

TRAINING COURSE
FOR
MULTI-MEDIA INSPECTORS

Student Manual

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SECTION II HEALTH AND SAFETY FOR FIELD ACTIVITIES

**SECTION III FUNDAMENTALS OF ENVIRONMENTAL COMPLIANCE
INSPECTIONS**

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MEXICAN ENVIRONMENTAL PROGRAM
OVERVIEW

HEALTH AND SAFETY MANUAL
FOR
FIELD ACTIVITIES

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INTRODUCTION

The Basic Health and Safety section of this SEDESOL inspectors' training course has been developed using many materials on occupational safety and health that are part of the training for inspectors from the United States Environmental Protection Agency (EPA). Their training is designed to protect them from many of the same hazards that you too will face. By following the practices detailed herein, you can help ensure your own health and safety and ultimately that of your family members as well.

In some places in your manual you will see references to standards or rules set by U.S. agencies such as the Occupational Safety and Health Administration (OSHA) or the National Institute for Occupational Safety and Health (NIOSH). The standards that these agencies establish for individuals who come in contact with hazardous materials, or who work under hazardous conditions, are based upon the best scientific estimates of conditions that are acceptable to maintain the good health of workers. You may see reference, for example, to Permissible Exposure Limits (PELs); it is believed that most people who are exposed to the PEL of a harmful substance during the course of an eight-hour work day will not experience any harmful effect from such exposure. Exceeding a PEL puts you at an increased risk to the toxic effects of hazardous materials.

You will also see references to rating standards for protective equipment or monitoring instruments. In the United States an independent group called Underwriters Laboratory (UL) examines and rates electrical equipment (including monitoring equipment) for safe use under different conditions. Inspectors are advised to look for these rating systems to help them evaluate whether or not equipment is safe to use under the expected work conditions. For instance, a monitoring device that is not spark proof may pose a severe risk if it is used in an environment that has sufficient concentrations of explosive vapors or dust.

Additional information pertaining to health and safety issues can be obtained from your instructors and the reference materials listed in this manual.

OPENING STATEMENT

**BASIC HEALTH AND SAFETY MANUAL
FOR FIELD PERSONNEL**

Field inspections involve a certain degree of risk. Inspections of wastewater treatment plants, manufacturing plants, laboratories and mines are each associated with various hazards. A safe field inspection depends on the recognition, evaluation and control of hazards. During field activities, it is not always possible to eliminate hazards. However, it is possible to reduce the risk associated with these hazards, through the use of monitoring or testing equipment, engineering controls, personal protective equipment and employee training.

This course manual is an introduction to the basic health and safety training required for conducting field activities. The goal of this manual is to provide you with the information necessary to make the correct health and safety decisions in the field. This manual examines health and safety principles and identifies methods to recognize and evaluate the hazards associated with field activities.

LIST OF ABBREVIATIONS AND ACRONYMS

| | |
|--------------|--|
| ACGIH | American Conference of Governmental Industrial Hygienists |
| ANSI | American National Standards Institute |
| CFR | Code of Federal Regulations |
| CPR | Cardiopulmonary Resuscitation |
| CHRIS | Chemical Hazard Response Information System |
| EPA | Environmental Protection Agency |
| IDLH | Immediately Dangerous to Life or Health |
| LEL | Lower Explosive Limit |
| MSHA | Mine Safety and Health Administration |
| NFPA | National Fire Protection Association |
| NIOSH | National Institute for Occupational Safety and Health |
| OSHA | Occupational Safety and Health Administration |
| PAPR | Powered Air-Purifying Respirator |
| PEL | Permissible Exposure Limit |
| PPE | Personal Protection Equipment |
| REL | Recommended Exposure Limit |
| SAR | Supplied-Air Respirator |
| SCBA | Self-Contained Breathing Apparatus |
| TLV | Threshold Limit Value |
| TWA | Time Weighted Average |
| UEL | Upper Explosive Limit |
| USCG | U.S. Coast Guard |

CHAPTER 1

1.0 PREPARATION FOR FIELD ACTIVITIES

1.1 OBJECTIVE

To identify key elements that must be considered when preparing for field activities.

1.2 INTRODUCTION

| | |
|----------------------------------|--|
| Importance of Preplanning | <ul style="list-style-type: none">• Field personnel encounter a wide variety of potential hazards.• Preplanning can reduce or eliminate many hazards. |
| Planning Process | <ul style="list-style-type: none">• Research potential hazards.• Evaluate the risks.• Select appropriate protective equipment and clothing. |
| Sources of Information | <ul style="list-style-type: none">• Plant personnel• Agency files• Agency employees• Industry standard references |

1.3 PRE-FIELD ACTIVITY EVALUATION

| | |
|---|---|
| Planning Guide | <ul style="list-style-type: none">• Prepare planning guide. (See Appendix 1-A).• Acquire pertinent medical records and other information.• Take guide and information to the site.• Leave a copy with your supervisor. |
| Components of the Planning Guide | <ul style="list-style-type: none">• Activity location<ul style="list-style-type: none">- name and address- contact name and telephone number- photographs• Historical information |

- Activity schedule
- Inspection personnel
 - names
 - restrictions
 - required training
- Lodging
- Hazards
 - transportation (distances, chemicals, supplies, test equipment, etc.)
 - noise
 - fire/explosion
 - biological
 - weather-related
 - chemicals
 - atmospheric
 - thermal
 - radiological
 - confined space
 - drowning
 - physical and mechanical (height, machinery, etc.)
- Vehicles
- Required permits
- Emergency and rescue
 - communication (telephone, two-way radio, etc.)
 - warning signals (fire, evacuation, severe weather, etc.)
 - hospitals, emergency assistance personnel
- Personal protective equipment and clothing
- Miscellaneous

1.4 ONSITE EVALUATION

- Request a health and safety briefing.
- Conduct a walk-through survey.
 - hidden hazards
 - natural hazards
- Record unexpected hazards, additional gear requirements.

APPENDIX 1-A

SAMPLE SAFETY AND HEALTH PLANNING GUIDELINE FOR FIELD ACTIVITIES

Facility/Site: _____

Location: _____

Agency files exist ____ Yes ____ No

If yes, list pertinent historical information _____

DATES AND LENGTH OF PROPOSED ACTIVITY: _____

SITE CONTACTS:

| Name | Position | Tel. Number |
|-------|----------|-------------|
| _____ | _____ | _____ |
| _____ | _____ | _____ |
| _____ | _____ | _____ |

INSPECTION TEAM:

| Name | Medical monitoring | Field training | Respiratory training | Medical/Physical restrictions |
|-------|-----------------------|-------------------|-------------------------|----------------------------------|
| _____ | _____ | _____ | _____ | _____ |
| _____ | _____ | _____ | _____ | _____ |
| _____ | _____ | _____ | _____ | _____ |
| _____ | _____ | _____ | _____ | _____ |

LODGING ARRANGEMENTS: Motel/Hotel _____

Location _____ Telephone _____

SITE ACCESS REQUIREMENTS:

Identification _____

Permits _____

Visitor's agreement _____

Special problems _____

Type of communication needed _____

VEHICLE(S) AND EQUIPMENT:

Motor Vehicles _____

Make _____ License Plate _____

Mobile laboratory _____ Other (list) _____

Vehicle safety check made? ____ yes ____ no

Boat/Airplane will be used? ____ yes ____ no

List vehicle to be used _____

Boat/plane safety check made? ____ yes ____ no

ANTICIPATED HAZARDS TO CONSIDER:

Driving distance _____ Biological hazards _____

Hauling reagents _____ Radiological hazards _____

Hauling test equipment _____ Noise _____

Moving hazards _____ Heights _____

Thermal hazards _____ Confined space _____

Chemical hazards _____ Weather _____

Flammable hazards _____ Terrain _____

TOXIC SUBSTANCES (LIST):

| | | |
|-------|-------|-------|
| _____ | _____ | _____ |
| _____ | _____ | _____ |
| _____ | _____ | _____ |
| _____ | _____ | _____ |
| _____ | _____ | _____ |

HAZARD MONITORING EQUIPMENT:

| | | |
|-------|-------|-------|
| _____ | _____ | _____ |
| _____ | _____ | _____ |
| _____ | _____ | _____ |
| _____ | _____ | _____ |
| _____ | _____ | _____ |

EMERGENCY SIGNALS AND COMMUNICATION:

Fire signal is _____

Evacuation signal is _____

Severe weather signal is _____

Toxic release signal is _____

EMERGENCY AND RESCUE:

Is first aid available in the area? ____ yes ____ no

Location _____ Telephone # _____

Is ambulance available? _____ on site _____ on call Tel. # _____

Nearest hospital with emergency services: Location _____

_____ Telephone # _____

Heavy and special rescue services/equipment available: Yes/No _____

Specify: _____

PERSONAL PROTECTIVE EQUIPMENT/CLOTHING: (Check if needed)

Eyes and Head

Safety glasses _____ Type _____

Face shield _____ Goggles _____

Hard hat _____ Type _____

Hearing protection _____ Type _____

Other _____

Body, Hands, Feet

Coveralls _____ Type _____

Foul weather gear _____

Fully encapsulating gear _____

Safety footwear _____ Type _____

Boot/shoe covers _____

Gloves _____ Type _____

Other special equipment/clothing _____

Respiratory Protection

Air-Purifying Respirator _____ Type _____

Cartridge, Filters _____ Type _____

SCBA _____ Type _____

Emergency Escape Mask _____ Type _____

Airtank Full ____ yes ____ no

Special Health and Safety Equipment

Life belt _____

Safety line _____

Other _____

Decontamination Supplies

Waste bags and ties _____

Cleaning solution _____

Disposable brushes _____

Disposable towels and towelettes _____

Disposable containment tubs _____

MISCELLANEOUS

Rope _____ String _____ Tape _____

Matches _____ Food _____ Additional Clothing _____

Potable Water _____

Note:

A copy of this summary should be taken along for reference in the event of an emergency. A second copy should be filed with a supervisor before leaving for the site. Such information is particularly important for visits to sites where crews may be stranded or lost.

CHAPTER 2

2.0 HAZARDS, EXPOSURE AND EVALUATION

2.1 OBJECTIVE

To provide information regarding general safety considerations, how exposures to hazardous chemicals may occur, how to assess these hazards, and how to protect oneself and others.

2.2 INTRODUCTION

- Inspectors will encounter a variety of physical, biological, and chemical hazards during inspections.
 - Exposure to chemicals is the most common and significant health hazard field personnel encounter.
 - Chemicals may be hazardous because they are toxic, flammable, combustible, explosive, corrosive, reactive, radioactive, biologically active, or some combination of these and other characteristics.
 - Inspectors should learn basic first aid techniques.
-

2.3 SAFETY GUIDELINES AND TECHNIQUES

- Lifting and carrying
- Ladders and climbing
- Power sources and electrical equipment
- Confined spaces
- Mechanical hazards
- Biological hazards

Lifting and Carrying

- Assess the following:
 - overall weight
 - distribution of weight
 - security of contents
 - distance
 - obstacles
 - surface conditions
 - visibility
- Use two people.
- Lift with power of leg muscles.
- Do not climb ladder with heavy load.

Ladders and Climbing

Portable Ladders

- Inspect ladders for hazards.
- Position ladder base 1/4 of working length from wall.
- Use only ladders with non-skid feet; be sure ladder rests on non-slip level surface.
- Wear appropriate clothing.
- Do not use:
 - step ladders > 6 m (20')
 - straight ladders > 9 m (30')
 - two-section extension ladders > 15 m (48')
 - three-section extension ladders > 18 m (60')
- Face ladder when climbing and descending.
- Have someone stabilize bottom.
- Do not hand carry anything up the ladder.
- Prevent tools and equipment from catching on ladder or falling.
- Do not use ladder as scaffold or bridge.
- Do not permit more than one person on ladder.
- Do not reposition ladder while on it.

| | |
|--|---|
| <i>Fixed Ladders</i> | <ul style="list-style-type: none"> • Minimum design load: 91 kg (200 lbs) • Evenly spaced stepping surface ≤ 30 cm (12") • Adequate clearance • Minimum 18 cm (7") clearance behind each rung • Safety devices or cages: > 6 m (20') • Pitch: 75°-90° |
| Working Surfaces | <ul style="list-style-type: none"> • Check integrity of elevated platforms before climbing up to them. • Discontinue inspection if personal safety is jeopardized. |
| Power Sources/ Electrical Equipment | <ul style="list-style-type: none"> • Shut off power where possible. • Remove highly conductive equipment if power cannot be shut off. • Wear protective gear - hard hats, gloves, etc. |
| <i>Electrical cords/plugs</i> | <ul style="list-style-type: none"> • Inspect periodically and repair. • Use three-wire equipment. • Ensure continuity of grounding wire. • Ensure diameter of wires is sufficient to prevent loss of voltage or overheating. |
| <i>Uninsulated Electrical Conductors or Metal Parts</i> | <ul style="list-style-type: none"> • Ensure exposed metal parts of electrical equipment are grounded. • Use a Ground Fault Circuit Interrupter (GFCI) in the line. • Use double-insulated power tools. |
| <i>Static Electricity</i> | <ul style="list-style-type: none"> • Sources include: <ul style="list-style-type: none"> - particulates in process stream - electrostatic precipitators - lightning • Safety precautions: <ul style="list-style-type: none"> - ground sampling probes - be aware of weather conditions - discontinue sampling where lightning hazard exists - use A.M. radio for weather reports/static interference |
| Mechanical Hazards | <ul style="list-style-type: none"> • Remotely controlled vehicles • Forklifts • Potential entanglements |

- Confined Space** • See booklet for information on confined space entry.
- Biological Hazards** Entering certain locations can be hazardous due to the presence of various biological hazards.
- Ticks**
- Live in areas with tall grasses, bushes.
 - Burrow into skin and suck blood.
 - Transmit Rocky Mountain Spotted Fever, Lyme's Disease.
 - Wear light-colored clothing; tuck pant legs into socks.
 - Examine body for presence of ticks.
 - Seek medical help if fever, rash or bull's eye pattern develops.
- Snakes**
- Learn to recognize poisonous varieties.
 - Wear knee-high, thick, leather boots and leather gloves.
 - Be aware of their habits.
 - Bring snake bite kit.
 - To treat snake bite:
 - keep victim calm
 - slow circulation
 - use snake bite kit
 - get immediate medical help
- Spiders**
- Learn to recognize dangerous varieties.
 - Get medical help for bites as soon as possible.
 - Tarantula bites are painful but seldom serious.
- Bees/wasps**
- Recognize their habitats.
 - Carry bee-sting kit if allergic.
 - To treat sting:
 - keep victim calm
 - remove stinger
 - cool area with ice
 - administer cardiopulmonary resuscitation (CPR) if necessary
 - seek medical help
- Scorpions**
- Usually found under other objects.
 - Carry anti-sting kit - sting can be fatal to allergic individual.
 - Administer CPR if necessary.
 - Seek medical help if stung.
- Rabid Animals**
- Can infect any warm-blooded animal (foxes, dogs, bats, raccoons, skunks, squirrels).

- Animals may exhibit lack of fear, aggressiveness, dropping head, peculiar trotting gait, unusual behavior.
 - Seek immediate medical help if bitten by rabid animal; infection nearly 100% fatal if untreated.
- Micoorganisms***
- Harmful bacteria, viruses and fungi can be found in soil, waste water, medical and pharmaceutical waste.
 - Inspectors should avoid direct contact with these materials.

2.4 HEAT STRESS

- Heat production exceeds heat loss.
 - Often accompanied by increased:
 - heart rate
 - body temperature
 - respiration
 - perspiration
 - Adverse effects range from cramps to death.
 - Contributing factors:
 - ambient temperature
 - radiant heat
 - physical labor
 - chemical exposure
 - humidity
 - altitude
 - inadequate acclimatization
 - fatigue
 - alcohol consumption
 - cardiac and respiratory conditions
 - some medications
- Preventing/
Reducing Heat
Stress**
- Assess probability of heat stress.
 - Schedule work for cool periods of day.
 - Take adequate breaks.
 - Hoist, rather than carry, heavy loads.
 - Use protective heat shields, insulating materials, reflectors, tarpaulins.

- Drink appropriate amounts and types of fluids: 250 ml (½ cup) water every 15 minutes.
- Wear head coverings and clothing.
 - light in color
 - absorbent
 - loose fitting
- Know the symptoms, prevention and treatment of major heat stress disorders.

Heat Stress Disorders

Heat Stroke

- **Life-threatening**
- Sweating mechanism shuts down; body overheats.

Symptoms

- Red or flushed skin
- Hot, dry skin
- Very high body temperature: 41°C (106°F)
- Dizziness
- Nausea
- Headache
- Rapid, strong pulse
- Unconsciousness

Emergency Treatment

- Cool person rapidly - water, fan, air conditioning.
- Get immediate medical care.
- Allow person to sip water if conscious.

Heat Exhaustion

- If left untreated, may progress to heat stroke.
- Inadequate blood flow and dehydration.

Symptoms

- Pale, clammy skin
- Profuse perspiration
- Extreme fatigue, weakness
- Normal body temperature
- Headache
- Vomiting

Emergency Treatment

- Move victim to cooler location.
- Have person lie down and elevate feet 20-30 cm (8-12").
- Loosen clothing.
- Have person drink electrolyte replacement solution or juice if possible (every 15 minutes for one hour).
- Get medical aid if condition does not improve.

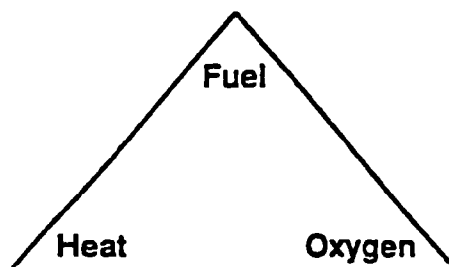
| | |
|---------------------------|---|
| <i>Heat Cramps</i> | <ul style="list-style-type: none"> • Muscle pains and spasms (abdomen, legs) caused by loss of electrolytes. |
| <i>Symptoms</i> | <ul style="list-style-type: none"> • Painful muscle cramping and spasms • Heavy sweating • Vomiting • Convulsions • Alert, well-oriented, normal pulse and blood pressure |
| <i>Treatment</i> | <ul style="list-style-type: none"> • Rest quietly in cool location. • Loosen clothing. • Massage cramped muscle. • Give clear juice or electrolyte replacement solution: 250 ml (½ cup) every 15 minutes for one hour. • Get medical help if symptoms not relieved |

2.5 FIRE AND EXPLOSION HAZARDS

During your field work you may be exposed to fire and explosion hazards from materials you may be using or encounter.

Recognition of Hazards

Recognizing fire and explosion hazards requires an understanding not only of the types of materials that can catch fire or are reactive with air or water, but also of the processes by which materials burn or explode.



- Essential Components**
- Combustible material (fuel)
 - Oxidizer (oxygen in atmosphere)
 - Ignition energy (heat)
- Combustible Materials** Those posing greatest concern are dusts, vapors, and gases that can be ignited easily and burn rapidly or explosively;
- **Gases** - diffuse and mix readily with oxygen.
 - **Combustible gases** - acetylene, ammonia, butane, hydrogen, methane, propane, etc. - hazard also from containers of combustible gases.
 - **Solids**
 - Must be converted to gas or vapor before they will burn.
 - Finely divided may be dangerous (flour, steel wool).
 - **Combustible dusts** - agricultural products, wood products, chemicals, pharmaceuticals, metals, and plastics.
 - **Liquids**
 - Must be converted to gas or vapor before they will burn.
 - Sprays, mists, foams, or dispersions.
 - **Combustible liquids** - liquids capable of being ignited - includes flammable liquids.
 - **Flammable liquids** - flash point temperatures below 100°F (38°C) - many industrial chemicals, paints, thinners, solvents, fuels - containers of these are also hazardous. See Table 2-1.
- Ignition Energy**
- Amount needed depends on:
 - state and concentration of the combustible material; and
 - concentration of oxygen.
 - Sources:
 - heated metal
 - sparks
 - flames
 - static electricity and sparks
 - sunlight
 - lasers
 - ionizing radiation

- Ignition temperature
 - Minimum temperature necessary to start the material burning.
 - Varies greatly for different materials.
 - Based on normal concentration of oxygen (21%).

Oxidizer

- Is usually oxygen in air.
- Peroxides, perchlorates, permanganates, sulfuric acid, chlorine and fluorine may act as oxidizers.

Fire and Explosion Characteristics

Many factors contribute to the occurrence of a fire or an explosion.

Flammable Concentration and Flammable Limits

- **Flammable concentration:** all concentrations at which flame will travel through the mixture.
 - **Explosion Limits** - range of concentrations of gases in air which will support the explosive process is bounded by measurable limits called explosive limits. The upper explosive limit (UEL) and the lower explosive limit (LEL) define the parameters of this range. Limits are measured and published as the percentages by volume of vapor or gas in air containing the normal concentration of oxygen. See Table 2-1.
 - **Lower explosive limit (LEL):** minimum flammable concentration of a material - also referred to as the lower flammable limit (too "lean").
 - **Upper explosive limit (UEL):** maximum flammable concentration of a material - also referred to as the upper explosive limit (too "rich").

Vapor pressure

- Pressure of the vapor above the surface of the liquid in a container; liquids with high vapor pressures are generally more hazardous than those with low vapor pressures (temperature dependent). See Table 2-1.

- Flash point*
- Temperature at which a liquid will give off enough vapor to allow flame to propagate through the vapor-air mixture; liquids with low flash points are generally more hazardous. See Table 2-1.
- Specific Gravity*
- Most combustible and flammable liquids have specific gravities less than 1.0 - will float on water; water should not be used for firefighting.
 - Greater than 1.0 - will sink in water; water can be used for firefighting.
- Vapor Density*
- If less than 1.0, vapor rises.
 - If greater than 1.0, vapor sinks.

TABLE 2-1. CHARACTERISTICS OF FLAMMABLE LIQUIDS

| Liquid | Explosion Limits (% in air) | Vapor Pressure (mm Hg at STP) | Flash Point (°C) |
|---------------------|--------------------------------|----------------------------------|------------------|
| Vinyl acetate | 2.6 - 13.4 | 115 | -8 |
| Acetone | 2.6 - 12.8 | 227 | -18 |
| Ethyl alcohol | 3.3 - 19.0 | 50 | 13 |
| Methyl ethyl ketone | 1.4 - 11.4 (93°C) | 71 | -9 |
| Gasoline | 1.4 - 7.6 | ? | -43 |
| Kerosene | 0.6 - 5.0 | ? | 38 |
| Toluene | 1.2 - 7.1 | 30 | 4 |
| Trichloroethylene | 12.5 - 90 | 77 | 37 |
| Xylene | 1.1 - 7.0 | 10 | 29 |

Preventing Fire and Explosions

- Keep ignition sources away from flammable concentrations.
- Limit amount of flammable liquids taken on field activities.
- Use available ventilation during transfer of liquids.
- Transport flammable liquids in tightly-sealed containers protected against impact.

Identification of Hazards

- Get information from Agency files, co-workers who have inspected the site, plant personnel.
- Identify materials which may be present; read reference sources to determine hazards; take appropriate precautions.
- Use direct-reading instruments to detect flammable concentrations onsite.

Control of Ignition Sources

- Be aware of sources: matches, cigarette lighters, electrical switches, electrical equipment, welding sparks, engines.
- All electrical equipment, sampling apparatus, portable instruments, and other possible sources of ignition must be safe for use in atmospheres containing flammable concentrations of dusts, vapors or gases.

Instruments and Equipment

- Most battery-operated or line-powered field instruments are not safe for use in flammable atmospheres.
- If possible, use only equipment approved by Underwriters Laboratory (UL) or Factory Mutual (FM) for use in specific flammable atmospheres.
- Enclose and ventilate sampling equipment which is not approved for use in such atmospheres.
- Be aware that some monitors which check flammable concentrations will give false readings if the concentration is above the upper flammable limit for the material.

Control of Static Electricity

Since static electricity (which accumulates to higher voltages in atmospheres with low humidity and during dry weather) can provide sufficient ignition energy to set fire to flammable concentrations of gases and vapors, it is important to recognize what can generate static electricity and what can be done to prevent accumulation and discharge of this energy.

Sources

- Particulates moving through a stack.
- Gas issuing from a nozzle at high velocity.
- Pouring or spraying nonconducting liquids or solids.
- Materials flowing through pipes, hoses or ducts.
- Belt running over a pulley.
- Person walking across a floor.
- Pouring solvents.
- Working near a process that generates static electricity.

Preventing Accumulation or Discharge

- Ground probes used for stack sampling.
- Provide a bonding connection between metal containers when flammable gases or liquids are transferred or poured.
- Wear footwear with adequate conductivity for the conditions.

2.6 SELECTION AND USE OF FIRE EXTINGUISHERS

Fire is an oxidation process which requires three key components: fuel, oxygen, heat. Removal of any of these three will stop the oxidation process.

Fire Classification/ Treatment

- See Table 2-2.

Fire Extinguisher Identification

- See Table 2-3.

Firefighting Precautions

- Warn others to evacuate area.
- Call Fire Department.
- Evaluate ability to fight the fire.
 - proper type and size of extinguisher?
 - additional help?
 - obstacles?
 - retreat?
- Contain the fire to prevent spread.
- Fight the fire.
- Never turn your back on the fire.

