCY INFORMATION**

---

Emergency Contact:

Fire/Rescue:

Ambulance:

Police:

Hazardous Waste Material Response Units

Health and Safety Director:

Poison Control Center:

On-site medical facility (clinic): YES / NO

Facility health and safety officer: YES / NO

Name:

Phone number:

Hospital Name and Address:

Directions to hospital (include a map):

**PART IV**

---

**SECTION VIII. PLAN APPROVAL**

---

Plan prepared by: \_\_\_\_\_  
(Date)

Plan approved by: \_\_\_\_\_  
(Date)

Plan approved by: \_\_\_\_\_  
(Date)