- Using a Fire Extinguisher**
 - Prepare and test extinguisher before approaching fire.
 - Aim at base of fire.
- Fire Hose**
 - Stream reaches about 9 m (30').
 - Stand back so pressure does not scatter fire.
- Soda-acid**
 - Turn upside down to mix chemicals and start flow.
- Aqueous-charged**
 - Spread stream into fan-shape with finger if pressure is not too great.
- Dry Chemical**
 - Usually rated "B" and "C"; some are rated "A", "B", and "C".
 - Use side-to-side sweeping motion.
 - Cover Class A fire.
 - Start spraying Class B fire at closest edge and continue to far edge; do not get too close.
- Liquid CO₂**
 - Low velocity discharge of CO₂; need to get within 2 to 4 feet of fire.
 - Flow of gas generates extreme cold and static electricity.
- Foam**
 - Aqueous foam.
 - Effective on Class A or B fires.
 - Works well on fairly large fires.

TABLE 2-2. FIRE CLASSIFICATION AND EXTINGUISHING MEDIA

| Class | Description | Examples | Extinguishing Media |
|--------------|--|--|---|
| A | ordinary combustibles | wood, paper, cloth, rubber | water, Halon 1211, baking soda |
| B | flammable or combustible liquid or gases | gasoline, fuel oil, kitchen grease, alcohol, propane | CO ₂ , dry chemicals, foam, Halon 1211, Halon 1301 |
| C | electrical equipment | electrical equipment | dry chemicals, CO ₂ , Halon 1211, Halon 1301 |
| D | combustible metals that burn vigorously and react violently with water | Na, K, Mg, Ti, Zr | dry powders (graphite, NaCl, other free-flowing noncombustible materials) |

TABLE 2-3. FIRE EXTINGUISHER IDENTIFICATION

| Class Type | Symbol Description |
|-------------------|--|
| A | Burning wastebasket and bonfire |
| B | Container pouring liquid and a fire |
| C | Electrical plug and a receptacle with flames |

2.7 CHEMICAL HAZARD RECOGNITION AND EVALUATION

- The degree of hazard associated with a particular chemical will depend on its toxicity, the way it is used and the environment in which it is encountered.
- The following factors must be considered in evaluating the degree of hazard present:
 - physical form or classification of the chemical
 - physical and chemical characteristics of the chemical
 - warning properties
 - airborne concentration
 - mode of usage
 - other environmental conditions

Physical Classification

- Solids
- Liquids
- Aerosols
- Gases and vapors

Solids

- Particulates (lead, asbestos)
- Sensitization (Ni)
- Fumes
- Sublimation
- Reactivity

Liquids

- Degree of hazard depends on characteristics of the liquid and how it is used
- Factors influencing hazard include:
 - temperature
 - vapor pressure
 - toxicity
- Types of hazards
 - skin damage
 - direct absorption through skin
 - enhanced absorption of other chemicals
 - splash hazard
 - slipping hazard
 - reactivity

Aerosols

- Aerosols are fine particulates (solid or liquid) suspended in air (dust, fumes, mist, fog, smoke and smog).
- See Table 2-4 for characteristics of air contaminants in work places.
- Results may present inhalation, eye or skin hazards.

Gases and Vapors

- A gas is a state of matter in which the material has very low density and viscosity.
- **Vapors** are the evaporation products of chemicals that are normally liquid at room temperature.
- See Table 2-4 for gas/vapor characteristics.
- Gases and vapors may present inhalation, eye and skin hazards.

Physical and Chemical Characteristics

- **Boiling point** - temperature at which liquid changes to a gas.
- **Melting point** - temperature at which a solid changes to a liquid.
- **Vapor pressure** - pressure of vapor immediately above the surface of a material. Term generally applied to liquids; however, solids have vapor pressure as well. Materials with high vapor pressure can create high airborne exposure risks.
- **Solubility** - maximum amount of that substance that will completely dissolve in a given volume of another substance.
- **Flash point** - lowest temperature at which a liquid gives off enough vapor to form an ignitable mixture with air and produce a flame when an ignition source is present. Flashpoint and boiling point are used to determine the classification of flammable liquids.
- **Explosion Limits** - range of concentrations of gases in air which will support the explosive process is bounded by measurable limits called explosive limits. The upper explosive limit (UEL) and the lower explosive limit (LEL) define the parameters of this range. The concentration is generally expressed in percent gas in air.

TABLE 2-4. CHARACTERISTICS OF AIR CONTAMINANTS IN WORK PLACES

| Form | How Generated | Example/Size (micrometers) | Concentration Expressed As |
|-------------------------|--|--|---------------------------------------|
| Aerosols | | | |
| Dust | From solids by mechanical means: - grinding - blasting - drilling | Quarry dust (less than 1 to 10) | mg/m ³⁽¹⁾ |
| Fumes | Condensation products of metals and solid organics, welding on metal | Lead fume (less than 0.001 to 0.1) | mg/m ³ |
| Mist | Liquid droplets formed by atomizing liquids or condensing liquids from vapors, entrainment | Chromic acid mist | mg/m ³ |
| Smoke | Products of combustion of organic materials | Incinerator (less than 0.5) | mg/m ³ |
| Gases and Vapors | | | |
| Gases | Occupy space of enclosure, liquify only under increased pressure and decreased temperature | CO H ₂ S | ppm ⁽²⁾ |
| Vapors | Evaporation products of substances normally liquid at room temperature (solvents, gasoline). | Acetone Carbon disulfide Benzene | ppm |

⁽¹⁾ mg/m³ - milligrams per cubic meter.

⁽²⁾ ppm - parts of gas or vapor per million parts of air.

| | |
|--|--|
| | <ul style="list-style-type: none"> • Reactivity - refers to the likelihood of reacting, rather than the ability to react. Most chemicals will react with some other chemical given the right set of conditions. |
| Warning Properties | <ul style="list-style-type: none"> • May include odor, eye, nose or throat irritation and taste. • To be useful in preventing overexposure, must be evident at a concentration below the permissible exposure limit (PEL). • Some chemicals have good warning properties (NH_3) while others have none at all (CO). |
| Odor Threshold | <ul style="list-style-type: none"> • Odor threshold is airborne concentration at which a chemical can be detected by smell. • Individuals vary. • Useful odor thresholds are well below the PEL. (NH_3) • Useless odor threshold is well above PEL. (vinyl chloride) • Olfactory fatigue may influence recognition of hazard. (H_2S) |
| Eye, Nose and Throat Irritation | <ul style="list-style-type: none"> • PELs for many chemicals have been based on irritation when it has been demonstrated that toxic effects are produced only by substantially higher concentrations. (HCl) |
| Taste | <ul style="list-style-type: none"> • May be useful if a taste is produced at concentrations below the PEL. (saccharin) |
| Airborne Concentration | <ul style="list-style-type: none"> • Since some chemicals do not have adequate warning properties and because individuals vary in their sensitivities to various substances, measurement of airborne concentrations of chemicals may prove to be useful. • If the potential for chemical exposure is unknown you should not enter the area unless you are properly protected or until the chemicals have been identified and the concentrations reliably measured or estimated. • If you find yourself in an area where an unknown exposure or spill occurs, or where you begin to experience signs or symptoms of exposure (headache, eye irritation, etc.), leave the area at once. |

| | |
|------------------------------------|--|
| Chemical Use | <ul style="list-style-type: none"> • Degree of hazard is significantly influenced by the way a chemical is used. <ul style="list-style-type: none"> - open tanks, hot chemicals, high vapor pressure, poorly designed or malfunctioning ventilation system = high airborne concentration - closed system = lower airborne concentrations |
| Other Environmental Factors | <ul style="list-style-type: none"> • Temperature. • Relative humidity. |

2.8 EFFECTS OF TOXIC CHEMICALS IN THE BODY

Toxic chemicals can affect the body in different ways, depending on the combination of several factors:

| | |
|--|---|
| | <ul style="list-style-type: none"> • Route of entry. • Length of exposure. • Organs or systems affected. • Absorption, distribution, storage, and elimination. |
| Routes of Entry | <ul style="list-style-type: none"> • Chemical substances may enter the body through the skin, respiratory tract and gastrointestinal tract. • Exposures during field activities are most likely to occur through skin contact or inhalation. |
| Skin | <ul style="list-style-type: none"> • Usually effective barrier for protecting underlying body tissues (see Figure 2-1). • Short exposures to strong concentrations of extremely toxic substances (e.g., organic phosphates, phenol, cyanide) can be serious or fatal. |
| Potential effects of chemical contact | <ul style="list-style-type: none"> • No reaction - skin acts as effective barrier • Skin irritation or destruction of tissue • Skin sensitization • Chemical penetrates skin and enters blood stream |

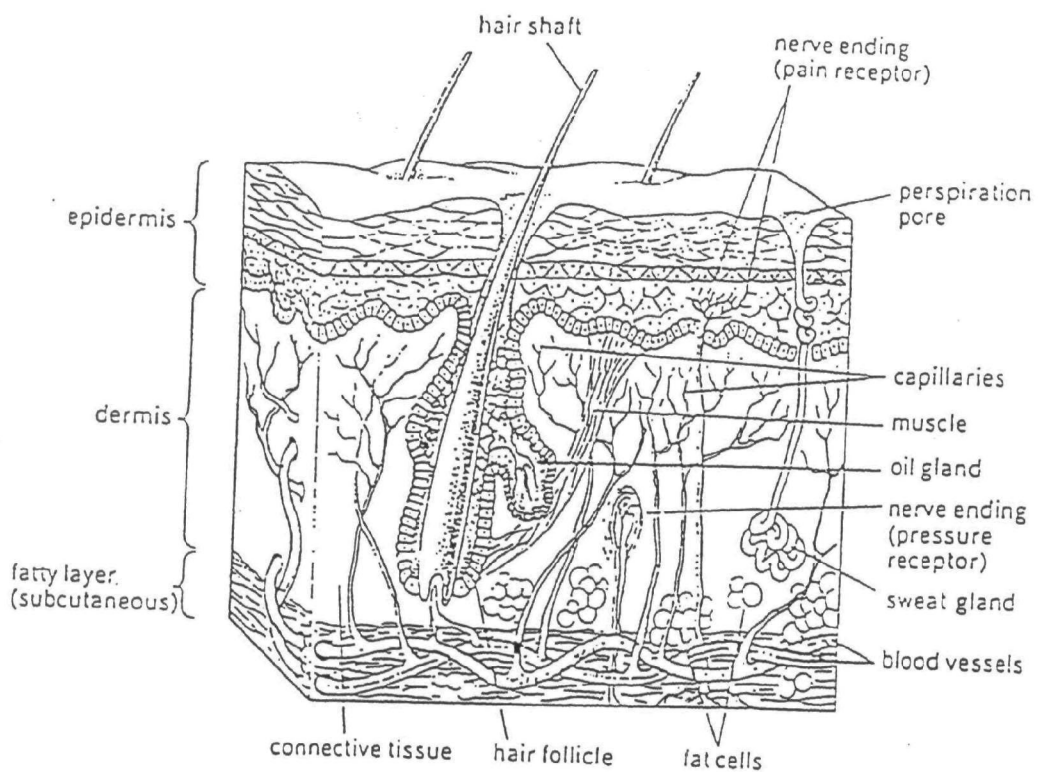


Figure 2-1. Skin cross-section

*Factors
influencing effects*

- Skin thickness
- Chemical properties
- Skin condition
- Duration of exposure

Respiratory System

- Most common route of entry for gases, vapors and airborne particulates (see Figure 2-2).
- Major factors influencing the toxic effects of airborne chemicals include:
 - concentration in ambient air
 - physical and chemical properties
 - sites of deposition within respiratory system
 - body's ability to counteract effects

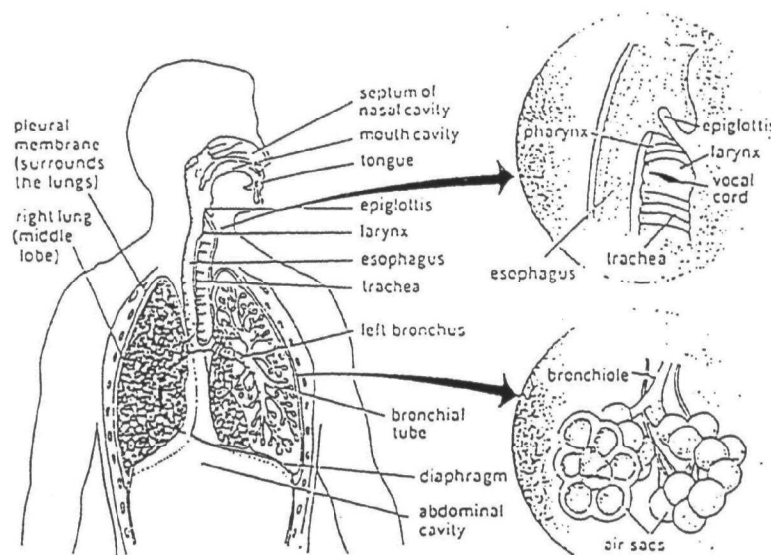


Figure 2-2. Organs of the human respiratory system

Damaging substances

- **Asphyxiants** - gases which can deprive body tissues of oxygen.
 - **simple asphyxiants** - displace oxygen and lead to suffocation (N_2 , He, CH_4 , Ne, Ar)
 - **chemical asphyxiants** - prevent oxygen utilization by chemical interaction (H_2S , CO, HCN)
- **Irritants** - may produce inflammation of the sinuses, throat, bronchi, and alveoli. Cell death may result, leading to edema and secondary infection. May cause increased pulmonary flow resistance. Examples: O_3 , HF, NH_3 , SO_x .
- **Fibrosis producers** - kill normal lung tissue and produce scar tissue which may result in oxygen deprivation. Examples: silicates, asbestos, beryllium.
- **Allergens** - substances that act as an antigen upon contact with body tissues (inhalation, ingestion, or skin absorption). Allergens may cause allergic response in the form of bronchoconstriction and pulmonary disease. Examples: isocyanates, sulfur dioxide.
- **Carcinogens** - substances that cause cancerous growth in living tissues, such as the lungs. Examples: coke oven emissions, asbestos, and arsenic.
- **Systemic Toxicants** - substances that enter via the respiratory tract, but affect other parts of the body. Examples: organic solvents, anesthetic gases, lead, and mercury.

Table 2-5 gives a partial list of industrial toxicants that produce respiratory tract disorders.

Gastrointestinal System

- Chemicals may have a toxic effect on all major and accessory organs (e.g., liver) of the gastrointestinal tract.

Potential means of ingestion

- Mouth pipetting
- Contaminated water or food
- Contaminated smoking materials or cosmetics
- Contaminated hands
- Drinking from contaminated containers

Length of Exposure

Toxic chemicals may affect the body in different ways, depending not only on the route of exposure but also on the length of exposure. Toxic effects may be produced by acute or chronic exposure to chemical agents.

Acute Exposures and Effects

- Acute, or short-term, exposures to some chemicals can cause:
 - acute effects (sudden onset, short duration)
 - permanent adverse effects
 - delayed effects (temporary or permanent)
 - chronic effects
- You may not be aware of an acute exposure unless there is an immediate reaction (pain, irritation).

Chronic Exposures and Effects

- Repeated or prolonged exposure to low concentrations of some toxic chemicals can cause adverse effects of long duration or frequent reoccurrence.

Organs and Systems Affected

- Many toxic substances are associated with specific toxic effects on one or more organs or systems, which suggests that there is a selective mode of action for many hazardous substances. While chemical substances may have a broad range of toxic effects on an organism, the effects are sometimes so specific that they are defined in terms of the most susceptible "target cell" or "target organ."
- Eight other major organs or systems are frequent sites of toxic response to chemical substances (see Table 2-6).

TABLE 2-5. INDUSTRIAL TOXICANTS THAT PRODUCE DISEASE OF THE RESPIRATORY TRACT

| Toxicant | Site of Action | Acute Effect | Chronic Effect |
|--|----------------------------|--|------------------------------------|
| Aluminum | Upper airways | Cough, shortness of breath, irritation | Fibrosis and emphysema |
| Ammonia | Upper airways | Irritation | Bronchitis, edema |
| Arsenic | Upper airways | Bronchitis irritation, pharyngitis | Cancer, bronchitis, laryngitis |
| Asbestos | Lung tissue | | Fibrosis, cancer |
| Beryllium | Alveoli | Edema, Pneumonia | Fibrosis, ulceration |
| Boron oxide | Alveoli | Edema, hemorrhage | |
| Cadmium oxide | Alveoli | Cough, pneumonia | Emphysema |
| Carbides of tungsten, titanium, and tantalum | Upper, lower airways | Hyperplasia, metaplasia of bronchial cells | Fibrosis |
| Chlorine | Upper airways | Cough, irritation, asphyxiant | |
| Chromium VI | Nasopharynx, upper airways | Nasal irritation, bronchitis | Cancer |
| Cobalt | Lower airways | Asthma | Fibrosis, interstitial pneumonitis |
| Hydrogen chloride | Upper airways | Irritation, edema | |
| Iron oxides | Alveoli, bronchi | Cough | Benign pneumoconiosis |
| Isocyanates | Lower airways, alveoli | Bronchitis, pulmonary edema, asthma | |
| Manganese | Lower airways alveoli | Pneumonia, often fatal | Recurrent pneumonia |
| Nickel | Nasal mucosa, bronchi | Irritation | Cancer |

TABLE 2-5 (CONTINUED)

| Toxicant | Site of Action | Acute Effect | Chronic Effect |
|--------------------|------------------------|--|---|
| Nickel carbonyl | Alveoli | Edema (delayed symptoms) | |
| Nitrogen oxides | Bronchi, alveoli | Edema | Emphysema |
| Osmium tetroxide | Upper airways | Bronchitis, bronchospasm | Bronchopneumonia |
| Ozone | Bronchi, alveoli | Irritation, edema, hemorrhage | Emphysema, bronchitis |
| Phosgene | Alveoli | Edema | Bronchitis, fibrosis, pneumonia |
| Phthalic anhydride | Lower airways, alveoli | Bronchitis, asthma | Emphysema |
| Sulfur dioxide | Upper airways | Bronchoconstriction, cough, tightness in chest | Bronchitis, nasopharyngitis |
| Tin | Bronchioles, pleura | | Widespread mottling of x-ray without clinical signs (benign pneumoconiosis) |
| Toluene | Upper airways | Bronchitis, edema, bronchospasm | |
| Vanadium | Upper, lower airways | Irritation, nasal inflammation, edema | Bronchitis |
| Xylene | Lower airways | Edema, hemorrhage | |

TABLE 2-6 ORGANS/SYSTEMS AFFECTED BY CHEMICAL EXPOSURE

| Organs or System | Chemicals Causing Effects |
|--|---|
| Liver and Bile Ducts (Hepatic System) | Vinyl Chloride, Aromatic Hydrocarbons |
| Kidney (Renal System) | Heavy Metals, Halogenated Hydrocarbons |
| Blood and the Blood- forming System (Hematopoietic System) | Benzene, Lead |
| Heart, Cardiovascular System (CVS) | Carbon Monoxide, Arsine |
| Neuroendocrine System | DDT |
| Immune/Allergy System | Triphenyltin |
| Central Nervous System (CNS) | Pesticides, Thallium |

2.9 DOSE-RESPONSE CURVES

A dose-response curve describes the relationship between the absorbed dose (concentration versus time) and the biological response. The threshold limit value (TLV) is that dose below which no significant effect is expected to occur. At higher doses certain effects may be observed which compensate for the toxic effect. At still higher doses, reversible damage to organs may be observed. This damage may become irreversible at sustained or higher levels. As this dose increases to even more toxic levels, death will occur. The shape of the curve will depend on the toxicological properties of the material. See Figures 2-3, 2-4, and 2-5 for representative dose-response curves.

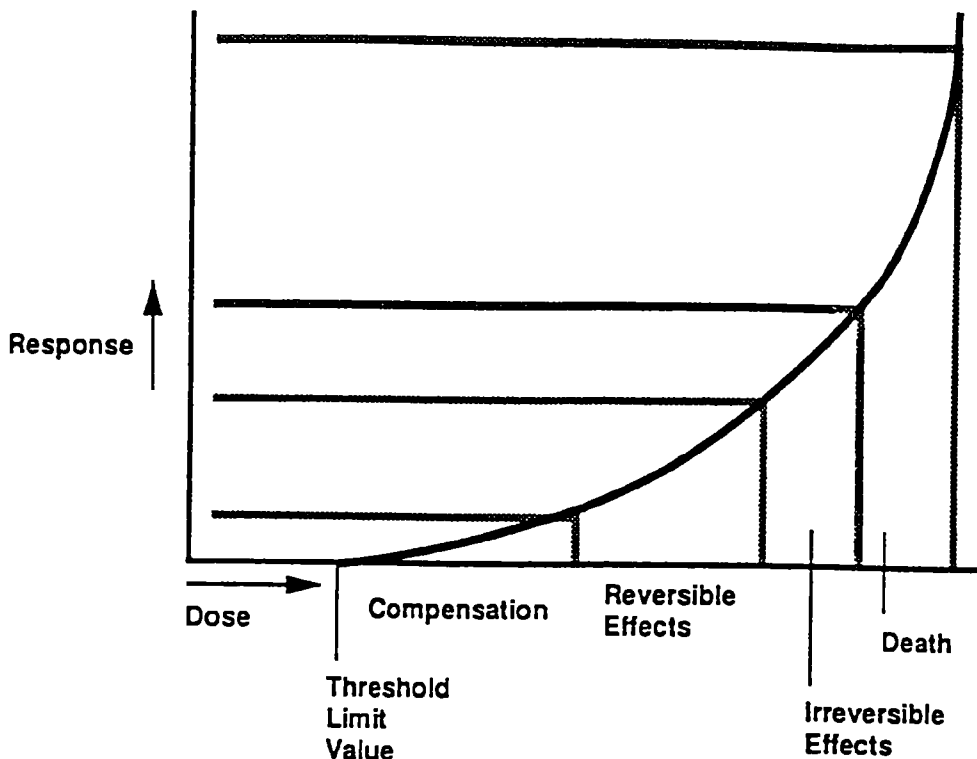


Figure 2-3. Classic Dose-response Curve.

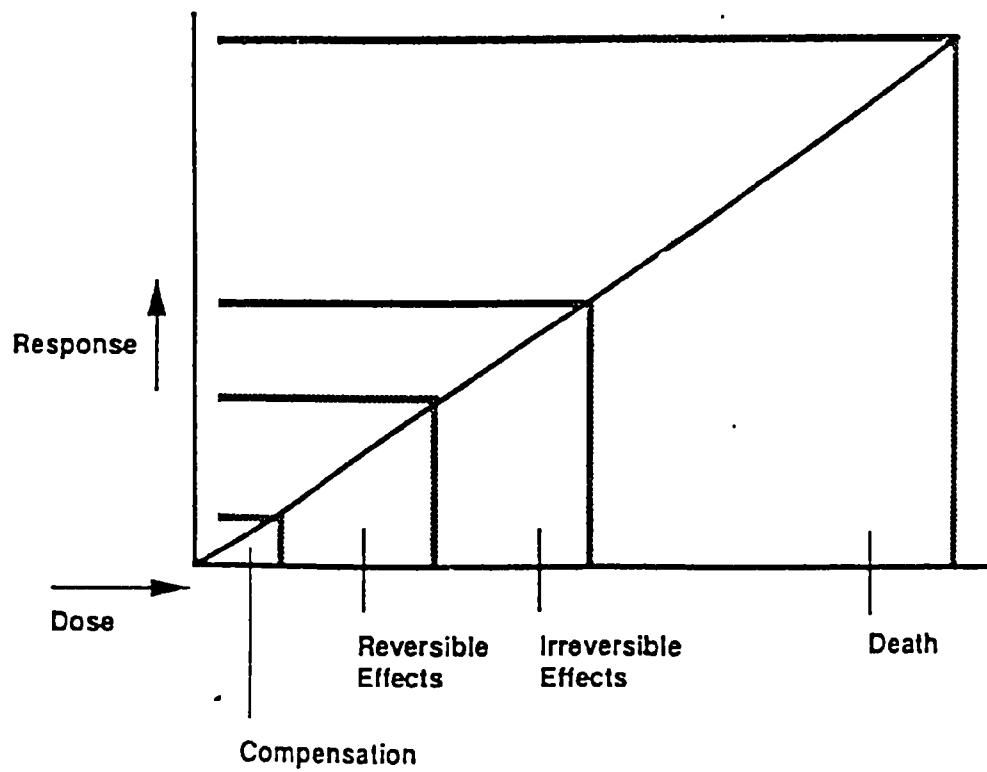


Figure 2-4. Dose-response Curve for a Chemical with no TLV.

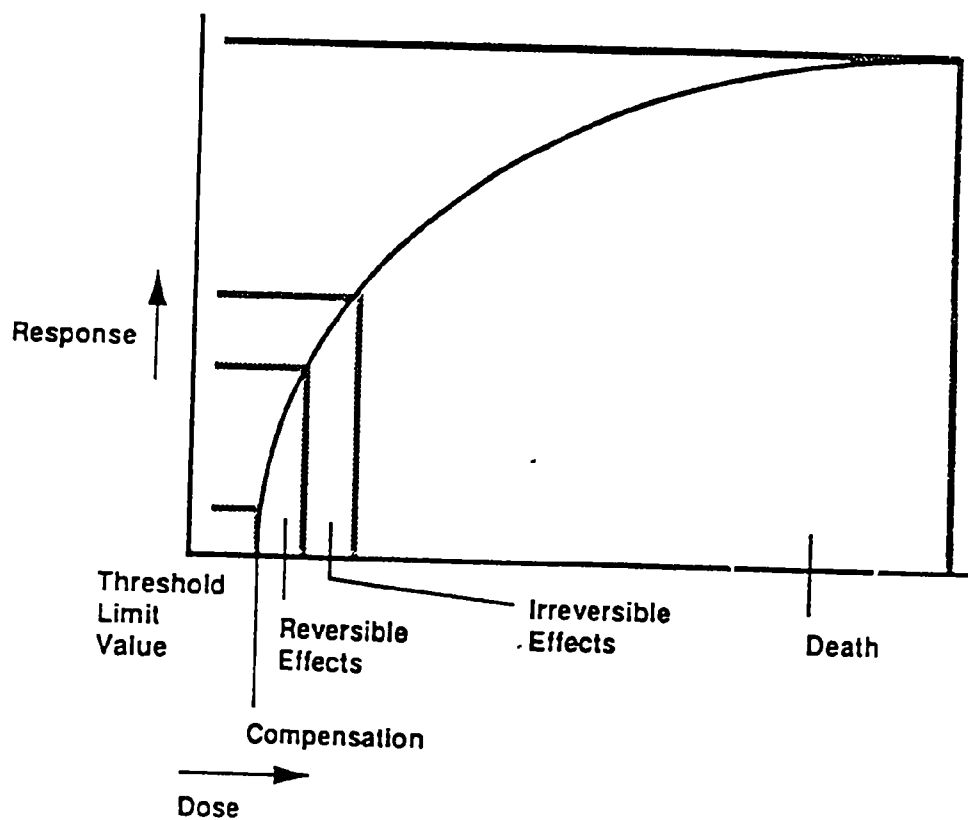


Figure 2-5. Dose-response Curve for a Highly Toxic Chemical.

| | |
|--|--|
| Types of Effects | Some chemicals do not elicit such dose-response relationships. |
| <i>Harmful Effects</i> | <ul style="list-style-type: none"> • Include toxic and lethal effects • Result from overexposure or overdose • Three major classes: <ul style="list-style-type: none"> - non-specific corrosive - irreversible damage to cells and tissues. (strong acids, bases, oxidants) - specific toxicological effects - effects on specific target organs or systems - usually reversible if recognized early. (CCl₄ liver cell damage, HCN asphyxiation) - pathological effects - chronic, usually irreversible. (cancer, mutations, birth defects) |
| <i>Sensitization Effects</i> | <ul style="list-style-type: none"> • Not dose-dependent • Require preconditioning exposure • Immune system affected • Allergic and hypersensitivity reactions (Ni, nitrophenols, isocyanates, formaldehyde, etc.) |
| Factors Influencing Intensity of Toxic Action | |
| <i>Route of Entry</i> | <ul style="list-style-type: none"> • Intensity and nature of response depends on route of exposure: lead (inhalation vs. ingestion). • Intensity also related to the acute and chronic toxicity of a substance: hydrogen sulfide. |
| <i>Age</i> | <ul style="list-style-type: none"> • Infants, children, adults, and senior citizens differ in their circulatory and excretory systems, musculature and metabolisms which affect the distribution and toxicity of substances: newborns (CNS stimulants/suppressants). |
| <i>State of Health</i> | <ul style="list-style-type: none"> • Pre-existing disease may increase sensitivity to toxic agents. • Nutrition may affect responses. • Diet can change body composition, physiological and biochemical functioning. |
| <i>Previous Exposure</i> | <ul style="list-style-type: none"> • Tolerance • Increased sensitivity • No effect |

- | | |
|-------------------------------------|---|
| <i>Environmental Factors</i> | <ul style="list-style-type: none"> • Temperature • Barometric pressure • Radiation |
|-------------------------------------|---|

- | | |
|----------------------------|--|
| <i>Host Factors</i> | <ul style="list-style-type: none"> • Species • Sex • Hereditary factors |
|----------------------------|--|

2.10 EVALUATING HEALTH HAZARDS AND TOXICITY INFORMATION

- | | |
|------------------------------------|--|
| Reasons to Seek Information | <ul style="list-style-type: none"> • Does a hazard exist? • What degree of risk? • Is air monitoring needed? • Can pre-exposure monitoring be done? • Can personal monitoring be done during the activity? • Should possible exposures be documented by medical monitoring? • What specific protective equipment and clothing are necessary? • How should one use such equipment and clothing? |
|------------------------------------|--|

- | | |
|------------------------|--|
| Exposure Limits | <ul style="list-style-type: none"> • Limits on skin contact • Permissible Exposure Limits (PELs) |
|------------------------|--|

- | | |
|---|--|
| <i>Skin Contact and Ingestion Exposure</i> | <ul style="list-style-type: none"> • Most industrial chemicals required to have precautionary labels, • Skin and systemic toxicity information provided. |
|---|--|

- | | |
|--|---|
| <i>Inhalation Exposure Limits</i> | <ul style="list-style-type: none"> • Threshold Limit Values (TLVs) - reviewed and adopted annually by the American Conference of Governmental Industrial Hygienists (ACGIH) - advisory, but more up-to-date. • Permissible Exposure Limits (PELs) - adopted by the Occupational Safety and Health Administration (OSHA) - mandated. |
|--|---|

*Categories of
Exposure Limits*

- **Time-Weighted Average (TWA)** - concentration of a toxic substance to which nearly all workers may be repeatedly exposed without adverse effect - based on eight-hour workday, 40-hour workweek.
- **Short-Term Exposure Limit (STEL)** - 15-minute time-weighted average exposure which shall not be exceeded at any time during a work day.
- **Ceiling (C)** - concentration that should not be exceeded during any part of the working day.

*Important
Information*

- PELs do not represent a fine line between safe and dangerous.
- PELs may not be appropriate for extended shiftwork.
- PELs may not protect all workers.
- PELs are not a relative index of toxicity.
- PELs are based on the best available information.

**Signs and
Symptoms of
Overexposure**

Since you may not know the identity of toxic chemicals to which you are being exposed, and many chemicals have inadequate warning properties, you must be aware of signs and symptoms of overexposure.

- **Signs** - observable by others
- **Symptoms** - not observable by others

*Signs of
Inhalation
Exposure*

- Sneezing
- Coughing

*Symptoms of
Inhalation
Exposure*

- Headache
- Dizziness
- Nausea
- Irritation of eyes, nose, throat
- Increased mucus in nose and throat

*Signs of
Skin Contact*

- Redness
- Swelling
- Dry, whitened skin

***Symptoms of
Skin Contact***

- Irritation
- Itching

***Other Signs
and Symptoms***

- Changes in behavior
- Periods of dizziness
- Muscle spasms
- Irritability

**Evaluating
Exposure with
Instrumentation**

Air monitoring instrumentation provides the most reliable means of identifying and quantifying airborne contaminants. Information may be used to help:

- Determine level of worker protection needed;
- Evaluate the level of exposure and, therefore, the health risk to field personnel and the need for medical monitoring;
- Assess potential environmental effects; and
- Provide indicators of the effectiveness of hazard abatement activities.

***Preparing for
Field Use of
Equipment***

Once the appropriate equipment has been selected:

- Read all instructions.
- Practice using the equipment.
- Calibrate the equipment before and after using it.

***Characteristics of
Air Monitoring
Instruments***

- Portable.
- Able to generate reliable and useful data.
- Sensitive and selective.
- Inherently safe.

***Quantification of
Airborne
Contaminants***

- Direct-reading instruments (See Table 2-7)
 - Flammable or explosive atmospheres
 - Oxygen deficiency
 - Certain gases and vapors
 - Ionizing radiation

TABLE 2-7. SOME DIRECT-READING INSTRUMENTS

| Instrument | Application | Limitations |
|---|---|--|
| Combustible Gas Indicator (CGI) | Measures the concentration of combustible gas or vapor | Accuracy depends, in part, on the difference between the calibration and sampling temperatures. Sensitivity is a function of the differences in the chemical and physical properties between the calibration gas and the gas being sampled. The filament can be damaged by certain compounds such as silicones, halides tetraethyl lead and oxygen-enriched atmospheres. Does not provide a valid reading under oxygen-deficient conditions. |
| Flame Ionization Detector (FID) with Gas Chromatography Option | In survey mode, detects the total concentrations of many organic gases and vapors. In gas chromatography (GC) mode, identifies and measures specific compounds. In survey mode, all the organic compounds are ionized and detected at the same time. In GC mode volatile species are separated. | Does not detect inorganic gases and vapors or some synthetics. Sensitivity depends on the compound. Should not be used at temperatures less than 40° F(4°C). Difficult to absolutely identify compounds. High concentrations of contaminants or oxygen-deficient atmospheres require system modification. In survey mode, readings can only be reported relative to the calibration standard used. |
| Gamma Radiation Survey Instrument | Gamma radiation monitor | Does not measure alpha or beta radiation. |
| Portable Infrared (IR) Spectrophotometer | Measures concentration of many gases and vapors in air. Designed to quantify one- or two-component mixtures. | In the field, must make repeated passes to achieve reliable results. Requires 115-volt AC power. Not approved for use in a potentially flammable or explosive atmosphere. Interference by water vapor and carbon dioxide. Certain vapors and high moisture may attack the instrument's optics which must then be replaced. |

TABLE 2-7 (CONTINUED)

| Instrument | Application | Limitations |
|--|---|--|
| Ultraviolet (UV) Photoionization Detector (PID) | Detects total concentration of many organic and some inorganic gases and vapors. Some identification of compounds is possible if more than one probe is used. | Does not detect methane. Does not detect a compound if the probe used has a lower energy level than the compound's ionization potential. Responses may change when gases are mixed. Other voltage sources may interfere with measurements. Readings can only be reported relative to the calibration standard used. Response is affected by high humidity. |
| Direct-Reading Colorimetric Indicator Tube | Measures concentrations of specific gases and vapors. Available for a wide variety of chemicals. | The measured concentration of the same compound may vary among different manufacturers' tubes. Many similar chemicals interfere. Greatest sources of error are (1) how the operator judges stain's endpoint, and (2) the tube's limited accuracy. Affected by high humidity. |
| Oxygen Meter | Measures the percentage of O ₂ in air. | Must be calibrated prior to use to compensate for altitude and barometric pressure. Certain gases, especially oxidants such as ozone, can affect readings. Carbon dioxide (CO ₂) poisons the detector cell. |

Source: NIOSH/OSHA/USCG/EPA Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities

- Laboratory analysis of air samples
 - Anions
 - Aliphatic amines
 - Asbestos
 - Metals
 - Organics
 - Nitrosamines
 - Particulates
 - PCBs
 - Pesticides

2.11 REFERENCES

Some sources which can provide information concerning the toxicity and other potential hazards of chemicals are listed below.

Airborne Exposure Limit Information

- **Occupational Safety and Health Administration (OSHA) -** Permissible Exposure Limits (PELs) can be found in 29 CFR 1910 Subpart Z.
- **National Institute for Occupational Safety and Health (NIOSH).**
 - Recommended exposure limits (RELs) can be found in criteria documents available from NIOSH, the National Technical Information Service (NTIS), or, in some cases, the EPA
 - **Pocket Guide to Chemical Hazards** - provides useful information on regulated chemicals: PELs, TLVs, RELs and data regarding synonyms, IDLH levels, physical description, chemical and physical properties, incompatibilities, measurement methods, personal protection, respirator selection and health hazards. Single copies available from NIOSH at no charge.
- **American Conference of Governmental Industrial Hygienists (ACGIH) -** Threshold Limit Values (TLVs) are reviewed periodically and the TLV list published annually - available from ACGIH Publications Office, 6500 Glenway Avenue, Building D-7, Cincinnati, OH 45211-4438.

**Material Safety
Data Sheets**

- OSHA Hazard Communication Standard requires all chemical manufacturers and vendors to provide material safety data sheets (MSDSs) for the products that they sell.
- MSDSs contain information concerning:
 - hazardous ingredients
 - physical and chemical characteristics
 - acute and chronic health hazards
 - respiratory protection and ventilation requirements
 - fire and reactivity data
 - spill control measures
 - disposal requirements
 - labeling requirements
 - other requirements relevant to the safe use of the product
- Employers are responsible for obtaining or developing an MSDS for each hazardous substance used in their workplaces and ensuring that employees have access to this information.

Other Sources

- **NIOSH/OSHA Occupational Health Guidelines for Chemical Hazards**, U.S. Government Printing Office, Washington, DC 20402
- **Documentation of the Threshold Limit Values (TLVs)**, ACGIH Publications Office, 6500 Glenway Avenue, Building D-7, Cincinnati, OH 45211
- **CHRIS: Chemical Hazard Response Information System** - available through the National Response Center - Volume 2 - information on hazardous waste spills and dump site cleanup.
- **Fire Prevention Guide on Hazardous Materials**, seventh edition, National Fire Protection Association (NFPA), Quincy, MA 02269 - information on pure chemicals; very little on mixtures.
- **The Merck Index**, 10th edition (1983), Merck and Company, Inc., Rahway, NJ 07065 - information on chemicals, drugs, and biological substances.

- **Dangerous Properties of Industrial Materials**, (current edition), edited by N. Irving Sax, Von Nostrand Reinhold Co., 135 W. 50th Street, New York, NY 10020 - information and technical data on nearly 13,000 industrial and laboratory chemicals.
- **Condensed Chemical Dictionary**, 10th edition (1981), Gessner G. Hawley, Von Nostrand Reinhold Co., 135 W. 50th Street, New York, NY 10020 - concise, descriptive technical data on thousands of chemicals and reactions.
- **Farm Chemicals Handbook**, (1984), Richard T. Meister, editorial director, Meister Publishing Co., 37841 Euclid Avenue, Willoughby, OH 44094 - annual publication listing information regarding pesticides and products.
- **NIOSH Registry of Toxic Effects of Chemical Substances**, (RTECS), 1980 edition, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, NIOSH, Cincinnati, OH 45226, or Government Printing Office, Washington, DC - contains toxicity data on nearly 40,000 chemicals and lists over 145,000 chemical substances.
- **1984 Emergency Response Guidebook: Guidebook for Hazardous Materials Incidents**, 1984, U.S. Department of Transportation, Materials Transportation Bureau, DMT-11, Washington, DC 20036.
- **Emergency Handling of Hazardous Materials in Surface Transportation**, 1981, Bureau of Explosives, Association of American Railroads, 1920 L Street, NW, Washington, DC 20036.
- **Handbook of Toxic and Hazardous Chemicals**, 1981, Marshall Sittig, Noyes Publications, Noyes Building, Park Ridge, NJ 07656.
- **Toxic and Hazardous Industrial Chemical Safety Manual**, 1982, International Technical Information Institute - available through Laboratory Safety Supply, P.O. Box 1368, Janesville, WI 53547-1368, and others.

- Data bases available to EPA personnel:
 - **OHMTADS: Oil and Hazardous Materials Technical Assistance Data System** (developed by EPA)
 - **HMIS: Hazardous Materials Information System** (developed by DOD, Defense Logistics Agency, Defense General Supply Center, Richmond, VA 23297)
 - **MEDLARS**
 - **TOXLINE**
 - **TOXBACK**
 - **TOXBACK/65**

2.12 EMERGENCY FIRST AID FOR FIELD ACTIVITIES

Since employees engaged in field activities are often in remote, unaccessible areas, it is essential that they know the basics of emergency first aid.

Every field team should have at least one member with current training in first aid, cardiopulmonary resuscitation (CPR) and chemical splash treatment.

Each employee should carry a wallet card with important medical information such as blood type, allergies, current medication and physical impairments.

The following information is very basic and does not take the place of a first aid or CPR course. You should obtain more information on each of the medical emergencies mentioned. The information in this section is derived from two publications: *American Red Cross: Adult CPR* and *American Red Cross: Multimedia Standard First Aid*.

Planning to Provide First Aid or Urgent Care

- Urgent care essential:
 - severe bleeding
 - breathing has stopped
 - no pulse

Preplanning

- Complete a Medical Emergency Planning Checklist:
 - location of nearest medical facility
 - emergency communication and transportation available
 - risks involved in field activities
 - exact location of field activity
 - identification of first aid/urgent care providers in the crew
- Ensure that crew members complete and carry medical information card.
- Gather first aid/urgent care supplies.

Initial Response

- Assess and prioritize treatment (breathing, bleeding).
- Request help or secure transportation for victim.

Providing First Aid or Urgent Care

- Make a prompt rescue.
- Ensure breathing/pulse.
- Control severe bleeding.
- Protect victim from unnecessary manipulation/disturbance.
- Avoid or overcome chilling.
- Determine injuries or cause for sudden illness.
- Examine victim methodically.
- Carry out appropriate first aid.
- Follow specific procedures for the following:
 - obstructed airway
 - adult rescue breathing
 - CPR
 - electrical shock
 - wounds (severe bleeding) and shock
 - specific injuries to head, neck and back
 - chemical splashes, inhalation of toxic gas and burns
 - drowning
 - heat stress

Obstructed Airway

- Determine whether the person is choking (ask him!).

Conscious Person

- Have another person request medical assistance.
- Perform "Heimlich Maneuver".

*Unconscious
Person*

- If you are choking, perform Heimlich Maneuver using fist or back of chair.
- Request help.
- Position person on back.
- Open airway.
- Look, listen and feel for breathing.
- Attempt to give two full breaths.
- If unsuccessful, retilt head and try again.
- If still unsuccessful, perform abdominal thrusts and finger sweep to clear obstruction.

*Adult Rescue
Breathing*

- May be required due to:
 - allergic reactions
 - electric shock
 - oxygen-deficient atmosphere
 - toxic gas paralysis
 - obstructed airway
- Check for consciousness, breathing and pulse.

Procedure

- Have someone get medical assistance.
- Position victim onto back.
- Open airway.
- Check again for breathing (listen, watch chest and feel for breath).
- Give two full breaths.
- If still not breathing, reposition head.
- Try again.
- Perform Heimlich Maneuver if airway is blocked.

- Check carotid pulse.
- Begin rescue breathing.
 - one breath every five seconds (approximately 1 to 1½ seconds/breath)
 - listen and feel for breath, watch chest
- Recheck pulse after one minute of rescue breathing.
- Continue rescue breathing until:
 - victim breathes;
 - another rescuer takes over;
 - emergency personnel arrive;
 - you can't continue.

***Cardiopulmonary
Resuscitation (CPR)***

- Chest compressions and rescue breathing used together (15 compressions/two breaths).
- May be needed for:
 - heart attack (most common)
 - electrical shock
 - chemical exposure
- CPR should be administered only by personnel specially trained in the procedure.

***Electrical
Shock***

- Can stop breathing and heart or cause heart to beat ineffectively.
- If victim still in contact with source of electricity:
 - shut off power; or
 - safely move victim away from source.
- Determine need for rescue breathing/CPR.

***Wounds
(Severe
Bleeding and
Shock)***

- Stop bleeding.
- Protect wounds from contamination.
- Prevent shock.
- Get medical help.

***Severe
Bleeding***

- Direct pressure/elevation.
- Pressure points.
- Tourniquet (sacrifice the limb!)

Shock

- Comfort, quiet, soothe victim.
- Keep victim lying down, normal temperature.
- Standard position - feet and injury elevated.
- If head wound or breathing difficulty, elevate head and shoulders.
- If fractures suspected and not splinted, or elevation is painful, keep victim flat on back.
- Bleeding from mouth, nauseous, vomiting - lie on side.

***Head, Neck,
Back Injuries***

Head, Neck

- Signs of injury:
 - bumps, bruises, cuts
 - headache
 - dizziness
 - unconsciousness
 - unequal pupils
 - sleepiness
 - bleeding/fluid - mouth, nose, ears
 - paralysis
- Sometimes difficult to decide - suspect injury whenever an accident involves force.
- Keep injured head, neck, spine from moving.
- Keep victim lying flat (raise head, shoulders), monitor breathing, get medical help, do not administer stimulants.

Back

- Handle victim carefully.
- Administer rescue breathing without repositioning.

***Chemical
Splashes***

- Flush chemicals off as quickly and thoroughly as possible (15 minutes).

- Splashes of hot, concentrated or corrosive chemicals (several hours).
 - Medical followup where indicated.
- Eyes*
- Irrigate thoroughly (15 minutes).
 - Contact lenses may aggravate chemical burns.
 - Do not use neutralizing solutions.
- Skin*
- Remove contaminated clothing.
 - Wash affected skin thoroughly.
 - Be aware of potential spread of contaminant.
 - Try to find water source whose temperature can be adjusted for prolonged washing.
 - If victim is conscious, give plenty of non-alcoholic liquids to drink.
- Inhalation of Toxic Gas*
- Get exposed person out of toxic atmosphere.
 - If a toxic liquid has been splashed on victim's face, wash it off quickly.
 - Administer rescue breathing.
 - Continue until normal breathing is restored or a resuscitator is available.
 - Treat for shock.
- Burns*
- Can be life-threatening depending on location and amount of body affected.
 - If burn results from chemical splash, first treat for splash, then burn.
 - Stop, drop, roll.
 - Major objectives:
 - relieve pain
 - prevent contamination
 - reduce likelihood of shock
 - Cooling and aspirin help relieve pain.

Small Shallow Burns

- Use cool water directly on burn on unbroken skin; immerse if possible.
- Pat dry with sterile gauze.
- Bandage if necessary.

Large Shallow Burns

- Cool with water until pain subsides.
- Dry gently and cover with thick, dry, sterile dressing.
- Use insulated cold packs over dressing if helpful.

Deep Burns

- Do not put water on open burn to cool it.
- Cover burn with thick sterile dressing and bandage.
- Do not remove clothing which is sticking to a burn.
- Use dry, insulated cold packs to relieve pain.
- Seek medical assistance for extensive deep burns.

Shock Prevention

- Have victim lie down.
- Elevate burned areas (if possible).
- Maintain normal body temperature.
- Have victim drink water if possible.

Insect Stings and Allergic Reactions

- Ensure adequate airway.
- Remove stinger.
- Use emergency kit.
- Obtain medical attention.

Drowning

- Unless trained in lifesaving, do not attempt personal rescue; use boat, life preserver, etc.
- Begin rescue breathing as soon as possible.
- Use proper technique to move or lift victim with suspected head, neck or back injury.
- Administer rescue breathing and CPR for lengthy time to victim of cold water drowning: <21°C (70°F)
- Victim may vomit.

CHAPTER 3

3.0 PROTECTIVE CLOTHING AND EQUIPMENT

3.1 OBJECTIVE

To provide general information on selecting and using appropriate personal protective clothing and equipment.

3.2 SELECTION OF PERSONAL PROTECTIVE CLOTHING AND EQUIPMENT (PPE)

Proper selection of PPE requires a thorough understanding of the hazards to be faced:

- Chemical - inhalation, skin contact
- Mechanical - falling objects, moving parts
- Physical - noise, radiation
- Thermal - heat, cold
- Electrical

General Precautions

- Use the correct type of equipment needed.
- Use only properly fitting personal protective equipment.

Head Protection

- Essential where there are overhead hazards (platforms, scaffolding, piping)
- American National Standards Institute (ANSI) standard: impact of 400 foot-pounds and insulation against 2,200 volts.
- Adjust suspension harness so there is 3 cm (1") clearance between hat and top of head.
- Can be equipped with insulation and chin strap.
- Store properly.

Eye and Face Protection

- Use whenever there is danger of flying or falling particles or chemical splashes.
- Use eye and face protection which meets ANSI Z87.1-1981 standards and OSHA requirements.

- Ordinary prescription glasses do not meet standards.
- Always carry and use your own eye protection.
- Side shields, goggles and face shields may be necessary.
- Contact lenses should not be worn at sites where eye and face protection is necessary:
 - May complicate first aid efforts.
 - May absorb gases and vapors from the air and aggravate chemical injury.
 - OSHA prohibits use of contact lenses when respirators are worn.

Foot Protection

Make selection based on hazard to be encountered:

- Impact
- Penetration
- Chemicals
- Ankle twists and sprains
- Slippery surfaces
- Cold
- Heat
- Static electricity

Impact

- Use steel-toed footwear where heavy objects may drop on the foot (ANSI Z41.1).
- Metatarsal guards may be required at the site.

Penetration

- Where soles may be penetrated, wear safety boots with reinforced soles.

Chemicals

- Select footwear (boots, pullover boots, shoe covers) based on ability to resist penetration or permeation by the chemicals.
- Possible materials: neoprene, PVC, butyl rubber, natural rubber.
- Do not wear leather footwear where contamination may occur.

Ankle Twists and Sprains

- Wear high-top industrial work boots where there are hazardous walking/working surfaces.

Slippery Surfaces

- Slips, trips and falls are most frequent and most disabling.
- Select footwear with hazard in mind - design and material of sole is important.

Static Electricity

- Rubber-soled shoes increase the hazard.
- Use special conducting shoes or other static diffusing devices.

Hearing Protection

- Long-term exposure can cause permanent loss of hearing (see Figure 3-1).
- Shorter exposures may result in temporary loss.
- If conversation is difficult at a distance of three feet, hearing protection should be used.
- **Noise Reduction Rating (NRR):** ability of hearing protector to reduce sound levels - NRR increases as ability to protect increases (See Table 3-1).
- Choose proper hearing protector for the work environment.
- Be aware of potential contamination of hearing protection.

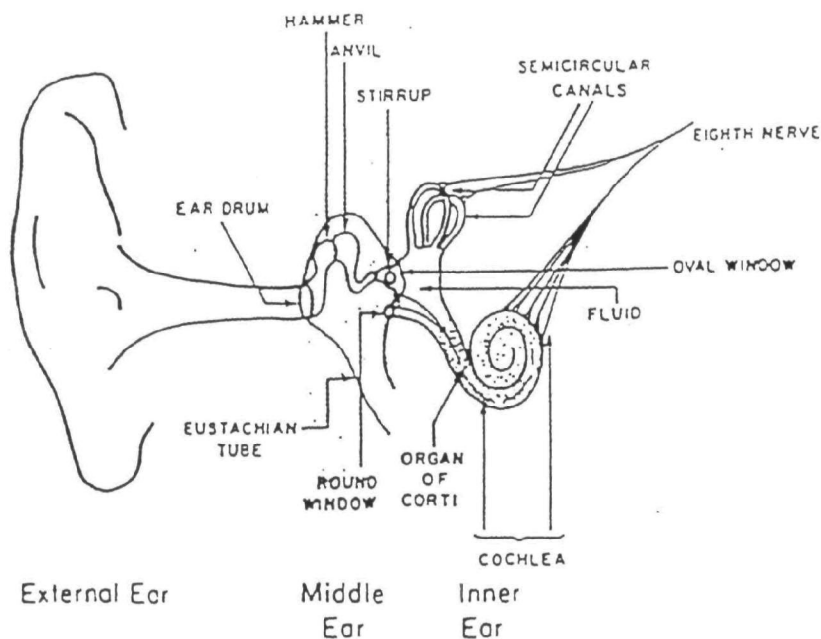


Figure 3-1. The ear

TABLE 3-1. TYPICAL NOISE REDUCTION RATINGS (NRRs) FOR COMMON HEARING PROTECTION DEVICES

| Type of Hearing Protection Device | Range of NRRs |
|---|----------------------|
| Premolded earplugs (including flanged and conical models) | 16 to 27 |
| Custom-molded earplugs | 11 to 31 |
| User-molded earplugs | 16 to 26 |
| Self-molding earplugs (expandable foam) | 29 to 32 |
| Self-molding earplugs (glass fiber) | 22 to 27 |
| Ear muffs (over the head) | 19 to 29 |

Source: NIOSH Compendium of Hearing Protection Devices, 1984.

- | | |
|---------------------------------|--|
| Hand Protection | <ul style="list-style-type: none"> • Gloves should be selected based on the probability of: <ul style="list-style-type: none"> - abrasions, bruises, lacerations, splinters, etc. - chilling, freezing, or burns - chemical and biological contaminants - electrical shock • Refer to the <i>Guidelines for the Selection of Chemical Protective Clothing</i> (EPA Regional Health and Safety Offices). • Liquid-proof gloves are not necessarily permeation resistant. • A variety of gloves may be necessary to provide proper protection (wear durable over impermeable but delicate). • See Table 3-2 for information on the physical characteristics of protective materials. • Have extra gloves available during field activities. |
| Skin and Body Protection | <ul style="list-style-type: none"> • Select clothing for resistance to chemical degradation and permeation, and heat resistance. |

TABLE 3-2. PHYSICAL CHARACTERISTICS OF PROTECTIVE MATERIALS*

| Material | Abrasion Resistance | Cut Resistance | Flexibility | Heat Resistance | Ozone Resistance | Puncture Resistance | Tear Resistance | Relative Cost |
|--|--------------------------------|---------------------------|--------------------|----------------------------|-----------------------------|--------------------------------|----------------------------|--------------------------|
| Butyl Rubber (Butyl) | F | G | G | E | E | G | G | High |
| Chlorinated Polyethylene (CPE) | E | G | G | G | E | G | G | Low |
| Natural Rubber | E | E | E | F | P | E | E | Medium |
| Nitrile-Butadiene Rubber (NBR) | E | E | E | G | F | E | G | Medium |
| Neoprene | E | E | G | G | E | G | G | Medium |
| Nitrile Rubber (Nitrile) | E | E | E | G | F | E | G | Medium |
| Nitrile Rubber & Polyvinyl Chloride (Nitrile & PVC) | G | G | G | F | E | G | G | Medium |
| Polychethylene | F | F | G | F | F | P | F | Low |
| Polyurethane | E | G | E | G | G | G | G | High |
| Polyvinyl Alcohol (PVA) | F | F | P | G | E | F | G | Very High |
| Polyvinyl Chloride (PVC) | G | P | F | P | E | G | G | Low |
| Styrene-Butadiene Rubber (SBR) | E | G | G | G | F | F | F | Low |
| Viton | G | G | G | G | E | G | G | Very High |

*Ratings are subject to variation depending on formulation, thickness, and whether the material is supported by fabric.
E-excellent; G-good; F-fair; P-poor

- No one suit will provide appropriate protection in all situations.
- A variety of protective garments are available.
- Materials are not intended for prolonged contact with concentrated chemicals; always have extra clothing at the site.
- Do not use synthetic fabric suits when contact with hot surfaces is possible.
- See Appendices 3-A and 3-B for information regarding protective clothing and materials.

3.3 LEVELS OF PROTECTION

To aid in selecting PPE, EPA has developed a protocol consisting of four levels of protection. Each level provides a given degree of protection to the skin and respiratory system (See Table 3-3).

| | |
|--------------------------------|---|
| Considerations | <ul style="list-style-type: none"> • Type, measured concentration, and toxicity of the chemical substance in the ambient atmosphere. • Potential for exposure to airborne materials, liquid splashes, or other materials. |
| Reasons for Upgrading | <ul style="list-style-type: none"> • Known or suspected presence of dermal hazard. • Occurrence or likely occurrence of gas or vapor emission. • Change in work task. • Personal request. |
| Reasons for Downgrading | <ul style="list-style-type: none"> • New information regarding hazard. • Change in site conditions. • Change in work task. |

3.4 CONTROLLING THE TRANSFER OF CONTAMINANTS

Improper use or handling of materials can unintentionally result in transfer of contaminants to unintended objects. Proper preparation will minimize the potential for such contamination.

TABLE 3-3. LEVEL OF PROTECTION

| Level of Protection | Equipment | Protection Provided | Should Be Used When | Limiting Criteria |
|----------------------------|---|--|---|---|
| A | <p>RECOMMENDED:</p> <ul style="list-style-type: none"> • Pressure-demand, full-facepiece SCBA or pressure-demand supplied-air respirator with escape SCBA. • Fully-encapsulating, chemical-resistant suit. • Inner chemical-resistant gloves • Chemical-resistant safety boots/shoes. • Two-way radio communications (intrinsically safe) <p>OPTIONAL:</p> <ul style="list-style-type: none"> • Cooling unit • Coveralls • Long cotton underwear • Hard hat • Disposable gloves and boot covers | <p>The highest available level of respiratory, skin, and eye protection.</p> | <p>The chemical substance has been identified and requires the highest level of protection for skin, eyes and the respiratory system based on either.</p> <ul style="list-style-type: none"> • measured (or potential for) high concentration of atmospheric vapors, gases, or particulates or • site operations and work functions involving a high potential for splash, immersion, or exposure to unexpected vapors, gases, or particulates of materials that are harmful to skin or capable of being absorbed through the intact skin. <p>Substance with a high degree of hazard to the skin are known or suspected to be present, and skin contact is possible.</p> <p>Operations must be conducted in confined, poorly ventilated areas until the absence of conditions requiring Level A protection is determined.</p> <p>Direct reading field instruments indicate high levels of unidentified vapors and gases in the air.</p> | <p>Fully-encapsulating suit material must be compatible with the substance involved</p> |

TABLE 3-3 (CONTINUED)

| Level of Protection | Equipment | Protection Provided | Should Be Used When | Limiting Criteria |
|---------------------|--|--|---|---|
| B | <p>RECOMMENDED:</p> <ul style="list-style-type: none"> • Pressure-demand, full-facepiece SCBA or pressure-demand supplied air respirator with escape SCBA. • Chemical-resistant clothing (overalls and long-sleeved jacket; hooded, one- or two-piece chemical splash suit; disposable chemical-resistant one-piece suit). • Inner and outer chemical-resistant gloves. • Chemical resistant safety boots/shoes. • Hard hat. • Two-way radio communications (intrinsically safe). <p>OPTIONAL:</p> <ul style="list-style-type: none"> • Coveralls • Disposable boot covers • Face shield • Long cotton underwear | <p>The same level of respiratory protection as Level A but less skin protection.</p> <p>It is the minimum level recommended for initial site entries until the hazards have been further identified.</p> | <p>The type and atmospheric concentration of substances have been identified and require a high level of respiratory protection, but less skin protection. This involves atmospheres:</p> <ul style="list-style-type: none"> • with IDLH concentrations of specific substances that do not represent a severe skin hazard; or • that do not meet the criteria for use of air-purifying respirators. <p>Atmosphere contains less than 19.5 percent oxygen</p> <ul style="list-style-type: none"> • Presence of incompletely identified vapors or gases is indicated by direct-reading organic vapor detection instrument, but vapors and gases are not suspected of containing high levels of chemicals harmful to skin or capable of being absorbed through the intact skin. | <ul style="list-style-type: none"> • Use only when the vapor or gases present are not suspected of containing high concentrations of chemicals that are harmful to skin or capable of being absorbed through the intact skin. • Use only when it is highly unlikely that the work being done will generate either high concentrations of vapors, gases or particulates or splashes of material that will affect exposed skin. |

TABLE 3-3 (CONTINUED)

| Level of Protection | Equipment | Protection Provided | Should Be Used When | Limiting Criteria |
|---------------------|--|--|---|--|
| C | <p>RECOMMENDED:</p> <ul style="list-style-type: none"> • Full-facepiece, air-purifying, canister-equipped respirator. • Chemical-resistant clothing (overalls and long-sleeved jacket; hooded, one- or two-piece chemical splash suit; disposable chemical-resistant one-piece suit). • Inner and outer chemical-resistant gloves. • Chemical-resistant safety boots/shoes. • Hard hat. • Two-way radio communications (intrinsically safe). <p>OPTIONAL:</p> <ul style="list-style-type: none"> • Coveralls • Disposable boot covers • Face shield • Escape mask • Long cotton underwear | <p>The same level of skin protection as Level B, but a lower level of respiratory protection</p> | <ul style="list-style-type: none"> • The atmospheric contaminants, liquid splashes, or other direct contact will not adversely affect any exposed skin. • The types of air contaminants have been identified, concentrations measured, and a canister is available that can remove the contaminant. • All criteria for the use of air-purifying respirators are met. | <ul style="list-style-type: none"> • Atmospheric concentration of chemicals must not exceed IDLH levels. • The atmosphere must contain at least 19.5 percent oxygen. |

TABLE 3-3 (CONTINUED)

| Level of Protection | Equipment | Protection Provided | Should Be Used When | Limiting Criteria |
|---------------------|--|--|--|---|
| D | <p>RECOMMENDED:</p> <ul style="list-style-type: none"> • Coveralls • Safety boots/shoes • Safety glasses or chemical splash goggles • Hard hat <p>OPTIONAL:</p> <ul style="list-style-type: none"> • Gloves • Escape mask • Face shield | <p>No respiratory protection</p> <p>Minimal skin protection.</p> | <ul style="list-style-type: none"> • The atmosphere contains no known hazard. • Work functions preclude splashes, immersion, or the potential for unexpected inhalation or contact with hazardous levels of any chemicals. | <ul style="list-style-type: none"> • This level should not be worn in highly contaminated areas • The atmosphere must contain at least 19.5 percent oxygen. |

Adapted from: NIOSH/OSHA/USCG/EPA: Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities, 1985.

Planning

- Disposable equipment
- Onsite decontamination
- Method of decontamination
- Disposal
- Appropriate supplies

- ## Preventing Transfer of Contaminants

- 3-11

3.6 DONNING AND DOFFING PROTECTIVE CLOTHING

Achieving the complete benefits of protective clothing depends on the techniques used for donning and doffing the clothing. In general, care must be taken to avoid tearing or puncturing the materials, and to avoid contaminating the inside of the garments.

Helpful Hints

- Pull pants of protective clothing down over the boots and tape in place.
- Tape gloves to sleeves of protective clothing in similar fashion.
- Have an assistant help when you are donning or doffing protective clothing.
- Store protective clothing where it will not become contaminated.
- See Appendix 3-C for specific donning and doffing procedures.

3.7 STORAGE OF EQUIPMENT

Proper storage can result in:

- longer life;
- reduced maintenance;
- increased availability of critical gear;
- minimization of cross-contamination; and
- prevention of punctures and tears.

APPENDIX 3-A

PERFORMANCE REQUIREMENTS OF PROTECTIVE CLOTHING

Clothing Section Select personal protective clothing which will provide the best possible protection against the chemicals and environment to which you will be exposed.

Important characteristics to consider:

- Strength and durability - generally proportional to thickness; however, increased durability generally reduces flexibility.
- Thermal resistance - behavior in hot/cold environments? - melting?
- Ability to be cleaned, decontaminated, or protected from contamination.
- Resistance of protective clothing to chemical damage or degradation, mechanical penetration, and permeation through the intact material.

Resistance to Degradation by Chemicals A great deal of information concerning the chemical resistance of materials from which protective gloves and clothing are made can be obtained.

Resistance to Penetration by Chemicals

- Select personal protective clothing with care; porous materials, tears, punctures, stitched seams, button holes and loose openings can allow penetration.
- Store, transport and handle gloves and protective clothing with care at all times.
- Inspect personal protective clothing for holes before use.
- Seal openings between garments, gloves and boots with adhesive tape that will resist the hazardous material you expect to encounter.

**Resistance to
Permeation by
Chemicals**

- Gases, liquids and some solids can diffuse through materials used to make protective gloves and clothing.
- Permeation can occur without degradation or damage to the protective material.
- No protective material will resist permeation by all chemicals.
- Reduce permeation by:
 - minimizing concentrations in contact with protective materials;
 - using thicker materials; and
 - avoiding prolonged exposure or contact with chemicals.

APPENDIX 3-B

PROTECTIVE MATERIALS

Fabrics

- **Tyvek:** non-woven fabric; resists tears, punctures and abrasion; relatively inexpensive; used for disposable garments; resists buildup of static electricity (unless laundered); melting point: 135°C (275°F).
- **Nomex:** woven fabric of polyamide fibers; very durable and acid-resistant; flame-resistant, but not noncombustible; allows passage of gas, vapor and steam.

Elastomers

Are natural or synthetic polymeric materials that exhibit good elasticity and varying degrees of resistance to chemical degradation and permeation.

- **Polyethylene:** inert but permeable material that will absorb organic solvents; sometimes used to coat Tyvek garments to provide resistance to acids, bases and salts.
- **Polyvinyl chloride (PVC):** resistant to acids, but somewhat permeable and retentive of contaminant; coating for fully-encapsulating suits made of Nomex.
- **Neoprene:** better general protection than PVC; retains contaminants; many respirator facepieces and breathing hoses.
- **Chlorinated polyethylene (CPE or Choropel):** resists degradation by many chemicals; permeation resistance unknown; splash suits and fully-encapsulating suits.
- **Butyl Rubber:** highly resistant to permeation by gases; does not resist halogenated hydrocarbons and petroleum compounds; does not retain contaminants; boots, gloves, splashsuits, aprons and fully-encapsulating suits.
- **Viton:** fluoroelastomer with greater resistance to degradation and permeation than neoprene and butyl rubber; does not protect against some chemicals like ketones and aldehydes; does not retain contaminants; fully-encapsulating suits.

- **Natural rubber:** resists degradation by alcohols and caustics; used for boots and gloves.
- **Milled nitrile:** resists petroleum products; boots and gloves.
- **Polyvinyl alcohol (PVA):** soluble in water but protects against aromatic and chlorinated hydrocarbons.

For additional information consult EPA's *Guidelines for the Selection of Chemical Protective Clothing*, 1987.

APPENDIX 3-C

PROCEDURES FOR DONNING AND DOFFING PERSONAL PROTECTIVE CLOTHING

Using Gloves *Gloves*

- Trim fingernails and remove jewelry which may puncture material.
- Use powdered gloves if possible.
- Use several layers of differing gloves if necessary.

Removing Gloves

- Loosen both gloves by pulling lightly on each fingertip of the gloves.
- Do not touch your skin with the outer surface of either glove.
- Remove the first glove either by pulling on the fingertips or by grasping it just below the cuff on the palm side and rolling the glove off the fingers.
- Remove the second glove by inserting the ungloved fingers inside the cuff on the palm side without touching the outside of the glove, and pushing or rolling the glove off the fingers.

Using Boots

Boots

- Before use, be sure shoes cannot puncture overboots.
- Use layers of boots of differing capabilities if necessary.

Removing Boots

- Wear gloves unless boots are very loose.
- Loosen boots by pulling them lightly with the gloved hand.
- Do not allow outside of boot to contact bare skin.
- Remove first boot by pulling it off the foot with a gloved hand or a bootjack, or by inserting the ungloved fingers inside the boot and pushing it off without touching the outside of the boot.

Using and Removing Full Body Suits

- Remove second boot in the same fashion.

Safe use of full protective equipment requires a team of persons who are physically fit and trained and practiced in the use of self-contained breathing apparatus and use of the complete suits. Assistants must be prepared to:

- Carry out emergency rescue if necessary.
- Assist the wearers into the breathing apparatus and the suits.
- Decontaminate the outside of the suit before it is removed.
- Assist the wearers in removing the suits (normal and emergency removals).

Donning the Suit

- Thoroughly inspect the suit for holes, rips, malfunctioning closures, cracked masks or other deficiencies.
- Wear a minimum of clothing beneath suit (cotton).
- Use talcum powder as necessary.

Doffing the Suit

- Remove any extraneous or disposable clothing, boot covers, or gloves.
- Have assistant perform the following:
 - Loosen and remove the steel-toe and shank boots.
 - Open front of suit to allow access to SCBA regulator. (Leave breathing hose attached as long as there is sufficient pressure.)
 - Open suit completely and lift the hood over the head of the wearer; rest it on top of the SCBA tank.
- Remove arms, one at a time, from suit. Once arms are free, have assistant lift suit up and away from the SCBA backpack, avoiding any contact between the outside surface of the suit and the wearer's body, and lay the suit out flat behind the wearer. Leave internal gloves on.
- While sitting, remove both legs from the suit.

- After suit is removed, remove internal gloves by rolling them off the hand, and turning them inside out.
- Proceed to the clean area and follow procedure for doffing SCBA.
- Remove internal clothing and thoroughly cleanse body.

CHAPTER 4

4.0 RESPIRATORY PROTECTION

4.1 OBJECTIVE

To provide basic information on the selection, use and maintenance of respiratory protective devices so that they may be used in a safe and effective manner.

4.2 RECOGNITION OF RESPIRATORY HAZARDS

Respiratory hazards may be encountered during any field activity. Respiratory protection is needed if personnel must enter any area in which there may be either a deficiency of oxygen or a high concentration of toxic chemicals in the air. In such atmospheres, life or health may depend on using respiratory equipment which can provide a supply of clean breathing air.

- | | |
|-------------------------------|---|
| Hazard Locations | <ul style="list-style-type: none">• Spill scenes• Discharge or emission sites• Mines• Industrial plants• Hazardous waste sites• Confined spaces |
| General Considerations | <ul style="list-style-type: none">• Do not rely on workaday respiratory use policy.• Assume the worst conditions.• Three basic categories of hazards<ul style="list-style-type: none">- oxygen deficiency- aerosols- gases and vapors |
| Oxygen Deficiency | <ul style="list-style-type: none">• Causes<ul style="list-style-type: none">- displacement- oxidation |

- Minor to fatal effects (see Table 4-1)
 - <19.5% oxygen at sea level (OSHA)
- Aerosols**
- Fine particulate (solid or liquid) suspended in air
 - Physical classifications
 - spray
 - fume
 - fog
 - smoke
 - smog
 - Physiological classification
 - nuisance
 - inert pulmonary reaction
 - lung fibrosis
 - irritation
 - systemic poison
 - allergen
 - carcinogen
- Gaseous Contaminants**
- Chemical classification
 - acidic
 - alkaline
 - organic
 - organometallic
 - hydrides
 - inert
 - Physiological classification
 - irritant
 - asphyxiant
 - anesthetic
 - systemic poison
 - allergen
 - carcinogen

TABLE 4-1. PHYSIOLOGICAL EFFECTS OF OXYGEN DEFICIENCY

| Oxygen Volume at Sea Level (%) | Effects |
|---------------------------------------|--|
| 12 to 16 | <ul style="list-style-type: none">-Breathing volume and heart rate increase.-Attention and coordination impaired. |
| 10 to 14 | <ul style="list-style-type: none">-Loss of peripheral vision.-Poor coordination.-Rapid fatigue with exertion.-Emotional upsets and faulty judgment.-Respiration disturbed. |
| 6 to 10 | <ul style="list-style-type: none">-Nausea and vomiting.-Unable to move freely.-Possible loss of consciousness. |
| Below 6 | <ul style="list-style-type: none">-Convulsions-Gasping respiration immediately prior to cessation of breathing which is followed quickly by death. |

4.3 TYPES OF RESPIRATORS

- | | |
|----------------------------------|---|
| Basic Types | <ul style="list-style-type: none">• Air-purifying• Atmosphere-supplying |
| Facepieces | <ul style="list-style-type: none">• Tight-fitting or loose-fitting |
| <i>Tight-fitting</i> | <ul style="list-style-type: none">• Quarter mask• Half mask• Full facepiece |
| <i>Loose-fitting</i> | <ul style="list-style-type: none">• Hoods• Helmets• Suits• Blouses |
| Air-Purifying Respirators | <ul style="list-style-type: none">• Consist of face-piece and air-purifying device.• Can remove specific airborne contaminants by<ul style="list-style-type: none">- filtration;- absorption;- adsorption; or- chemical reaction.• Are approved for use only in atmospheres of certain concentrations of chemicals (see cartridges or canisters).• Usually operate in negative-pressure mode (exception: powered air-purifying respirators). |
| <i>Precautions</i> | <ul style="list-style-type: none">• Cartridges in two-cartridge respirators must be of same type.• Combination cartridges may be used for protection against more than one type of chemical.• Use air-purifying respirators when:<ul style="list-style-type: none">- identify and concentration of contaminant are known;- oxygen in air is at least 19.5%;- contaminant has adequate warning properties;- approved canisters or cartridges for the contaminant and concentration are available; |

- the Immediately Dangerous to Life or Health (IDLH) concentration is not exceeded.

- See Table 4-2 for advantages/disadvantages of air-purifying respirators.

Styles

- See Table 4-3 for styles of respirators.

Atmosphere Supplying Respirators

- Consist of facepiece (loose or tight-fitting) and device which provides clean respirable air.
- Two basic types:
 - self-contained breathing apparatus (SCBA)
 - supplied air respirator (SAR)

SCBA

- Carried by wearer
- Consists of:
 - facepiece
 - hose
 - regulator
 - air source
- Protects against most levels and types of contaminants.
- Duration of use limited by amount of air carried and breathing rate.
- Increases likelihood of heat stress and fatigue due to weight.
- Impairs movement.
- See Table 4-4 for advantages/disadvantages of SCBAs.

SAR

- Also known as air-line respirators.
- Supply air to facepiece via a supply line from a stationary source.
- Source may be onsite compressor or compressed air cylinders.
- Available in positive- and negative-pressure modes.

| TABLE 4-2. RELATIVE ADVANTAGES AND DISADVANTAGES OF AIR-PURIFYING RESPIRATORS | | |
|--|---|---|
| Type of Respirator | Advantages | Disadvantages |
| Air-Purifying | | |
| Air-Purifying Respirator (including powered air-purifying respirators (PAPRs)) | <ul style="list-style-type: none"> Enhanced mobility Lighter in weight than an SCBA. Generally weighs 2 pounds (1 kg) or less (except for PAPRs). | <ul style="list-style-type: none"> Cannot be used in IDLH or oxygen-deficient atmospheres (less than 19.5 percent oxygen at sea level). Limited duration of protection. May be hard to gauge safe operating time in field conditions. Only protects against specific chemicals and up to specific concentrations. Use requires monitoring of contaminant and oxygen levels. Can only be used (1) against gas and vapor contaminants with adequate warning properties, or (2) for specific gases or vapors provided that the service life is known and a safety factor is applied, or if the unit has an ESLI (end-of-service-life indicator) |

Source: NIOSH/OSHA/USCG/EPA: Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities, 1985.

| TABLE 4-3. RESPIRATOR STYLES | | | | |
|------------------------------|--------------------|---------------|-----------------------|--------------------------|
| Facepiece | Air-Purifying Unit | | | |
| | Twin Cartridges | PAPR at Waist | Chin-mounted Canister | Harness-mounted Canister |
| Half-mask | X | X | | |
| Full-face mask | X | X | X | X |
| Helmet | | X | | |

**TABLE 4-4. RELATIVE ADVANTAGES AND DISADVANTAGES OF
ATMOSPHERE-SUPPLYING RESPIRATORY PROTECTIVE
EQUIPMENT**

| Type of Respirator | Advantages | Disadvantages |
|---|---|---|
| Self-Contained Breathing Apparatus (SCBA) | <ul style="list-style-type: none"> ● Provides the highest available level of protection against airborne contaminants and oxygen deficiency. ● Provides the highest available level of protection under strenuous work conditions. | <ul style="list-style-type: none"> ● Bulky, heavy (up to 35 pounds). ● Finite air supply limits work duration. ● May impair movement in confined spaces. |
| Positive Pressure Supplied-Air Respirator (SAR) (also called air-line respirator) | <ul style="list-style-type: none"> ● Enables longer work periods than an SCBA. ● Less bulky and heavy than a SCBA. SAR equipment weighs less than 5 pounds (or around 15 pounds if escape SCBA protection is included). ● Protects against most airborne contaminants. | <ul style="list-style-type: none"> ● Not approved for use in atmospheres immediately dangerous to life or health (IDLH) or in oxygen-deficient atmospheres unless equipped with an emergency egress unit such as an escape-only SCBA that can provide immediate emergency respiratory protection in case of air-line failure. ● Impairs mobility. ● MSHA/NIOSH certification limits hose length to 300 feet (90 meters). ● As the length of the hose is increased, the minimum approved air flow may not be delivered at the facepiece ● Air line is vulnerable to damage, chemical contamination, and degradation. Decontamination of hoses may be difficult. ● Worker must retrace steps to leave work area. ● Requires supervision/monitoring of the air supply line. |

Source: NIOSH/OSHA/USCG/EPA Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities, 1985.

Precautions

- Should not be used in IDLH atmospheres unless equipped with escape SCBA.
- Use of compressors limited by quality of ambient air.
- Couplings must be incompatible with outlets of other gas systems used onsite.
- See Table 4-4 for advantages/disadvantages of atmosphere-supplying respirators.

Combined SCBA/SARs

- Can operate in either SCBA or SAR mode.
 - SCBA - entry and exit.
 - SAR - extended work in contaminated area

Respirator Certification

- NIOSH/MSHA
- Respirators and components are certified as a unit; interchanging parts voids certification.

Limitations

- Air-purifying filters and cartridges approved for only certain materials and conditions of use (organic vapor cartridge - adequate warning properties and at least 19.5% O₂).

Assigned Protection Factor (APF)

- Each type of respirator (half-mask, PAPR, etc.) is assigned an APF.
- $APF = \text{Outside Concentration} / \text{Inside Concentration}$.

Example - respirator with APF of 100

If outside concentration = 200 ppm, what is concentration inside facepiece?

$$100 = 200 \text{ ppm} / x \text{ ppm}$$

$$x = 2 \text{ ppm}$$

- Can use APF and PEL or TLV to determine maximum concentration of contaminant in which respirator can be used.

Maximum concentration (ppm) = APF x Allowable Exposure Limit

Example - Air-purifying, half-mask respirator: APF = 10.

Contaminant: TLV = 20 ppm

Maximum Concentration = APF x TLV

x = 10 x 20

x = 200 ppm

- See Table 4-5 for assigned protection factors.

4.4 RESPIRATOR SELECTION

Respirator selection is a complex process that should be performed only by a trained industrial hygienist familiar with the actual work environment and job tasks to be performed.

| | |
|-----------------------------------|---|
| General Considerations | <ul style="list-style-type: none">• Nature of hazardous operation, process or condition• Contaminant, type of hazard, concentration, effects on body• Activities to be conducted• Time protection needed• Escape time• Available respiratory protection equipment• Service life of cartridges/canisters |
| Contaminant Considerations | <ul style="list-style-type: none">• Physical, chemical, toxicological properties• Odor threshold• REL, TLV, PEL• IDLH concentration• Eye irritation potential |
| Respiratory Hazards | <ul style="list-style-type: none">• Oxygen deficiency• Flammable atmosphere• Toxic atmospheres |
| Oxygen Deficiency | <ul style="list-style-type: none">• SCBA/pressure-demand• SAR/auxiliary SCBA |
| Flammable Atmospheres | <ul style="list-style-type: none">• General Policy: do not enter if >25 % of LEL.• SCBA/pressure-demand |
| Toxic Atmospheres | <ul style="list-style-type: none">• IDLH - SCBA/pressure-demand• Above PELs but below IDLH - APR or SAR• Below PEL - none required |

TABLE 4-5. RESPIRATOR PROTECTION FACTORS

| Assigned Protection Factor | Type of Respirator | Contaminant | | |
|----------------------------|--|--------------|-----------|---------------------------------|
| | | Particulate | Gas/Vapor | Combination |
| 10 | APR/half-mask | X | X | X |
| | APR/full-face | X (any type) | | X (any type particulate filter) |
| | SAR/half-mask/negative | | X | X |
| 25 | PAPR/hood or helmet | X | X | X |
| | SAR/hood or helmet/continuous flow | X | X | |
| 50 | APR/full-face | X (HEPA) | X | X (HEPA) |
| | PAPR/tight-fitting | X (HEPA) | X | X (HEPA) |
| | SAR/full-face/negative | X | X | X |
| | SAR/tight-fitting/continuous flow | | X | X |
| | SCBA/full-face/negative | X | X | X |
| 1000 | SAR/half-mask/positive | X | X | X |
| 2000 | SAR/full-face/positive | X | X | X |
| 10,000 | SCBA/full-face/positive | X | X | X |
| | SCBA/full-face/positive/auxiliary positive | X | X | X |

4.5 RESPIRATOR USE

- | | |
|--|--|
| Respirator Policy | <ul style="list-style-type: none">• Provide appropriate respiratory protection devices for agency employees.• Require use of devices when necessary to protect health:<ul style="list-style-type: none">- high potential for sudden release, or actual release of toxic gases/vapors;- hazardous environments or locations (spill sites);- confined spaces;- engineering controls not feasible.• Allow employees to wear respiratory protection even when concentrations are not expected to harm health and others are not affected.• Keep hazardous conditions under surveillance.• Keep employee exposure or stress at safe levels.• Require standby personnel at IDLH atmospheres.• Require written Standard Operation Procedures (SOPs) for selection and use of respiratory protective equipment. |
| Respirator Program Requirements | <ul style="list-style-type: none">• Written program (SOPs)• Respirator selection• Training• Respirator assignment• Cleaning• Storage• Inspection and maintenance• Surveillance• Program evaluation• Physical examination |

4.6 SPECIAL CONSIDERATIONS

- Facial hair
 - Eye glasses
 - Contact lenses
 - Facial deformities
 - Communication
-

4.7 RESPIRATOR FIT TESTING

- | | |
|--------------------------------|--|
| | <ul style="list-style-type: none">• Required for negative pressure air-purifying respirators. |
| Varieties | <ul style="list-style-type: none">• Two types:<ul style="list-style-type: none">- qualitative- quantitative• See Table 4-6 for advantages/disadvantages of qualitative and quantitative fit testing. |
| Fit Checks | <ul style="list-style-type: none">• Negative Pressure Test - tests exhalation valve and facepiece seals.• Positive Pressure Test - tests inhalation valves and facepiece seals. |
| Qualitative Fit Testing | <ul style="list-style-type: none">• Determine sensitivity to challenge material:<ul style="list-style-type: none">- banana oil (isoamyl acetate)- saccharin- irritant smoke (stannic chloride)• Select respirator.• Conduct positive/negative fit check.• Enter test chamber.• Introduce challenge material. |

| TABLE 4-6. ADVANTAGES AND DISADVANTAGES OF QUALITATIVE AND QUANTITATIVE FIT TESTING | | |
|---|--|---|
| Fit Test | Advantages | Disadvantages |
| Qualitative | Fast Inexpensive Simple Easily performed in the field | Relies on wearer's subjective response (may not be reliable). |
| Quantitative | Does not rely on wearer's subjective response (Is recommended when the respirator is used in highly toxic atmospheres or those immediately dangerous to life and health). | Requires qualified personnel and equipment. Testing cannot be done on the respirator which will be used. |

- Perform test exercises (minimum of one minute each):
 - breathe normally
 - breathe deeply
 - turn head side to side
 - nod head up and down
 - talk aloud several minutes
 - jog in place
 - breathe normally
- If challenge material is not detected, subject has passed test (PF = 10).

Quantitative Fit Testing

- Conduct qualitative fit test.
- Follow instructions for quantitative fit testing equipment used (fit test chamber, "Portacount").
- Perform test exercises.
- Determine fit factor.

**FUNDAMENTALS OF
ENVIRONMENTAL COMPLIANCE INSPECTIONS**

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CHAPTER 1

1.0 INTRODUCTION TO ENVIRONMENTAL COMPLIANCE

1.1 COURSE OBJECTIVES

This section of the SEDESOL inspector's course provides a brief overview of the course *Fundamentals of Environmental Compliance Inspections* that EPA uses in training its new inspectors. It is hoped that you will 1) gain an understanding of the policies, procedures and techniques an EPA inspector is required to follow and 2) find the information provided to be useful in conducting your own environmental compliance inspections as well.

Note: All the following information represents EPA, not SEDESOL policy.

1.2 COMPLIANCE MONITORING

**Purpose of
Inspections**

To ensure that environmental requirements are being implemented effectively, inspections are conducted to:

- Assess compliance status and document violations for enforcement action.
- Provide oversight of inspection programs carried out by other agencies such as state jurisdictions.
- Gather data as part of an area/industry-wide inspection plan to assess the need for additional controls.
- Promote voluntary compliance.
- Establish an enforcement presence to promote compliance.
- Support the permit issuance process.

1.3 MOTIVATION FOR COMPLIANCE

| | |
|--------------------------------------|---|
| Motivating Factors | <ul style="list-style-type: none">• Societal/moral factors• Short-run economic factors• Long-run economic factors |
| Natural Disincentives | <ul style="list-style-type: none">• Individual property rights• Economic advantages of noncompliance• Fear of change• Expediency• Lack of knowledge on how to comply or where to get that knowledge |
| Role of Enforcement | <ul style="list-style-type: none">• Fear of detection• Assurance of fairness |
| Credible Enforcement Presence | <ul style="list-style-type: none">• Likelihood of detection• Serious consequences of detection• Swift and sure response• Fair and consistent response |

1.4 THE INSPECTOR'S ROLE

The inspector plays a crucial role in motivating companies to comply with environmental regulations, thereby protecting the people who might otherwise be exposed to toxic chemicals and other hazardous materials. The more effective the inspector can be, the higher the rates of compliance will be. Higher rates of compliance mean lower risks to human health and the environment. If an inspector does not find and properly document a violation, there can be no enforcement.

Inspectors must master both the "science" and the "art" of inspections. You need not only a thorough understanding of the technical aspects of the job -- you also need to learn to ask the right questions, follow the paper trails, and check out inconsistencies.

CHAPTER 2

2.0 INSPECTION PLANNING AND PREPARATION

Planning and preparation are essential to:

- Focus the inspection on the most important issues.
- Make the most efficient and effective use of time on site.
- Ensure that equipment will be available when needed.
- Ensure that proper procedures are followed.

2.1 RESPONSIBILITIES OF THE INSPECTION TEAM

Inspector Responsibilities

Effective inspections begin with careful planning that includes:

- Reviewing available information on the facility, and
- Preparing an inspection plan.

2.2 REVIEWING AVAILABLE INFORMATION

A review of available information will enable inspectors to:

- Become familiar with the facility (personnel, size, operations);
- Learn about findings from previous inspections, including violations;
- Avoid requesting previously submitted information; and
- Clarify legal and technical issues before entry.

**Available
Information**

The following information might be available:

- Facility location, geographical features;
- Names of officials or representatives;
- Descriptions of recordkeeping/filing systems;
- Previous entry problems;
- Safety requirements;
- Special exemptions from requirements;
- Notifications;
- Prior inspection records;
- Compliance problems/enforcement actions;
- Complaints from citizens about the facility; and
- Correspondence.

2.3 PREPARING THE INSPECTION PLAN

An inspection plan is an organized approach to guide the conduct of the inspection. It:

- States the reason for inspection;
- Defines the scope of the inspection;
- Specifies procedures;
- Defines tasks; and
- Identifies equipment and materials needed.

**Inspection
Plan Elements**

An inspection plan should include:

- Objectives and scope;
- Inspection activities and field techniques;
- Quality Assurance Project Plan, including a sampling plan;
- Safety plan; and
- Administrative requirements.

Use the preinspection checklist that follows this section or develop one of your own to ensure that you have completed all planning tasks for each inspection.

2.4 PREINSPECTION CHECKLIST

GENERAL EQUIPMENT

- Camera
- Film and flash equipment
- Pocket calculator
- Tape measure
- Clipboard
- Waterproof pens, pencils, and markers
- Locking briefcase
- "Confidential Business Information" stamp
- Stamp pad
- Pre-addressed envelopes
- Plastic covers
- Plain envelopes
- Polyethylene bags
- Disposable towels or rags
- Flashlight and batteries
- Pocket knife
- First Aid Manual
- Kneeboard
- Knapsack
- Rope

SAMPLING EQUIPMENT

Sampling equipment will vary by program and media. Examples of typical sampling equipment follow.

- Crescent wrench, bung opener
- Siphoning equipment
- Weighted bottle sampler
- Bottom sediment sampler
- Liquid waste samplers (e.g., glass samplers)
- Auger, trowel, or core sampler
- Scoop sampler
- Sample bottles/containers (certified clean bottles with teflon-lined lids)
- Labeling tags, tape
- Storage and shipping containers with lids
- Ice chest
- Container for contaminated material

- Hazard labels for shipping samples
- Ambient air monitor
- Field document records
- Vermiculite or equivalent packing
- Thermometer
- Colorimetric gas detection tubes
- pH equipment
- Explosimeter
- Oxygen meter

SAFETY EQUIPMENT

- Safety glasses or goggles
- Face shield
- Ear plugs
- Rubber-soled, metal-toed, non-skid shoes
- Liquid-proof gloves (disposable, if possible)
- Coveralls, long-sleeved
- Long rubber apron
- Hard hat
- Plastic shoe covers, disposable
- Respirators and cartridges
- Self-contained breathing apparatus
- Drinking water - plain and salted (1 tsp. salt/5 liters H₂O)

EMERGENCY EQUIPMENT

- Substance-specific first aid information
- Emergency telephone numbers
- First-aid kit with eyewash
- Fire extinguisher
- Soap, waterless hand cleaner, and towels
- Supply of clean water for washing

CHAPTER 3

3.0 ENTRY AND OPENING CONFERENCE

3.1 KEY ELEMENTS OF ENTRY

Inspectors should:

- Follow correct administrative procedures and requirements -- failure to do so can jeopardize subsequent enforcement actions.
 - Check planned inspection activities against the actual situation at the site and make adjustments as needed.
-

3.2 APPROACHING THE FACILITY

The investigation begins before you reach the front door of the facility. As you approach the facility, look for signs of potential violations. These can include:

- Dead or unhealthy vegetation
- Unusual emissions from stacks
- Ponds or lagoons on the property that appear to contain oily or discolored water or sludges
- Leaking containers
- Uncovered piles of waste
- Open burning or burn pits
- Oil or discoloration of water in streams or rivers that surround the property

- Strong or noxious odors
- Dust or debris on haul roads
- Deposits on vehicles

Be prepared to amend your plan to focus on these potential problems.

3.3 ENTRY PROCEDURES

Inspectors should follow proper procedures when entering a facility so that no questions or challenges can be raised regarding the legality of the inspection.

- Arrive during normal working hours.
- Use the main entrance.
- Ask to see the owner or other authorized facility representative.
- Present your credentials.
- Explain the inspection authority.

3.4 OPENING CONFERENCE

The inspector should use the opening conference to inform the facility representative of planned activities, to gain an understanding of the facility's operations and practices, and to address logistical arrangements. Inspectors should:

- Explain the anticipated inspection activities in *general terms*.
- Identify activities and processes that occur at the site and their environmental implications.

- Determine what environmental programs and controls are in place (e.g., air monitoring, employee training, equipment maintenance) and what records are available.
- Verify the applicability of regulations or requirements.
- Determine who the responsible parties are for the site.

3.5 AMENDING THE INSPECTION PLAN

Information gathered as you approach the site and during the opening conference may lead to changes in the inspection plan. Be prepared to add or change interviewees, sampling points, and record reviews.

CHAPTER 4

4.0 INFORMATION GATHERING AND DOCUMENTATION

4.1 TYPES OF INFORMATION AND DOCUMENTATION

Types of Information

There are four types of information and documentation:

- Testimonial (what you are told)
 - Real (physical samples you gather)
 - Documentary (written records you collect or copy)
 - Demonstrative (photographs and drawings you make)
-

4.2 DOCUMENTING INFORMATION

Field Logbook

An inspector's field notes/logbook:

- Provides the foundation for preparing reports.
- Is useful in refreshing memory.
- Should contain information which is objective, factual, and free of personal feelings or conclusions.
- Should be bound and consecutively numbered.
- Should list documents taken or prepared, photos taken, unusual conditions, problems, interview notes, general information, incidents, and administrative data.

Inspectors should:

- Maintain one logbook per inspection.
- Use waterproof ink.
- Write legibly.
- Draw a line through incorrect entries and initial them.
- Make a diagonal line at the conclusion of an entry and initial it.

4.3 TECHNIQUES FOR IMPROVING INFORMATION GATHERING SKILLS

Detecting hints of potential violations will help you focus your inspection on the most important issues.

In interviews, listen for:

- Reports of knowing violations, such as night dumping or shutting down of pollution control equipment.
- Reports of accidental releases, such as spills.
- Complaints about odors, skin problems, or other health effects that workers believe might be related to contact with hazardous or toxic materials in the workplace.
- Stories or information that conflict with written records or reports from other workers.

During the inspection, look (and smell) for:

- Excess or uncontrolled emissions.
- Excess odors.
- Spills, leaky containers, and generally poor housekeeping.
- Inoperable equipment or equipment in a gross state of disrepair.
- Equipment that has been damaged from fire or explosion.

4.4 RECORDS INSPECTION

The two objectives of inspecting facility records are to:

- Determine whether required records are being maintained; and
- Use facility records as a substantiation of compliance or noncompliance.

Review Considerations

The inspector should note the kinds of records examined and why. When reviewing records, consider these questions:

- How complete is the information?
- What are alternative sources for the same information?
- Has the facility tried honestly to meet recordkeeping requirements?
- Are there discrepancies or suspicious consistencies between current reports and field data or past reports?
- Are the required reports complete, accurate, and of good quality?
- Do the records comply with retention requirements?
- Does information in the records seem consistent with first-hand observations?

Targeting and Locating Records

As part of determining exactly what records an inspector needs to examine, he or she should:

- List the kinds of records needed for compliance and their retention requirements.
- Become familiar with the facility's recordkeeping system.
- Establish priorities for the material to be reviewed.
- Request that facility personnel identify pertinent files and sources.

- Check back-up and cross-filing systems that might make retrieval more efficient.

Records Sampling Time constraints often prevent inspectors from examining all records at a facility. Therefore, the inspector reviews only a sample of these records. To increase the likelihood that problems will be detected, it is important that the sample is "representative" of the entire universe of records, just as it is important that a physical sample is representative of air emissions or water effluent.

The key point in sampling is to think systematically. If the inspector suspects a problem, the sample should be drawn from records that are likely to document the problem. The sample could focus on a particular time period, a specific set of employees, or specific activities.

Sampling methods include:

- **Random sampling** -- each record has an equal chance of being included in the sample.
- **Interval sampling** -- every fifth, tenth, etc. record is selected based on a random starting point.
- **Stratified sampling** -- breaks the entire population into categories based on relevant characteristics and applies random or interval methods within categories. A larger sample can be drawn from categories of concern.
- **Block sampling** -- selects records only within a specific category.

4.5 PHYSICAL SAMPLING

Why Take Physical Samples

Physical samples are taken during a compliance inspection to substantiate that a violation occurred. Samples provide quantitative data to assess the nature, level, and extent of pollution or contamination that result from a violation. Physical samples may include the results of in-situ monitoring, or later analysis of samples of soil, water, air, wastes, sludges, and residues from a site. Sampling may even include biological sampling to establish whether or not contaminants have damaged or have the potential to damage the environment or human health.

Developing A Plan

In order to conduct sampling that supports the goals of an environmental inspection, it is important to develop a plan that will guide the selection of appropriate sampling methods. The Plan should:

- Establish and communicate sampling objectives and data quality requirements;
- Identify levels of discharge that will be within compliance;
- Make realistic projections of cost and time required for sampling;
- Establish comprehensive sampling and quality assurance protocols; and
- Identify and characterize broader site conditions to support sampling data.

What Information Can Be Used for Planning?

SEDESOL Inspectors are responsible for monitoring compliance for all potential sources of pollutants. An examination of any available records about a site is a useful way to begin planning an inspection. Many of the sites you will inspect may already be permitted. If this is the case, the office with jurisdiction over the facility might maintain a file on the permits that contains information about the types and amounts of discharges that will be found at a site. It may also contain reports and information on previous inspections. Your job, here, will be to assess whether or not a site has come into compliance or has maintained compliance.

Many of the sites that you will inspect may not have permits or applications for permits on file. These sites may have been brought

to your attention by citizen complaints, news reports, police reports, or observations collected in a visit to a nearby site. You may have little information to use in developing a plan but you will need to identify a best approach before you go into the site to conduct an effective compliance inspection.

Developing A Project Plan

A quality assurance project plan (QAPP) should be developed for each sampling inspection. This plan details how the inspection will be conducted and what the objectives for the inspection are. It should include the following:

- A description of the site and project;
- Identification of the data quality objectives for the study;
- A description of the sampling to be done and justification for selection of sample sites;
- A description of quality assurance and quality control methods and requirements;
- A description of the analysis and sampling plans and standard operating procedures (SOPs);
- A description of sample preservation and chain of custody requirements;
- A description of documentation required to meet the administrative and technical requirements;
- A project safety plan; and
- Other relevant information.

The description of the site should include any available maps that will be useful in identifying sampling locations and points of reference. Even for unpermitted and undocumented sites, it may be useful to include the best available map so that probable points of discharge, wells, and other surface features can be used to identify probable sampling points. Samples and/or appropriate on-site monitoring instrument analysis should be taken from every observable aqueous discharge. Samples may also be taken from process reactors when necessary to identify or confirm the chemical processes occurring at a facility. Samples from pools of water near waste drums and containers may reveal leakage from these containers.

Because many of the facilities that you will visit are not yet permitted, you will often need to make decisions in the field on what should be sampled. Let your eyes, nose, and ears be your guide! The presence of unusual solids, scums, and corrosion near a discharge outlet, pipes, or valves may be a good indicator that a toxic or hazardous material has escaped into the environment. You may want to carefully collect samples of these residues for analysis. Samples from nearby wells may also reveal the presence of contaminants in groundwater.

For air quality, you may want to monitor, or collect samples from stacks, but you may also want to use monitoring equipment to check around tank seams, pipes, valves, and tank openings to look for fugitive emissions.

You may also want to take samples of soil surrounding process tanks or piping if there is any indication of spillage. Similarly, soil samples from storage depots where drums or containers of suspected wastes are kept may confirm the nature and extent of any spills. Soil samples can be taken from the surface or from deeper in the ground using coring or drilling devices.

Data quality objectives (DQOs) should be identified as part of the QAPP, prior to the actual inspection. DQOs are specifications for what is required to establish a statistically sound characterization of conditions at the site. DQOs will identify where and how many samples will be taken to establish a representative picture of site conditions. The DQO statements will also establish the statistical requirements for detectability, precision and accuracy in analysis or on-site monitoring and identify what will be required to achieve completeness in sampling. These short definitions may help you understand these concepts associated with chemical analysis:

- Detectability -- the lowest concentration of a substance that can be measured as being present
- Accuracy -- the degree of agreement of a measured value and a true value for a substance
- Precision -- the degree of agreement between repeated measurements of the same sample

How Do DQOs Help?

It has been said that "the ability to correctly determine the difference between a bull and a mouse at least 95% of the time" is a data quality objective for selecting the right mouse trap. While this is a very simplified picture of what DQOs do, it does illustrate how important it is to identify what you will need to do the job correctly. A better example of how to select DQO's might be found in

selecting methods of chemical analysis that will be sensitive enough to determine if the concentrations of a contaminant in a sample are in violation or not.

When and how often you sample may also be very important and the QAPP should identify the timing and frequency of samples. An example of this is often seen when you are required to monitor discharges that are part of specific industrial process that occur only at specific times. Unless you have a system that monitors continuously over a period of time, you may miss the discharge violation.

QA/QC

There are a number of steps an inspector should take to provide information about the quality of sampling and analysis. The laboratory should provide you with information from analysis that will allow you to assess whether or not the analytical quality objectives were met, but you must also be prepared to assess the quality of on-site monitoring and sample collection. The QAPP should also include protocols and special samples (Quality Assurance or QA Samples) that will help you assess data quality. These steps should include:

- Exact protocols on daily calibration of field monitoring equipment such as pH meters, flow meters, UV gas detectors, and conductivity meters. Manufacturers' manuals should be provided to ensure correct calibration.
- Protocols for quality control checks during operation of field and laboratory instruments. Frequent use of independent quality control check standard materials (QCCS) (independent of calibration standards) will be necessary.
- Protocols for collection of QA samples including field duplicate samples to measure field variability; and field blank samples - samples that are laboratory pure water (deionized and distilled) but handled just as any other sample - are used to check for cross-contamination between samples.
- Protocols for cleaning of equipment and safe decontamination of field equipment to avoid cross-contamination of samples or health risks to inspectors and technicians.
- Protocols for laboratory QC sample analysis for assessment of accuracy, precision, and detectability.
- Protocols to identify the number and types of sample containers to be used and the volumes of samples and preservatives required.

Plan The Logistics Arrangements for travel and secure shipment of samples should be made ahead of time. Make sure that the materials you will require are collected, packed and shipped (when necessary) to a place where they will be secure until you arrive. Checklists are often used to verify that you will take everything you need. Use a field log book with numbered sequential pages for maintaining observations taken during your inspection. Make all entries directly in this book. Do not transcribe them from other papers but take this book into the field with you. Do not obliterate entries but place a single line through incorrect entries, make corrections and initial corrections in the margin of the page.

If you are taking any monitoring instruments to the inspection site, such as pH meters, flow meters, gas detectors, etc. check them out before you pack them to make sure they work and can be calibrated for use. Carry fresh spare batteries for instruments that are battery-powered as well as some alcohol and an abrasive cloth to keep battery terminals clean.

Carry an ample supply of clean laboratory water for use as field blanks or to make buffers and other reagents in the field. If possible, make up standards for calibration fresh for each inspection and refrigerate them while you are in transit.

It will be important to coordinate your activities with the laboratory that will analyze the samples. Check requirements for sample volumes and preservation methods with the laboratory and give them advance warning about when and how many samples will arrive at the laboratory. Make sure someone will be there to receive them so that the samples will be maintained in a chain of custody.

**Identifying
Sampling Points**

Inspectors should rely on the QAPP and the Sampling Plan in that document to identify sites where samples are to be taken. In permitted sites, you may find conditions that are not in agreement with what is stated in the QAPP and you will have to use your discretion about drawing additional samples based upon your interview and what your eyes, ears, and nose tell you. Monitoring instruments that you carry may extend the sensitivity of those senses but your most important tool will be your judgment. Remember that deviations from your Sampling Plan and QAPP will need to be documented in your field notes and that you will need to amend your QAPP when you return to your office to provide justification for the change in the inspection and guidance to the next inspector who visits that site.

Many inspectors find it useful to photograph each sample location at the time the sample is taken or monitoring is performed to capture a visual image of conditions. If you can photograph the sampling, remember to write the frame number in your field notes.

Using Monitoring Equipment

If you are using monitoring instruments, you will need to check their operation and calibrate them at the beginning of each day. Follow the manufacturer's instructions regarding recalibration and use of quality control check standards.

Record all instrument readings in your log book along with date, time, and specific sample site location (for example - "air vent near process tank on northwest corner/second floor of building #2- see indicator on map"). Also indicate in your field notes if other samples were also collected at the site.

Collecting Samples

Samples or monitoring readings (when appropriate) should be collected at all observed discharges for water and air effluents when discharges are occurring. Locations that show discoloration, scums, slimes, deposits, corrosion, and other indications of chemically contaminated discharges should have the highest priority. Similarly, air monitoring may be appropriate where discharges are apparent, or where odors, visible vapors, air flow noises, or abrupt heat differences indicate stack or fugitive emissions. Permanent collection devices, such as bag or precipitator air cleaning devices may be sampled as can process reactors if it is desirable to characterize and quantify ingredient/process/waste/ product streams for the application of mass-balance approaches to determining wastes.

Water samples may be collected directly from flows by grab sample, or by pump or collection bottle, taking precautions to rinse collection devices and go from areas of lowest contamination levels to high if possible to minimize sample cross-contamination.

Air samples are most often obtained using monitoring instrumentation, or by the use of a pump and adsorbent system to capture contaminants from an air stream (see Figure 4-1).

Solids such as soil can be scoop sampled, or drilled, or cored. Liquid wastes such as solvents or chemicals in barrels are best sampled using a dipper that is usually called a "thief".

AT ALL TIMES DURING SAMPLING, INSPECTORS SHOULD KEEP THEIR SAFETY FOREMOST IN THEIR MIND. INSPECTORS SHOULD NOT RISK THEIR LIVES OR HEALTH TO COLLECT SAMPLES.

Sample volumes vary with the media to be analyzed and the contaminants of interest. Laboratories can advise you concerning the types of containers that should be used for specific sampling and the volume or weight of sample to be collected. Reference guides such as the Water Pollution Control Federation (WPCF) *Handbook for Chemical Analysis of Freshwater* can also give you guidance.

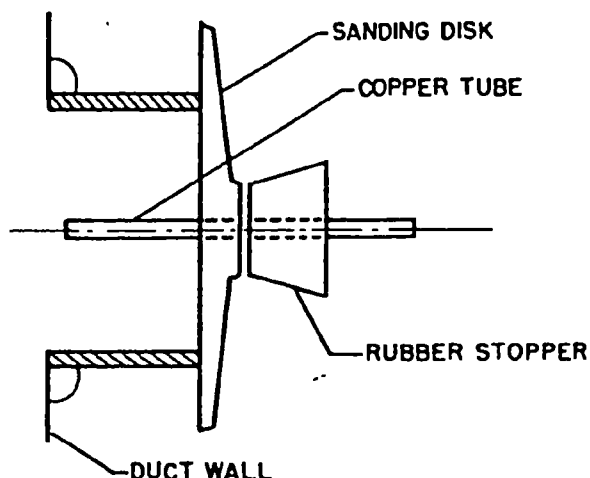


Figure 4-1. Sampling from a high-negative-pressure duct

QA Samples

Quality Assurance Samples from the field will account for about 10% of the total number of samples sent to the laboratory. They include field blank samples to identify background levels of contamination encountered in sampling; field duplicates to identify site variability; and split samples (where a sample is divided in half and put into two separate containers in the field) for estimating variability introduced by sampling itself.

Preservation

Most samples will need to be preserved to stabilize the contaminants in the sample against thermal, chemical, or biological decomposition. Some samples can be preserved chemically but many will need to be refrigerated at 4 degrees Celsius for shipment to the laboratory to retard decomposition. It is very important to ship samples well chilled in the fastest possible way. The temperature of the samples upon arrival at the laboratory will also need to be recorded.

Labels

Samples taken in the field need to be labeled completely and correctly prior to shipping. Every sample label should contain:

- a unique sample number;
- site name;
- date;
- time;
- analysis;
- preservative used; and
- inspector's name.

The sample control number should be recorded in the field log book along with a description of the sample that includes sample location and type as well as the dates of sampling and shipping and conditions of shipping. Later, you will confirm the sample's condition at the time of arrival at the laboratory and make that part of your log entry.

Sealing

Samples should be sealed with a protective band of tape that prevents seepage that could contaminate the sample. Sealing the sample in a plastic bag, or even two plastic bags, will help prevent contamination of other samples. Ice that is used to cool the samples in the cooler for shipping should also be bagged in plastic to minimize the risk of melt-water contaminating the samples. At the laboratory, the bags and seals should be inspected by the technicians to confirm that no breakage, leakage, or tampering has occurred.

Chain of Custody

Once the shipping container containing the samples is full, and the shipping temperature of the samples can be confirmed at 4 degrees C., the cooler should be closed, sealed with packing tape, and then sealed with a custody seal. Transfer of the cooler from inspector, to shipping agent, to laboratory clerk should be documented with signatures and dates on a chain-of-custody receipt that travels with the samples. Upon arrival at the laboratory, the laboratory technician or clerk who receives the samples should examine the seal for tampering and certify it's integrity before opening the shipping cooler. The technician should confirm the 4 degree C temperature in the cooler upon opening, and store the samples in a secure, cold location, where access is regulated and documented. In this way sample integrity can be assured and documented to refute any claim of tampering or mishandling that could compromise the data. In general, samples should arrive at the laboratory within a day or two of collection to ensure adequate refrigeration, and samples should be packed with an equivalent weight of ice (5 liters of samples needs 5 kilograms of ice) to ensure adequate preservation in transit.

| | |
|--|--|
| Confirm Condition of Samples on Arrival | It is the inspector's responsibility to confirm that the samples arrived safely and that all samples were intact and that refrigeration was adequate. To complete his records, the inspector should request the chain of custody receipt form and seals be returned to him for inclusion in the inspection file. |
| Evaluating the Data | Both quality control and quality assurance data need to be evaluated before you can use the sample data with confidence. Here are some things to look for. |
| <i>Laboratory and Field Quality Control Data</i> | <ul style="list-style-type: none"> • Confirm that all laboratory analyses support the "accuracy" data quality objective for each analysis parameter. • Confirm that the laboratory has tested accuracy of analysis using either analysis of an independent audit material, recovery of a "spike" of the analyte of concern added to a sample after original analysis, or in the case of analysis for unknown organic materials, that a surrogate organic compound of similar molecular weight and structure can be quantified accurately. • Confirm that the laboratory has analyzed duplicates or splits of samples and that the results are repeatable within the data quality objective for precision. • Confirm that the laboratory has satisfactorily demonstrated the detection limit for the analytes of interest on a regular basis. |
| <i>Quality Assurance</i> | <ul style="list-style-type: none"> • Examine the results of field blank analysis and confirm that field blanks do not contain contaminant of interest in concentrations greater than 3 times higher than the instrument detection limit. • Examine the results of field duplicate analysis to characterize field variability of the contaminant. • Examine the results of field split analysis -- variability should not exceed the specified data quality objective for precision. • Examine sample results data for outlier values -- data which lie far below or far above the mean and standard deviation for the rest of the field sample (don't include the blank) results. These data may be suspect. Applying a statistical test for outlier value (such as Grubbs outlier test) can assist you with this evaluation. |
| Maintaining Records | Original copies of laboratory reports, chain of custody documents, calculation worksheets, and your field notebook should be maintained as part of the inspection file. These records should be secured to avoid loss or tampering. |

4.6 INTERVIEWS

Planning the Interview

As the first step in the interviewing process, planning the interview should involve:

- Identifying the interviewees who could provide information to meet inspection objectives;
- Identifying the specific reason that a particular person is to be interviewed and information to be obtained; and
- Scheduling the interview at a convenient time and place for the interviewee, if possible.

Conducting and Documenting the Interview

The initial contact between inspector and interviewee sets the tone. The main points of the interview include:

- Asking the employee to explain his or her responsibilities as they relate to the topics being reviewed in the inspection;
- Asking specific and concrete questions to help answer the compliance questions raised in the inspection plan;
- Rechecking after each phase of the interview to see that all the "unknowns" have been explored;
- Rearranging the information mentally into a logical order; and
- Summarizing the interview to allow the interviewee to correct any mistakes.

An inspector should always document an interview, either by taking detailed notes, getting signed statements, or tape recording the interview.

Questioning Techniques

The basic questions used in interviewing are:

- What happened?
- When did it happen?
- Where did it happen?
- Why did it happen?
- How did it happen?
- Who was involved?

Suggestions for improving interviews are:

- Ask questions that require narrative responses rather than "yes" or "no" answers. Yes/No questions should be used only when summarizing or verifying information that has already been given.
- Avoid leading or suggestive questions which might bias the interviewee's answers and detract from their objectivity.
- Avoid questions that ask for two separate pieces of information.
- Order the questions from general to specific topics: determine what was done before exploring how it was done. Start with the known areas of information and work toward the undisclosed information.
- Work backwards in time, from the most recent events.
- To help interviewees estimate quantities more accurately, use well-known reference points, relate to commonly observed quantities, or compare to similar items or distances at the interview site.
- Give the interviewee time to think about the response.

Collecting Written Statements

When taking written statements, an inspector should:

- Determine the need for a statement.
- Ascertain all the facts and record those which are relevant regardless of the source.
- Prepare a statement by:
 - Using a simple narrative style,
 - Narrating the facts in the words of the person making the statement, and
 - Presenting the facts in chronological order.
- Identify the person positively (name, address, position).
- Show why the person is qualified to make the statement.
- Present the pertinent facts.

- Have the person read the statements and make any necessary corrections before signing (all mistakes that are corrected must be initialed by the person making the statements).
- Ask the person making the statement to write a brief concluding paragraph indicating that he or she read and understood the statement.
- Have the person making the statement sign it. If the person refuses, then ask for a statement in the person's own handwriting stating that the statement is true, but that he or she refused to sign it.
- Give a copy of the statement to the signer if requested.

4.7 OBSERVATIONS AND ILLUSTRATIONS

Make use of all sense perceptions: sight, smell, hearing, or touch. Make use of sketches, field notes, and photography.

Photographs as Evidence

Photographs are becoming increasingly important in the enforcement of environmental law because they are persuasive in court proceedings and provide excellent documentation.

For these reasons it is very important that inspectors become good photographers. Before visiting a facility inspectors should learn:

- Which film type is best for the expected conditions;
- How to load and unload the film;
- How to insert batteries for the flash unit (if separate) and camera;
- The minimum focal distance of the camera;
- How to operate the flash unit;
- The maximum flash distance; and
- Whether the camera has a sliding lens cover.

Although the right to photograph is part of the right to inspect, inspectors must testify that photographs fairly and accurately represent site conditions.

Tips on Taking Photos

- Maintain fresh film and batteries.
- Use a waterproof camera if possible.
- Pay special attention to composition, including the center of interest, background, and scale.
- Use a camera which automatically records the date and time on the film.
- Document photos by noting in logbook the frame number along with a detailed description of the subject matter.
- Take a picture of your business card as the first photograph on the film.
- Record necessary information on the back of the photo when working with an instant camera.
- Place a common item next to the item of interest to indicate size and scale.
- Photograph all sides of an item if necessary to document a violation.
- Take several photographs using different settings if the light is poor.
- Take overlapping photographs to depict a wide area.

Drawings and Illustrations

Maps showing location of facility and plot plans showing activities within facility are useful. Use sketches to supplement photos of equipment. Identify photo sites, sample sites, and observation sites on a sketch map or on the original site map in your logbook.

4.8 EXIT INTERVIEW

When the inspection is complete, the inspector should conduct a quick, concise, wrap-up interview to obtain any additional information necessary and to convey to the facility representative the findings of the inspection.

However, inspectors should carefully avoid conveying conclusive compliance determinations because:

- The inspector has not had time to reflect upon and correlate all observations;
- Laboratory analyses have not been completed;
- Other individuals may ultimately determine the facility's compliance status; and
- The inspection findings may represent only a portion of an enforcement case.

If asked if any violations were found, the inspector may point out various items the facility officials might want to recheck for compliance purposes. Inspectors should never say "there are no violations" at the facility.

Inspectors also should not leave a copy of field notes or checklists with the facility representative because:

- The inspector's notes or shorthand may be misunderstood; and
- The inspector may remember and write down something after leaving the site (may result in discrepancies).

4.9 EXIT OBSERVATIONS/ACTIVITIES

Upon leaving the facility, the inspector should resurvey the site and note whether any significant changes have occurred since the inspection began. Such observations may better represent typical operating conditions than what was recorded while the inspector was on site.

The inspector should also review and complete site drawings and chain-of-custody forms following the inspection.

CHAPTER 5

5.0 POST-INSPECTION ACTIVITIES

5.1 THE INSPECTION REPORT

The purpose of the inspection report is to present a complete, accurate, and factual record of an inspection. It organizes all evidence gathered in an inspection.

Elements of an Inspection Report

Although the format and exact contents of an inspection report will vary, each one should provide enough information to tell the reader:

- The specific reason for the inspection;
- Who participated in the inspection;
- That all required notices, receipts, and other legal requirements were met;
- What actions were taken during the inspection, including the chronology of these actions;
- What statements, records, physical samples, and other evidence were gathered during the inspection;
- What observations were made during the inspection; and
- The results of the sample analyses related to the inspection.

Also, most reports will contain inspection report forms, narrative reports, and documentary support.

Writing an Effective Inspection Report

When writing an inspection report, it is important to relate the facts and evidence relating to the inspection simply and with the reader in mind. A good inspection report exhibits:

- Fairness;
- Accuracy;
- Conciseness;
- Clarity;
- Completeness;

- The source of evidence;
- Exhibits (supplementary material);
- Organization; and
- Good writing.

Narrative Report Narrative reports, as part of an overall inspection report, should be a concise, factual summary of observation and activities. Basic steps involved in writing the narrative report include:

- Receiving the information;
- Organizing the material;
- Referencing accompanying material; and
- Writing the narrative report. Be sure to:
 - use a simple writing style;
 - keep paragraphs brief and to the point;
 - avoid repetition; and
 - proofread the narrative.

Despite the variations in the specific information contained in a narrative report, most reports can follow an outline, which features the:

- Introduction
 - general information
 - summary of findings
 - history of the facility;
- Inspection activities
 - entry/opening conference
 - records
 - evidence collection
 - physical samples
 - closing conference; and
- Attachments
 - list of attachments
 - documents
 - analytical results.

Include photos, maps, and illustrations if they are available.

WASTE WATER INSPECTIONS

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CHAPTER 1

1.0 GENERAL WASTEWATER INSPECTION PROCEDURES

1.1 OBJECTIVE

This section provides general procedures to follow when inspecting a facility's wastewater generation and discharge.

1.2 PURPOSES OF WASTEWATER INSPECTIONS

Purposes of Inspections

There are many purposes for conducting wastewater inspections at industrial and commercial facilities. One of the primary purposes is to gather information about the facility's processes and operations and to characterize its discharges. This characterization should include the volume of wastewater discharges, the types of pollutants the facility discharges or has the potential to discharge, and whether or not the facility's discharge has the potential to cause damage to the receiving stream or the environment. Information gathered can be used to assess the need for pollutant controls and to develop discharge permit conditions or other associated requirements aimed at reducing pollutant discharges and thus reducing the negative impacts of these discharges on the environment. If facilities are required to submit information such as permit applications, or responses to surveys, inspections can also serve as a means of verifying the accuracy of data and information submitted by the facility. Once this information has been gathered, inspections should be performed to maintain and update information on facilities.

Information gathered during inspections can also be used to evaluate the facility's compliance with any standards or requirements and to support any necessary enforcement action for noncompliance. Inspections can also be performed to verify the correction of problems and the attainment of compliance, such as the installation of wastewater treatment equipment.

1.3 INSPECTION PROCEDURES

Inspection Procedures

As with all types of inspections, a wastewater inspection consists of three general steps; pre-inspection preparation, onsite activities, and follow-up activities. Pre-inspection preparation is important so that an inspection is well planned and efficient and that the inspection objectives are met. Onsite activities are the most essential part of the inspection and may include

meeting with facility representatives, conducting a thorough inspection of the facility (including its operations and manufacturing processes, storage areas, and wastewater treatment systems), and examining records. Follow-up activities are necessary to ensure that inspection findings are properly documented. Each of these steps will be discussed in greater detail.

1.4 PRE-INSPECTION PREPARATION

Pre-Inspection Preparation Pre-inspection preparation involves several activities including review of facility records and literature references, development of an inspection plan, notifying the facility (if applicable), and assembling and calibrating safety and sampling equipment. Each of these activities will be discussed in greater detail.

Records Review The inspector should begin preparation for an inspection by reviewing any background information already gathered on the facility. Information to be reviewed may include data submitted by the facility such as responses to surveys or questionnaires or permit applications and correspondence. In addition, reports from any previous inspections or site visits and information relating to the facility's compliance history should be reviewed. During this review, any unresolved compliance problems should be noted so that the inspector can verify these problems onsite. In order to determine compliance, the inspector must be knowledgeable about any regulatory requirements that apply to the facility. If not familiar with these requirements, the inspector should review all relevant requirements, such as permit conditions prior to the inspection.

Literature Review To perform a thorough but efficient inspection and to establish credibility with the facility, the inspector should have at least a basic working knowledge of the facility's manufacturing process. If the inspector is unfamiliar with the particular operation or manufacturing process performed by the facility, applicable literature sources should be reviewed in order to gain a better understanding of the specific process or operation.

Inspection Plan Once the inspector is familiar with the facility's background information, an inspection plan should be developed. Basically, an inspection plan should outline the scope and objectives of an inspection and identify how the inspection objectives are going to be met. The objective of the inspection will determine the scope and depth of the inspection.

During preparation for an inspection, the inspector should note any questions that need to be answered during the onsite activities. By preparing a list of, the inspector can better ensure that all necessary information to develop a complete picture of the facility is gathered.

**Facility
Notification**

In some cases it may be appropriate to notify the facility of an impending inspection. For instance, if a complete facility tour is desired, it may be beneficial to notify the facility so that the appropriate representatives are present. In other cases, such as if noncompliance is suspected or in the event of a spill, notification may not be desirable. The inspector should determine if notification is appropriate and, if so, should contact the facility by telephone or by sending a letter.

In the United States three types of inspections are performed—scheduled, unscheduled, and demand.

- Scheduled inspections are those that are scheduled in advance and that the facility has been notified of the approximate date and time the inspection will occur. Scheduled inspections are most often used for initial or routine inspections.
- Little or no advance notice is given to the facility in an unscheduled inspection. Unscheduled inspections are useful as random spot checks in certain cases such as the facility is suspected to be out of compliance.
- Demand inspections are generally conducted in response to a specific problem or emergency situation such as a spill.

Health and Safety

Ensuring inspector safety is very important during an inspection. Specific information on safety equipment necessary for the particular facility being inspected should be gathered prior to the onsite activities.

This information can be obtained from previous inspection reports, talking to people that have visited the facility in the past, or by obtaining the information directly from the facility. If the facility is notified of an inspection, this may be a good opportunity to inquire about safety equipment necessary for the inspection.

Equipment Preparation

The final step prior to an inspection is to prepare any equipment necessary for the inspection. The type of equipment needed will be dependent on the nature of the inspection and may include safety and/or sampling and flow measurement equipment. The inspector should ensure that all equipment to be used is calibrated and is in proper working order. The inspector may also want to take a camera so that photographs of the facility can be taken.

1.5 ONSITE ACTIVITIES

Periphery Inspection

Prior to entering, the inspector should conduct an examination of the periphery of the facility. If an inspection has not been performed previously, the inspector should note the general size of the facility including the number of buildings at the site.

Any problems around the facility's perimeter such as apparent spills or improperly stored chemicals should be noted. Environmental conditions such as the condition of surrounding vegetation, odor problems, abnormal stack emissions, and whether the facility has a direct discharge to a receiving stream should be noted.

If outside chemical or waste storage areas are visible, the inspector should note the condition of these areas, including spill containment, and any associated problems such as leaking drums.

Finally, if located in an easily accessible area, the inspector may want to look at the facility's discharge points to see if there are any unusual discharges.

If sampling is to be conducted as part of the inspection, the inspector may want to set up the sampling equipment at this time. It may also be useful to perform certain analyses such as pH prior to entering the facility. Doing this may provide insight to additional problems that should be addressed during the inspection. Any problems noted during the examination of the facility's periphery should be addressed during the inspection.

**Facility
Entry**

When entering the facility, the appropriate facility representative should be located. The inspectors should identify themselves and be familiar with and follow applicable procedures for facility entry. Inspectors should provide a copy of the written inspection order.

**Opening
Conference**

It is generally a good idea to conduct an opening conference or pre-inspection meeting with facility representatives, particularly if it is the first visit to the facility.

During this meeting the inspector should briefly state the purpose of the inspection and inform the facility representatives of the intended schedule and order of the inspection. By doing this, it can be better assured that the proper facility representatives will be available to conduct the tour and answer questions. The inspector should also identify any additional records or information that will be needed so that the facility can gather the necessary information while the inspector is onsite.

The inspector should use the opening conference to ask any questions identified during the pre-inspection preparation and to obtain general background information such as the number of employees, production rates, wastewater flow rates, and any changes that have been made since the last inspection. Since many manufacturing facilities are noisy, it may be difficult for the inspector to hear during the tour. Therefore, it may be beneficial to have facility representatives give a brief description of the industrial processes during the opening conference, particularly if it is the inspector's first visit to the facility. If the facility has a plant schematic, the inspector should obtain a copy to make the tour easier to follow and to better ensure that all areas of the facility are covered.

Inspectors should also answer any questions the facility may have. From the start the inspector should strive to establish a good rapport with facility representatives so that they are comfortable and will more readily answer questions and provide the information the inspector needs.

Inspectors should also provide facility representatives with information on applicable regulations and their associated responsibilities. If the facility does not have copies of applicable regulations, the inspector should provide and review these during the opening conference. General information on

pollution reduction and pollution prevention techniques such as brochures or guidance manuals should also be provided.

Inspectors need to remain flexible and be ready to make changes in their inspection plans. Based on the observations during the examination of the facility's periphery or information obtained during the opening conference, it may be necessary to change the objectives or order of the inspection. For instance, if it was noted during the examination of the facility's periphery that a sump collecting runoff from a hazardous materials storage area was being pumped directly to the surrounding ground, this area should be investigated as soon as possible so that the problem is not discovered and corrected by the facility before the inspector has a chance to investigate it.

Facility Tour

After the opening conference, the inspector should conduct a full tour of the facility. Conducting a tour is very important to allow a full description and understanding of the facility's processes and to verify information provided by the facility. Tours also allow the inspector to identify problem areas that can be improved through pollution reduction techniques. The tour should focus on areas of the facility where wastestreams and/or pollutants are produced, processed, pumped, conveyed, treated, or stored. Such areas may include the facility's production processes, storage areas, and treatment equipment. The inspector needs to gain a full understanding of the facility's wastewater generation and treatment. For better understanding of the entire process, it is best to tour the facility in order of production, starting from raw materials and following to the finished product.

Throughout the inspection, the inspector needs to locate all sources or potential sources of wastewater discharge. Sources may range from those that are easily identified such as a running water rinse from a plating bath to those more difficult to identify such as a discharge from a wet air scrubber. A description of each discharge should be obtained. This information should include whether the discharge is batch or continuous, the amount of discharge, pollutants potentially in the discharge, and frequency of each discharge. The inspector also needs to identify the destination of all wastewater generated and all discharge points. Some wastewater may be discharged directly to a receiving stream while some may be discharged to the sanitary sewer with or without first going to a pretreatment system.

If possible, all wastewater flows should be measured or information on wastewater flows from each process should be requested from facility representative. All recirculating systems such as air conditioners should be noted and it should be determined if these systems ever discharge. Evaporation, use in products, and washwater should be accounted for. Washdown of vessels and process areas can be a significant source of wastewater. It should be determined if any batch discharges occur.

Reactors, plating tanks, and process tanks are often periodically discharged. The amounts and chemical nature and frequency of discharge, and treatment and disposal should be noted.

The inspector should also gather information on the flow of incoming water to the facility. With information on incoming water flow and wastewater generation and flow, the inspector may be able to calculate a rough flow balance. A flow balance compares the incoming water flow to the total outgoing wastewater flow to ensure all water use at the facility is accounted for. If the flow balance indicates discrepancies in flow volumes between the incoming water and outgoing wastewater, the inspector should discuss them with the facility representatives. Causes of the discrepancies may include evaporation or water that is used but not discharged such as water contained in the product used in a recirculating cooling system.

All industrial processes, raw materials, and finished products should be evaluated to determine pollutants being used or generated. For example, at a facility performing electroplating, quantities and types of plating and associated chemicals used, frequency of disposal and treatment and/or disposal methods should be noted.

Throughout the entire inspection process, inspectors should attempt to identify areas in which the industry can decrease its use of chemicals and reduce the amount and pollutant concentration of its discharges through pollution reduction technologies.

The inspector should require schematics of the facility from the industry before the first inspection. A schematic of the facility that shows the processes, their wastewater discharges, flow through the treatment system, and discharges points. A description and process flow diagram for each major product line should also be provided. Then, throughout the inspection, these schematics should be checked by the inspector to make sure these are accurate.

The quantities and types of raw materials, finished products, and wastes stored at the facility should be noted. The inspector should evaluate storage areas to determine the potential for spills to occur and to enter the sanitary sewer. The proximity of floor drains to any area where pollutants are stored or handled such as storage and processing areas should be determined.

If floor drains are present, the inspector should determine whether or not the floor drains are used. The condition of a floor drain may indicate whether or not it is used.

For example, the floor drain may be corroded, indicating that corrosive materials have been discharged. Floor drains that are permanently capped or welded shut are preferable to just being plugged since these can be removed. In cases where the floor drains are capped or plugged, but not welded, the inspector should inspect the floor drain for evidence that the cap or plug is simply removed when the facility wants to discharge material. The inspector should also determine where the floor drains flow. For example, some floor drains may flow to the wastewater treatment system while others may discharge directly to the sanitary sewer.

Spill containment structures such as berms and dikes should also be evaluated to determine if they are adequate to contain spills.

Inspectors should inquire as to the cleanup and disposal procedures the facility would follow in the event of a spill. The industry should have a spill plan on file at the facility. The inspector should evaluate the potential for a spill to enter the sanitary sewer when the facility's procedures are followed.

The wastewater treatment system should also be inspected to ensure that it is properly maintained and is in good working condition. Treatment systems may consist of physical, chemical, or biological processes that are used to remove or treat pollutants prior to discharging wastewater. Wastewater treatment can range from a simple oil and grease separator to a complex chemical system designed to remove metals. The inspector should note the type of treatment used, any associated chemicals used, and any circumstances under which the treatment system would be shut down or bypassed.

Information should also be obtained on any sludges or residuals generated during the wastewater treatment process and methods by which these sludges and residuals are disposed.

Operation and maintenance procedures implemented in the treatment system should be discussed and appropriate documentation should be reviewed. For example, if the facility continuously monitors pH, the pH logs should be reviewed and the inspector should determine the frequency at which the pH probe is calibrated, ink is added, or the paper is changed. In addition, the inspector should verify that adequately trained staff are available to properly operate and maintain the wastewater treatment system. It is also helpful to develop a diagram detailing the treatment process.

Many industrial processes such as cleaning, degreasing, grinding, and chemical wastewater pretreatment produce a sludge or other waste that must be disposed of. For instance, vapor degreasing often produces a sludge as well as spent solvent waste that must be disposed of. The inspector should

determine the waste generation rates, how often disposal occurs, and the method of disposal.

If sampling is to be conducted at the facility, the inspector may want to identify an appropriate sampling location during the inspection.

The inspector should review any records the facility may have compiled that relate to its discharges. These records may include analytical results of its wastewater discharge, flow records, and treatment system operation and maintenance records.

Although general inspection procedures have been outlined in this presentation, questions to ask facility representatives and necessary information to gather depends on the type of facility being inspected. Checklists that detail questions for general industrial inspections as well as questions for specific types of industries are included as part of the handout. It may be useful to review these questions and take a copy of the checklist into the field. For example, specific information to obtain during inspection of a facility performing electroplating may include the following:

- Chemicals used in plating and cleaning baths (including cyanide)
- Volume of plating and cleaning baths
- Frequency at which plating and cleaning baths are changed
- Treatment and disposal methods of spent baths
- Description of all wastewater generated and methods of treatment and disposal
- Whether any floor drains are located in process or storage areas
- Whether any solvents or degreasers are used and, if so, methods of treating and disposing of spent solvents
- Whether any sludges are generated in plating baths, degreasing units, or wastewater treatment systems and, if so, how are they treated and disposed. The inspector should review any records or file with the industry showing how much sludge was generated and where it was disposed (onsite or offsite). If shipped offsite, the inspector should inquire as to the final destination. If these waste tracking records do not exist, the inspector may want the industry to start keeping records.
- Whether any air pollution control equipment uses water.

Note the ventilation system above the plating tanks. The inspector should determine whether the collected vapors pass through a wet air scrubber.

**Closing
Conference**

After conducting the facility inspection, the inspector should meet with facility representatives to ask for any further information or clarify any outstanding issues. The inspector should prepare a written summary of inspection findings. The inspector should also answer any of the facility's questions and allow the facility to respond to the inspection findings.

1.6 FOLLOW-UP ACTIVITIES

**Follow-Up
Activities**

In order to ensure that the inspection is documented so that information can be readily retrieved for subsequent pretreatment program activities and to aid in any enforcement action necessary, an inspection report should be prepared. All inspection information including inspection notes, copies of file information, photographs, and other information should be carefully documented. Inspectors may also need to initiate or follow-up on any enforcement actions necessary based on the findings of the inspection.

CHAPTER 2

2.0 SAMPLING TECHNIQUES

2.1 PURPOSES FOR SAMPLING

Purposes for Sampling

Although inspections may indicate which pollutants are potentially in a facility's discharge, they cannot conclusively determine specific pollutant information. To determine the types and concentrations of pollutants in a facility's discharge, it is necessary to perform sampling. This specific pollutant information can then be used to identify which pollutants in a facility's discharge need to be reduced. Pollutant information can also be used to determine the significance of a particular pollutant in the discharge so that necessary monitoring frequencies can be determined. Sampling also provides a means to determine a facility's compliance with its discharge limits and as a basis for supporting enforcement actions. Finally, if a facility performs self-monitoring, sampling can be performed to verify the accuracy of that self-monitoring.

2.2 SAMPLING PROCEDURES

Preparation and Implementation of Sampling Procedures

It is important to be adequately prepared prior to going onsite so that all the equipment needed to perform the sampling is available and that personnel are properly prepared for the types of sampling required. Therefore, general sampling procedures should be developed and followed when sampling at all facilities. Sampling procedures should include designation of sample types, volumes, containers, and preservation methods to be used for each pollutant parameter as well as sample identification and documentation procedures. Although these general procedures apply to all facilities, specific information on each facility should also be developed. This information may include pollutant parameters to be sampled, sampling location, and safety concerns. Obtaining this information prior to the sampling trip will allow the sampler to bring the proper equipment, know where to sample and what pollutants to sample for, and be familiar with necessary safety precautions.

Coordination with Analytical Laboratory

The samplers should coordinate their sampling activities with the laboratory that will be performing the analyses. The laboratory can provide information on the types and volume of samples needed for particular pollutant parameters, sample preservation methods and holding times, and shipping instructions. Laboratories may also provide sampling equipment such as samplers, pH meters, sample containers, chain-of-custody forms, sample labels, tags, and seals.

**Preparation
of Sampling
and Safety
Equipment**

Prior to the sampling trip, any required sampling and safety equipment should be assembled, cleaned, and checked to ensure that it is in proper working order. All necessary paperwork should also be prepared prior to the trip. This may include assembling and marking, as possible, the required sample container labels or tags, chain-of-custody forms, and lab request sheets. Sampling and field analytical equipment such as pH meters should be calibrated.

When conducting sampling, samplers need to be aware of health and safety hazards and take the proper precautions. Safety requirements can be gathered from file information, personnel that have previously sampled the facility, or by contacting the facility. Samplers need to be properly clothed and have adequate safety equipment available.

Samplers should not enter confined spaces unless they are properly trained and have the proper equipment such as rescue equipment and respirators. Confined spaces should never be entered unless first tested for sufficient oxygen and lack of toxic and explosive gases. Two persons should be present, one to enter the confined space and one to be outside of the confined space. The person entering the confined space should wear a safety harness that is attached to a retrieval system. Use of this type of system will allow the rescue of the person in the confined space without requiring anyone else to enter.

**Sampling
Location**

Samples should be collected from a location that is representative of the facility's discharge. If the facility has more than one discharge point it may be necessary to collect samples from several locations in order to adequately characterize the facility's entire discharge. Convenience, accessibility, and safety should also be considered when selecting a sampling site. Appropriate sampling sites may include manholes as shown here. Other appropriate sites may be a process tank.

Samples should be collected from the center of flow with the container facing upstream to avoid contamination. Samples should be collected in areas that are turbulent and well mixed and where the chance of solids settling is minimal. When sampling, the surface of the wastewater should not be skimmed nor should the channel bottom be dragged. Samples should not be collected from stagnant areas containing immiscible liquids or suspended solids.

Sample Types There are two basic types of samples: grab and composite samples.

Grab samples are individual samples collected over a period of time not exceeding 15 minutes and represent wastestream conditions only at the time the sample is collected. Grab samples are usually taken manually but can be collected using an automatic sampler. Grab samples may be appropriate for batch discharges, constant waste conditions, to screen the discharge to see if particular pollutants are present, or if extreme conditions such as high pH are characteristic of the discharge. In addition, grab samples should be collected for pollutants that tend to change or decompose during the compositing period such as pH, cyanide, total phenols, and volatile organics. In addition, grab samples should be collected for oil and grease samples since the oil and grease tends to adhere to sampling equipment.

Composite samples are collected over time (either by continuous sampling or by combining individual grab samples) and reflect the average characteristics of wastewater during the sampling period. Composite samples are either flow proportional or time composited:

- In *flow proportional* sampling, the volume of sample collected is proportional to waste flow at the time of sampling. Flow proportional samples can be obtained by collecting various sample volumes at equal time intervals in proportion to flow or by collecting a constant sample volume per unit of wastewater flow.
- *Time composite* samples consist of constant volume sample aliquots collected in one container at equal time intervals. For example, 500 milliliters of sample collected every 15 minutes over a 24-hour period.

Composite samples may be needed to determine the average characteristics of wastestreams, particularly if the wastestream has a highly variable pollutant concentration or flow rate. Composite samples should be collected during the entire period the facility is operating and discharging. For example, if the facility has processes that discharge 16 hours a day, samples should be collected during the entire 16-hour period.

**Sampling
Equipment**

Both grab and composite samples can either be collected manually or with automatic samplers. However, it is not recommended that automatic samplers be used to collect samples for certain pollutants such as oil and grease and volatile organics since oil and grease may adhere to the sides of the sampler tubing and air may be introduced into volatile organic samples.

| | |
|--|---|
| Sample Volumes | Sample volumes needed for analyses depend on the type and number of analyses to be performed. The sampler should contact the person or laboratory that will be performing the analyses to determine sample volumes needed for a particular sampling event. Adequate sample volume should also be collected to allow for QA/QC and for spillage |
| Sample Containers | <p>Sample containers should be made of chemically resistant materials that will not affect the nature or concentration of pollutants being measured. Containers must be large enough to hold the required sample volume. Glass containers should be used for oil and grease, phenol, and organics samples. Amber glass sample containers should be used for pollutants such as iron cyanide that oxidize when exposed to sunlight. Containers with teflon lined lids should be used when collecting volatile organics. Plastic is easier to handle and is less likely to break, so it may be the best type of container to use when glass is not needed. Sample containers should be properly cleaned prior to use. The laboratory that will be performing the sample analyses should be contacted for specific cleaning instructions. Some laboratories may provide pre-cleaned sample containers.</p> |
| Sample Preservation and Holding Times | <p>Many pollutants are unstable and may alter in composition prior to analysis. Therefore, to ensure that samples remain representative, they should be analyzed as soon as possible after collection. If immediate analysis is not possible, samples should be preserved to minimize the changes in pollutant concentrations between collection and analysis. There are three basic types of preservation: cooling, pH adjustment, and chemical fixation. Cooling is accomplished by chilling samples to 4°C by either refrigeration or by placing on ice. Cooling suppresses biological activity and volatilization of gases and organic substances.</p> <p>If composite samples are collected, the samples should be cooled to 4°C throughout the compositing period. Samples should also be kept cool during transport to the analytical laboratory.</p> <p>Even with proper preservation, samples should be analyzed within certain recommended holding times. These holding times are the maximum times allowed between the time the sample is collected and when it is analyzed. If composite samples are collected, the holding time limitations begin when the last aliquot is added to the sample. Performing sample analyses within the allowable holding times helps ensure that the analytical results are valid and representative of the wastewater. Certain pollutant parameters such as pH have no standard method of preservation and should be analyzed immediately.</p> |

CHAPTER 3

3.0 WASTEWATER TREATMENT TECHNOLOGIES

3.1 INTRODUCTION

It is helpful to understand the types of wastes generated in various industrial categories and common waste treatment and reduction techniques. The following discussion will provide a brief description of some of the most common types of waste treatment.

3.2 TYPES OF WASTEWATER TREATMENT

Classification of Treatment Techniques

Wastewater treatment technologies can be grouped by type of treatment into four classifications:

Physical treatment technologies modify the physical structure of the wastewater and its pollutants or separate the wastewater into various components. Physical treatment does not change the chemical structure of the wastewater pollutants. Physical treatment is useful for separating hazardous and non-hazardous components of a wastestream, separating a wastestream into various components for different treatment operations, conditioning a wastestream for further treatment, and removing solid particles or objects. The most common physical treatment processes include; equalization, screening, sedimentation, flotation, filtration, adsorption, ultrafiltration, and stripping.

Chemical treatment technologies modify the chemical structure of the wastewater pollutants to aid removal of these pollutants from the wastewater. Chemical treatment technologies are usually relatively easy, but generate a solid sludge that must be managed and disposed. The most common chemical treatment processes include neutralization, precipitation, oxidation/reduction, and dechlorination.

Biological treatment technologies degrade organic components of the wastewater using microorganisms. These organics may be decomposed into water and methane, other less toxic simpler organics, or microbial matter. Toxic chemicals can inhibit biological treatment systems by killing the microorganisms. Also, high concentrations of inorganics and high temperatures can inhibit biological treatment. Also of concern, nitrogen

and phosphorus are needed for biological activity to occur and are often not present in industrial wastewater. The most common biological treatment processes include stabilization, activated sludge, trickling filters, anaerobic digestion, and aerated lagoons.

Thermal treatment processes achieve significant reductions in waste volumes and achieve a high degree of destruction of organics. Unfortunately, thermal treatment often generates hazardous air emissions that must be controlled. The most common thermal treatment technologies include incineration and evaporation.

Probably the most appropriate way to discuss treatment technologies is in terms of the nature of pollutants to be removed (i.e., metals, organics, oil and grease, etc.). A brief discussion of various accepted treatment technologies for removing these pollutants follows; with a discussion of some treatment practices common to all types of wastewater treatment presented first.

3.3 FLOW EQUALIZATION

Flow Equalization

Combining wastewater flows to dampen fluctuations in flow rates and pollutant concentrations prior to further treatment or prior to discharge (i.e., equalization) provides an extremely valuable performance specification. Equalization typically occurs in tanks or basins that often contain a large capacity to handle wastewaters for an extended period of time. Often variable flowrates and pollutant concentrations can reduce treatment efficiency. For example, equalization before chemical treatment reduces the variability of flow, thereby reducing the necessary process controls, minimizing the likelihood of over-or under-feeding of the treatment chemicals. Equalization is useful for preventing slug loads from inhibiting further treatment processes or for preventing excessive concentrations in the treatment system effluent. Equalization can also act as neutralization where both acidic and basic wastes are combined.

Another technique for equalizing wastewaters is to hold high concentration wastes in a separate tank or basin and then bleed this waste into the more dilute waste stream over a period of time to minimize the impact.

3.4 TYPICAL TREATMENT FOR METAL FINISHING WASTEWATER

Chemical Treatment

Metal finishing/plating/printed circuit board manufacturing facilities are one type of facilities that most often use chemical treatment technology. Typically, these facilities will require four types of chemical treatment for pollutant removal; neutralization, hexavalent chromium reduction, cyanide destruction, and chemical precipitation. A discussion of these treatment technologies follows.

Neutralization/ pH Control

Biological treatment operates most effectively at a pH of 7. Variations in pH can have a significant impact on the treatment efficiency of biological systems including total inhibition of microbial activity. Another reason for pH control is for treatment performance optimization. This is especially true for treatment to remove metals. Therefore, pH control is a crucial component in wastewater treatment.

A pH control system typically comes in one of three forms, continuous uncontrolled, batch controlled, and continuous controlled.

The simplest form is a continuous uncontrolled system that consists of running acidic wastewater through a bed of limestone chips.

Another method is to batch treat a wastewater, whereby the pH is taken, acid or base is added, the pH is reanalyzed, and the process continues until the desired pH is achieved. At that point, the wastewater can be discharged to the sewer or to additional treatment, if necessary.

The most advanced method of pH control is a continuous system where pH sensors are used to measure the pH and to add the necessary treatment chemicals. In a continuous system, a pH sensor determines the pH and signals a pump to add neutralizing chemical, and the wastewater is mixed to provide homogeneous chemical addition. More complex systems have multiple pH sensors and multiple chemical addition points to further refine chemical addition to obtain more constant pH values. Electrode maintenance is a must for proper operation of the system as the electrodes are prone to fouling, especially in extremely corrosive wastewaters.

Chromium Reduction

Chromium is one of the most common plating metals. Wastewaters containing hexavalent chromium are generated from chromium electroplating, chromate conversion coating, etching with chromic acid, and metal finishing on chromium metal. Hexavalent chromium (i.e., Cr^{+6}) is the soluble ion most commonly used in the plating bath and is much more

toxic than the trivalent form (i.e., Cr^{+3}). Hexavalent chromium, which includes chromic acid (H_2CrO_4), chromium trioxide (CrO_3) and chromates, must be reduced to the trivalent state to allow for chemical precipitation. Some manufacturers will use a trivalent form of chromium, such as chromium trichloride (CrCl_3) or chromium sulfate ($\text{Cr}_2(\text{SO}_4)_3$), in the process baths although these chemicals are more expensive to use and may not provide desirable qualities on the finished product that are achieved with hexavalent chromium. Once the chromium has been reduced to its trivalent state, it can be subjected to chemical precipitation to remove the chromium and any other toxic metals.

Reduction is typically done using gaseous sulfur dioxide or sodium bisulfite. Because the reaction proceeds much faster at low pH, the reduction should be performed at a pH of 2-3. The closer this reaction is to a pH of 3, the less sulfur dioxide will be released.

Iron or iron salts may also be used to reduce the hexavalent chromium to its trivalent state. A third, patented process, uses small pieces of scrap steel, adjusting the pH of the influent to a pH of 2.0-2.2, and then flowing the wastewater through the steel scraps.

Chromium reduction is a proven technology that is easy to use and well suited to automation. Reduction efficiencies of over 99.5 percent are easily achieved with concentrations of 0.05 mg/l readily attained. [Development Document for Effluent Limitations Guidelines and Standards for the Metal Finishing Point Source Category, June 1983] Chromium reduction equipment is very simple and should include: a separate wastewater collection system for wastewater that contains hexavalent chromium only (as chemical interference is possible if mixed metal wastes are subjected to the chromium reduction process), metering equipment, contact tanks with agitation, and pH and oxidation-reduction potential (ORP) instrumentation.

Cyanide Destruction

Cyanide may be used as a cleaning agent and a complexing agent in zinc, cadmium, silver, copper and other plating baths. Cyanide can be destroyed through oxidation techniques. Chlorine (elemental or hypochlorite) is the most common oxidation chemical used to destroy cyanide. Chlorine gas treatment is about half the cost of sodium hypochlorite treatment, but chlorine gas is dangerous to handle and should be accounted for when evaluating options.

The alkaline chlorination reaction, by far the most common cyanide destruction method, is a two step process and proceeds as follows:

- 1) $\text{Cl}_2 + \text{NaCN} + 2\text{NaOH} = \text{NaCNO} + 2\text{NaCl} + \text{H}_2\text{O}$
- 2) $3\text{Cl}_2 + 6\text{NaOH} + 2\text{NaCNO} = 2\text{NaHCO}_3 + \text{N}_2 + 6\text{NaCl} + 2\text{H}_2\text{O}$

The destruction typically occurs in two tanks. In the first tank, the system is monitored to maintain a pH of 9.5-11 with an oxidation-reduction potential of 300-400 millivolts. This is where the cyanide is oxidized to cyanates. This is also where the metal complex is broken, thus allowing some of the metals to precipitate. In the second tank, the desirable pH is 8.0-8.5 with an oxidation-reduction potential of 600-800 millivolts.

Since cyanide is destroyed in the first stage reaction, many facilities have eliminated the second stage since this second stage is costly and poses a dangerous reaction situation (hydrogen cyanide gas generation) if the first stage is not adequately controlled.

Alkaline chlorination of cyanide wastes is a proven technology with destruction efficiencies of over 99 percent and effluent concentrations below detection readily available.

Very simple equipment is needed for cyanide destruction including a separate collection system for cyanide bearing wastewaters, contact vessels with agitation, chemical metering, and pH and ORP instrumentation.

Chemical Precipitation

The most common pretreatment technology for pollutant removal is chemical precipitation. Chemical precipitation is used to reduce the concentration of metals in wastewater to levels below concern.

Chemical precipitation is a three step process consisting of coagulation, flocculation, and sedimentation. Through chemical addition, the interparticulate forces in the contaminants are reduced or eliminated thus allowing interaction of particles through molecular motion and physical mixing. Rapid mixing allows for dispersion of the treatment chemical throughout the wastewater and promotes collisions of particles. Collision of these particles causes the particles to aggregate and form larger particles, which is known as coagulation. The chemicals added to promote this aggregation, known as coagulants, serve two basic purposes: (1) to destabilize the particles, thus allowing for interaction, and (2) to promote aggregation of particles through floc strengthening.

Alum (i.e., aluminum sulfate) and lime (calcium oxide) are the two most common coagulants used in the U.S. although organic polymer coagulants (i.e., long-chain, water-soluble polymers) have gained widespread acceptance. Ferric compounds also are used as coagulants although these compounds are corrosive and difficult to dissolve in water. [Water Treatment Principles and Design, James Montgomery Consulting Engineers, 1985.]

After a rapid mix period, mixing must be slowed to allow for formation of larger flocs. (At higher mix rates, the aggregate floc will continue to be

destroyed through excessive physical contact.) This process is known as flocculation. Because of the size of the particles, some mixing is required to cause contact between solid masses and to promote larger floc formations that will settle rapidly.

During precipitation, the solids are separated from the liquid, usually by settling. This should result in two distinct layers, one solid and one liquid that can be readily separated.

Typically, coagulation equipment consists of tanks with rotating impellers for rapid mixing, but in-line blenders and pumps or baffles may be used. Flocculation equipment consists of tanks with paddle type mixers for slow agitation and flocculation. Sedimentation equipment usually consists of a clarifier unit which has inclined plates (lamella separator) or tubes. These units operate by gravity, require little space, and have minimal installation and maintenance costs.

3.5 OTHER TREATMENTS FOR METALS REMOVAL

Ion Exchange In the ion exchange process, wastewater is passed through a container of anionic or cationic resin particles. As the solution passes through the resin bed, there is an exchange of innocuous ions (e.g., H^+ or OH^-) from the resin for the undesirable similarly charged ions (e.g., Cu^{2+} or CN^-) dissolved in the solution. Each resin has a distinct number of ion sites that determines the maximum number of exchanges per unit of resin. As the resin exchanges ions, it will reach a state in which it has adsorbed its capacity of ions. The resin must then undergo regeneration during which the resin will be backwashed. The regeneration process results in a small volume of backwash solution which has a very high concentration of the removed ions.

Ion exchange units may be a batch tank, but are normally an enclosed pressurized column. The process may be operated as a single unit, in parallel, or in series.

The resin used in a column is selected for the constituents to be removed. Resins can be broadly classified as strong or weak acid cation resins or as strong or weak base anion resins. Strong acid and base resins operate independently of pH, while the operation of weak acid and base resins depends on the pH. Chelating cations may also be used, but are expensive.

As described above, typical ion exchange systems consist of one or more columns operated in a continuous mode, with separate columns included for each type of resin. Multiple columns of the same resin are used to prevent

pass through of pollutants into the effluent after breakthrough has occurred. Additionally, duplicate systems are often employed to allow a flow to be diverted to a second unit during regeneration of the columns.

Reverse Osmosis

Osmosis is the spontaneous flow of water from a dilute solution through a semipermeable membrane to a more concentrated solution. Reverse osmosis includes the application of pressure to overcome osmotic pressure and force the flow of water through the membrane toward the more dilute solution. This increases the concentration of pollutants in the wastewater, but reduces the volume of contaminated water. Ions and small molecules can be separated using this technology.

Reverse osmosis units are sensitive to the environment and must be carefully checked for chemical attack, fouling, and plugging. Maintaining a pH of 4 to 7.5 will help to minimize fouling and plugging. Reverse osmosis is not effective for highly organic wastes as the organic materials act to dissolve the membrane. Oxidizing agents, such as iron and manganese, particulates, and oil and grease must be removed prior to reverse osmosis. Biological growth on the membrane (which is promoted at low organic concentrations) can also reduce unit efficiency, although addition of chlorine or other biocides can eliminate this fouling. Operating reverse osmosis units in series can improve the handling of variable flowrates and pollutant concentrations.

3.6 ORGANICS TREATMENT

Organics Treatment

Wastewater treatment to remove organic compounds has historically been through biological degradation (i.e., the breakdown of compounds through microbial digestion). While this method is quite effective for domestic type wastes, biological treatment of industrial wastes containing organic chemicals is not always as effective. Reasons for this ineffectiveness include; certain organic compounds may be toxic to the microorganisms thereby inhibiting the degradation activity, not all materials are biologically degraded, and it is often difficult to treat down to the necessary concentrations. As such, several techniques common to organic chemical production have been further developed as wastewater treatment technologies.

The treatment technologies found to be the most effective at reducing the concentration of organic pollutants in wastewater and used regularly in the treatment of organics include:

- Carbon adsorption
- Air stripping
- Steam stripping

Carbon Adsorption

First, definition of the term "adsorption" is helpful when understanding the concept of carbon treatment. Commonly, this term is confused with "absorption." Adsorption is the taking up of a liquid, gas, or dissolved solids onto the surface of a solid or liquid. Absorption is the taking up of a liquid, gas, or dissolved solids into the molecular structure of the solid or liquid. The basis for carbon adsorption is the high surface area per weight on the activated carbon due to a very high porosity and the natural affinity of a liquid (or gas) to be attracted to and held on the surface of a solid. Surface areas of 100 m²/g are common.

Carbon adsorption is typically the most effective technology for removing dilute concentrations of organic compounds from wastewater. Often it is used as a final polishing step prior to discharge. Carbon is widely used in the U.S. for drinking water treatment.

Two types of activated carbon application are used for wastewater treatment, granular and powdered. Granular carbon typically is contained in packed columns, with the wastewater flowing either up or down through the carbon packing.

Typically, carbon columns are operated in series, with two or more columns. This ensures that as the first column reaches its capacity and the effluent from this column becomes more contaminated, the second column can treat this contamination and prevent contaminated discharges to the municipal treatment plant. New carbon can then be added to the first column, the second column can become the first column while the old first column is being refilled, and the old first carbon column can now become the second column in series. A similar approach can be taken for more than two columns as well.

Powdered activated carbon is added to water to form a slurry and then introduced into the wastewater. This wastewater and carbon mixture is then agitated to increase contact between the carbon and contaminants, and then allowed to settle in a quiescent state. The treated wastewater can then be pumped off the top with the carbon sludge hauled off for disposal or regeneration.

Air Stripping

Air stripping defines the practice of removing volatile contaminants from wastewater by contacting the wastewater with a steady stream of air through a packed column (typically countercurrently). The air (which now contains the contaminants from the wastewater) can then be released to the atmosphere or preferably recovered or further treated using carbon adsorption, incineration, or open flame.

In a packed column, air is drawn up through the column with fans and the water trickles down the column. Packing materials, such as berl saddles or

raschig rings, provide more surface area to promote mass transfer between the air and wastewater.

The benefits of air stripping columns are that they take up little space, operate in a continuous mode, and are inexpensive to operate. Energy costs comprise the sole operating cost.

Air stripping is a common practice for treatment of contaminated groundwater. Here, the water is pumped out of the ground and treated.

Steam Stripping

Steam stripping operates similar to air stripping except that steam is introduced rather than air, thereby heating the water and improving the transfer of contaminants. This is similar to distillation of volatiles from the wastewater. One method to improve the efficiency of a steam stripper is to condense a portion of the vapor leaving the top of the column and return it to the column as a liquid. In the U.S., where organic chemical plants use stripping technology for wastewater, over 90 percent use steam stripping rather than air stripping. Halogenated aliphatics (e.g., methylene chloride, chloroform, and vinyl chloride) are very conducive to steam stripping technology.

For volatile pollutants, over 99-percent removal is common. Steam stripping is more effective than air stripping although considerably more expensive (because of energy costs).

3.7 OIL REMOVAL

Oil Removal

Many types of industrial facilities generate wastewater containing oil and grease, the concentration of which can vary drastically. For example, a textile manufacturer may generate wastewater with 10-50 mg/l of oil and grease; a food processor between 100-1,000 mg/l; a commercial laundry between 100-2,000 mg/l; and a metal fabricator between 10,000-150,000 mg/l. [Toledo Division of Continuing Education.]

To discuss oil and grease removal, the three types of oil and grease must first be identified. These include free oils (which rise to the surface and can be skimmed off), emulsified oils (which must have the emulsion broken before removal), and dissolved oils (which require biological treatment or more sophisticated treatment techniques for removal).

The simplest form of oil removal is gravity separation. Oil-containing wastewater is held in a quiescent state, where the free oil being lighter than water, will float to the top and can be skimmed or pumped off. Rotating

belts are often used to remove the oil from the surface. Solids that settle to the bottom can also be removed.

Emulsion breaking is necessary to remove oils where the oils are present as an emulsion (e.g., coolants applied directly to metal components or metal fabricating equipment during operation). (Emulsified oils are often called "soluble oils" as the oil appears to be dissolved in water; however, the oils are actually present as tiny droplets suspended in water.) Typically, emulsions are broken by pH adjustment or chemical addition.

Polyelectrolytes have come to be the treatment method of choice for emulsion breaking because of the wide selection of chemicals available and the limited volume of sludge produced (versus the older method of choice of lime or alum addition).

After breaking the oil emulsion, the oil can be removed using air flotation techniques; either dissolved air flotation or induced air flotation. In dissolved air flotation, the wastewater is pressurized in the presence of air, thereby dissolving the air in the water. When the water is discharged from the pressure line into an open tank, small air bubbles form which carry the free oil and suspended solids to the surface where they can be removed with skimming apparatus. Induced air flotation consists of introducing fine bubbles underneath a liquid and as the air rises, the bubbles collect the oils and suspended solids lifting them to the surface where they can be removed. (Air bubbles in induced air systems are an order of magnitude larger than in dissolved air systems.)

Recently, ultrafiltration techniques have been used to remove oil from wastewater. In ultrafiltration, the wastewater is pumped past a membrane where the water and other dissolved substances flow through the membrane. The large emulsified oil molecules are retained. Subsequent passes through an ultrafiltration unit can further purify the contaminant oil. Reductions in volume by 95-97 percent are achievable through ultrafiltration.

CHAPTER 4

4.0 POLLUTION PREVENTION TECHNIQUES

4.1 INTRODUCTION

Introduction Pollution prevention techniques are considered to fall under the first two tiers of the waste management hierarchy, that being, source reduction and recycling. As described previously, pollution prevention techniques under these two categories can be grouped into eight classifications. To better understand the impacts of these eight types of pollution prevention techniques, specific methods to reduce wastewater pollution in the electroplating/metal finishing industry are presented and discussed in detail.

4.2 PROCESS CHANGES

Process Changes The greatest number of pollution prevention techniques in the electroplating/metal finishing industry can be classified as process changes. As mentioned above, process changes may affect either procedures or equipment and influence the quantity or toxicity of wastes generated.

Considering how a metal part is electroplated, in an ideal situation, all the water would drain off the workpiece as it is removed from the plating bath, negating the need for rinsing. However, it is clear that this is not the case and that even in the best of situations, a small amount of plating bath remains on the workpiece and must be removed to stop any further chemical action by this solution. This phenomenon leads to the first and often the most opportunistic area for pollution prevention at a plating facility: dragout. Dragout is the plating term for the plating solution that is carried out of the plating bath as the workpiece is removed from the bath. Minimizing the carryover of this dragout into subsequent rinse tanks can drastically reduce wastewater flow rates and pollutant loads, thereby reducing both the amount of raw materials that must be purchased and the cost of pollution control.

Plating Bath The first area to consider for dragout reduction is the plating bath. Several modifications to the plating solution makeup can impact the amount of dragout. The most common techniques include:

- Increase the temperature of the bath, thereby reducing the surface tension and viscosity of the bath (promoting quicker drainage of the plating solution)
- Decrease the concentration of metals in the plating bath such that a more dilute solution is being carried over into the rinse tanks
- Add wetting agents/surfactants to the bath to reduce the surface tension (again promoting quicker drainage).

Plating Techniques Even if the plating bath is adjusted as described above, dragout can still be a major source of wastewater pollutants if improper plating techniques are used. When plating, workpieces are either hung on a rack or loaded into a barrel (for small parts) and then submerged into the plating tank. After a specified period of time, the parts are lifted out of the bath and transferred to a rinse tank where the residual plating solution is cleansed off the parts. Techniques that can minimize carrying over dragout from the plating tank to the rinse tank include:

- Design plating racks that do not have cups or pockets that could possibly carry plating solution over into a rinse tank.
- Design racks that hold the workpieces in an optimum configuration to minimize dragout (i.e., the part should be at an angle with the smallest surface area the last to leave the plating bath). For example, if plating an axle, the axle should be removed from the bath near vertical rather than horizontal.
- Inspect racks regularly for worn insulation or corrosion that could form pockets for plating solution.
- Withdraw parts from the plating bath slowly and allow to drain over plating tank for at least 10 seconds.
- Install air knives over plating solution that drives the plating solution off the workpiece and back into the plating tank as the part is withdrawn from the plating bath.
- Install a fine mist spray (fog spray) over the plating bath to spray the plating solution off the workpiece and back into the tank. However,

the flowrate of the spray cannot exceed the evaporation rate of the plating solution.

- Agitate the workpiece or barrel after it is removed from the plating bath, thus promoting drainage back into the tank.
- Install drain boards and drip guards between the plating tank and subsequent rinse tanks to catch any residual drainage and return this solution back into the plating tank.

Rinsing Techniques

When designing the rinse system, several configurations are recommended, including:

- Use a static rinse (often called a dragout tank or dead rinse) as the first rinse to cleanse off the most concentrated plating solution. After a period of time, the concentration of plating solution in this tank will increase to the point where it can either be fed directly back into the plating tank or can be purified using techniques such as evaporation or reverse osmosis and then fed back into the plating tank.
- Add air or mechanical agitation to the rinse tank and all subsequent rinse tanks to promote complete rinsing (this is especially important for complex workpieces with a lot of angles and crevices).
- Install rinsewater control hardware such as flow control meters, flow restrictors, foot-controlled spray nozzles, and photosensors (which turn on the rinsewater as the plated parts pass through the line of sight of the photosensor) to minimize and control rinsewater usage
- Use high-pressure spray rinses for effective cleansing with a minimal amount of water.
- Allow an adequate amount of time in the rinse tank to promote good rinsing (for rinsing simple parts in well agitated tanks, 5-10 seconds may be enough time, but, for complex parts in a poorly agitated rinse tank, 10 minutes may not even be enough time).
- Use multiple countercurrent rinse tanks.

Extending Plating Bath Life

In addition to dragout control, several techniques can be used to minimize contamination of the plating bath as well as any precleaning baths (e.g., acids or alkaline cleaners), thereby extending the useful life of the bath

while at the same time promoting recovery/recycling techniques. These methods include:

- Preclean parts using mechanical methods, such as wiping, squeegeeing, or shot blasting
- Minimize dust and dirt in the plating room
- Cover plating bath to minimize contamination
- Replenish baths rather than batch dumping and replacing
- Reduce dragging of pre-plating solutions (e.g., acids or alkaline cleaners)
- Install a continuous filtering system on the bath to remove impurities
- Remove anodes from the plating tank when not in use.

Use of the process changes described above can save the plating shop a lot of time and money without changing the physicochemical process.

4.3 MATERIAL SUBSTITUTION

Material Substitution

The second pollution prevention category, material substitution, takes electroplating modification one step further. In this case, a plating facility may choose to modify the raw materials used at the facility to minimize pollution. These modifications may include:

- Use deionized water in the plating bath and dragout tank (i.e., the tank that will eventually be recycled back into the plating tank) to remove contaminants that will build up over time and contaminate the bath.
- Use high-purity raw materials (i.e., anodes, plating chemicals, acids, etc.) that will minimize contamination.
- Change to a non-cyanide plating bath (e.g., pyrophosphate copper, acid sulfate cadmium, or zinc chloride) to eliminate the use of toxic and hazardous cyanide.
- Use non-chelated chemicals (i.e., chemicals that do not form organic/inorganic complexes with the toxic metals, thereby inhibiting metal removal using conventional treatment technologies).

- Use aqueous cleaners rather than organic solvents to remove dirt and oil.
- Reuse spent acids and bases in other areas where purity is not as vital (e.g., similar to countercurrent plating baths, countercurrent acid rinses can minimize acid and water use)
- Use treatment chemicals that minimize sludge generation (e.g., magnesium hydroxide rather than lime or caustic).

4.4 MATERIAL INVENTORY AND STORAGE

Material Inventory and Storage

The process of electroplating requires the use of a wide variety of raw materials, from plating chemicals, to acid/alkaline cleaners, organic solvents, and wastewater treatment chemicals. Proper inventory and storage of these materials can minimize pollutant loadings to the environment. Considerations include:

Material Inventory

- Use raw materials before the shelf life or expiration date (use the first-in, first-out practice)
- Buy an appropriate amount of raw materials, only buying large amounts of materials with an unlimited shelf life (e.g., metal prices fluctuate regularly and the quantity and time of purchase is often highly dependent on the current price)
- Purchase raw materials from suppliers that will buy back chemicals that are out-of-date.

Material Storage

- Divert storm water away from material storage (including covering raw materials, either inside or under roof, tarp, etc).
- Install spill containment around raw materials and do not store materials outside this containment (as is often done with one drum or a few bags of a chemical).
- Store raw materials as specified by the manufacturer (e.g., proper light, temperature, etc).

4.5 WASTE SEGREGATION

| | |
|--------------------------|--|
| Waste Segregation | <p>Segregation of wastes is important for two reasons: (1) regulations differ for different wastes and by segregating, costs can be minimized, and (2) treatment techniques often are more effectively performed on individual wastestreams rather than on the combined wastestream. However, oversegregation of wastes can also be a problem, causing greater environmental release potential, repetitive equipment costs, and more difficulty meeting environmental regulations. Therefore, segregation of wastes should be analyzed in detail before designing wastewater management systems and procedures. Factors that should be considered include:</p> <ul style="list-style-type: none"> ● Segregating hazardous and non-hazardous wastes to keep waste management costs to a minimum. ● Using separate treatment systems for different metals to produce higher quality sludge, thereby increasing its likelihood of reuse. ● Keeping non-metallic and metallic wastes separate to eliminate unnecessary metals treatment of nonmetallic wastes. ● Keeping hexavalent chromium and cyanide wastes separate to minimize the flow to be reduced or oxidized. |
|--------------------------|--|

4.6 GOOD HOUSEKEEPING/PREVENTATIVE MAINTENANCE/ EMPLOYEE EDUCATION

| | |
|---------------------------------|---|
| Good Housekeeping | <p>Proper operation and implementation of the equipment and procedures assure pollutant loading reductions. Good housekeeping practices that should be employed in a plating shop include:</p> <ul style="list-style-type: none"> ● Use a dry floor for the plating line, rather than an overflow system where water overflows the plating line tanks into a sump. (This stresses the importance of keeping the plating area clean and dry and inhibits sloppy water use practices.) ● Keep area clean and dry at all times (so that if leaks, spills, or overflows occur, the source of the problem can be easily identified and corrected). |
| Preventative Maintenance | <p>As with any manufacturing operation, preventative maintenance is essential if a facility intends to operate for any length of time without fear of equipment failure or loss of product quality. In the plating shop, this type</p> |

of situation can occur quickly if proper preventative maintenance is not performed. Activities should include:

- Install high-level alarms on tanks that could overflow and cause environmental or safety hazards
- Regularly check for leaks in tanks, valves, fittings, pumps, etc. and repair immediately
- Keep a supply of extra parts on hand for commonly replaced components
- Maintain plating racks in good condition to minimize dragout or poor electrical conductivity
- Calibrate conductivity, pH, and flow meters regularly
- Inspect workpieces prior to plating to eliminate rejects before processing through plating line.

Employee Education

One of the most critical components of pollution prevention in a plating shop (especially in a small shop where parts are manually transferred from tank to tank), is the need for employee education and training. Throughout the U.S., plating shops have been found to have excellent equipment and procedures in place to minimize pollution, but for one reason or another, the plating line operators prevented these pollutant reductions from actually occurring. Steps that can be taken to improve employee habits include:

- Provide regular training to employees on proper operating practices, including the economic benefit of following those procedures.
- Provide employee incentives for beneficial suggestions or for meeting certain pollution prevention goals (e.g., no noncompliance events while maintaining a low wastewater flowrate).
- Educate employees on water conservation. [Water use can be a significant concern since many plating line operators will increase rinse rates to speed up the process, irrespective of supervisor's instructions.]
- Post important information on equipment and procedures for employees to use as a reference (e.g., dragout times and a clock, contents and concentrations in all tanks, markings on valves as to the proper open position, spill cleanup procedures and equipment).

4.7 PRODUCT CHANGES

Product Changes

Similar to material substitution, the plating facility should consider product changes that can minimize pollution. For electroplaters, this could include:

- Replace toxic metals with non-toxic metals (e.g., replace cadmium with aluminum).
- Replace hexavalent chromium with trivalent chromium. [Note: most trivalent chromium formulations produce a duller plate than the shiny plate produced by hexavalent chromium, trivalent chromium is more expensive than hexavalent chromium, and, excluding decorative applications, the physical and chemical properties of the trivalent chromium may limit the applicability.]
- Redesign manufactured parts to minimize pockets and cups that can dragout plating solution (often this is done simply by designing a hole in the location of the cup or pocket)
- Evaluate the possibility of non-plated parts (e.g., powder coating).

Most often, product changes resulting from material substitutions must be evaluated in great detail to determine the saleability of the redesigned product. In some instances (e.g., putting holes in the legs of chrome plated chairs and tables to promote drainage during plating), the change likely will not effect the resale value of the part. Conversely, a plater may be able to use this redesign to its advantage by advertising the new chair as an environmentally-sensitive design.

4.8 WATER/ENERGY CONSERVATION

Water/Energy Conservation

Water/energy conservation is often the result of one of the other seven pollution prevention classifications. However, several steps can be taken in the plating shop to further minimize energy and water consumption. This includes:

- Reuse deionized rinsewater in other areas of the plating shop where purity is not as important.
- Cover tanks when not in use to reduce heat loss and evaporative losses (e.g., the use of polypropylene balls, which float on the surface of the bath, reduce evaporation significantly).

- Recycle once-through cooling water for rinse water or makeup water for other baths (it is unlikely that this water is suitable for the plating bath or the stagnant rinse tank).
- Turn off rinse tanks when not in use (e.g., use of photosensors which automatically turn the water on and off as working pieces are rinsed).
- Use conductivity sensors and pH probes to control rinsewater quality, whereby freshwater is added only when the conductivity or pH approaches a certain unacceptable level.

4.9 RECYCLING

Recycling

1. **Waste Exchange.** One technique that has been increasing in popularity in the U.S. as the cost of pollution control continues to rise is waste exchange. This technique encourages exchanging of wastes with others for reuse of the waste or recovery of valuable materials. Several types of wastes in the electroplating/metal finishing industry are conducive to waste exchange, namely metal sludges, spent plating baths, and spent acids and alkaline cleaners. Some of the wastes suitable for exchange include pickling wastes (i.e., sulfuric acid and ferrous sulfate) for use in fertilizer production, sodium hydroxide from electrowinning for use in neutralization, and reclaimed oils available for reuse as fuel.
2. **Wastewater Recycling.** Several technologies are commonly used to reduce the volume of contaminated wastewater in the metal finishing industry with the purpose of recovering the concentrated solution for reuse. Techniques such as evaporation, ion exchange, reverse osmosis, ultrafiltration/microfiltration, electrodialysis, and electrowinning are readily available technologies for the recover/recycle of raw materials.
3. **Evaporation.** Evaporators can be used to recover a wide variety of acidic and basic baths including; chrome plating, chromic acid etch, nickel plating, copper sulfate, precious metals, cyanide plating (zinc, copper, cadmium, silver), and zinc chloride. Recovery consists of boiling off water until the concentrate can be returned to the plating bath. Vapor is condensed and recycled for use as rinse water. Pressurized evaporation prevents thermal degradation of plating chemicals and reduces energy costs. Evaporation also concentrates contaminants in the plating bath which must be removed before reuse. Technologies such as carbon filtration or ion exchange may remove these contaminants to a sufficient concentration to allow for reuse.

**AIR POLLUTION/HAZARDOUS WASTE
INSPECTIONS**

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CHAPTER 1

1.0 BASELINE INSPECTION TECHNIQUES FOR AIR POLLUTION SOURCES

1.1 OBJECTIVE

To provide information and techniques to support inspection personnel in conducting field inspections which are necessary to promote compliance.

1.2 INTRODUCTION

During the period from 1970 to 1975, the majority of sources in the U.S. installed pollution control equipment to satisfy recently promulgated regulations. Most of these systems operated well initially; however, as they aged, operation and maintenance problems began to emerge. The baseline inspection method was developed to provide agency personnel with an aid to diagnosing these emerging problems. The ultimate goal is to be able to identify deteriorating performance before non-compliance occurs and restore collection efficiency to its original level.

In this chapter, information concerning the baseline method, various types of inspections, air pollution control systems, and common air pollution control devices is presented.

1.3 PRINCIPLES OF THE BASELINE METHOD

The baseline inspection method embodies four major principles:

1. *Every source and every control device is unique.*

Each control system should be approached initially as if it performs in a manner different from other similar systems on other similar sources. This is important, because substantial differences in performance and vulnerability to problems have

been noted in a number of cases where identical control systems have been installed on identical or similar sources. With the baseline method, a symptom of potential problems is simply a shift in a measured or observed parameter from the value or condition it had when the source was known or assumed to be in compliance. It should be noted that one symptom is rarely used alone. Rather, a combination of symptoms is analyzed to determine if there are potential problems.

2. *On-site instruments are often unreliable or unavailable.*

If the control device has operation and maintenance problems, it is very likely that the instruments are also not working properly. Also, particularly on smaller systems, a parameter of interest may not be measured. It is important that the inspector be aware of this possible limitation and be prepared to either use less-than-desirable data or to make the needed measurements with portable instruments.

3. *A counterflow inspection approach ensures that information of most value is obtained first.*

In the counterflow approach, the inspection begins at the stack and proceeds toward the source in a direction counter to the gas flow. One of the main advantages of this is that the scope of the inspection can be limited to specific conditions, if any, which are symptoms of operating problems. Thus, process equipment would be inspected only if it had been determined that process changes were the likely cause of control system performance shifts. In many cases, this approach will minimize both the inspector's time and the inconvenience to operator personnel.

4. *Judgement of the inspector is the most important factor.*

Effective inspection of air pollution control systems goes beyond simply filling out a checklist. Because of the diversity of control system designs and differences in the degree of maintenance, it is important that the inspection procedure not be rigid. Maintaining this flexibility requires the inspector to continually exercise judgement, both in determining how to proceed with the inspection and in interpreting the symptoms observed.

1.4 LEVELS OF INSPECTION

Introduction

It is desirable to conduct detailed engineering-oriented inspections at all sources. This is obviously impractical, however, since large numbers of air pollution sources must be inspected regularly, and Agency manpower and resources are limited. To give control agencies the opportunity to properly allocate limited resources, four levels of inspections have been designed.

The levels of inspection are denoted as I through IV with the intensity of the evaluation increasing numerically. The types of activities normally associated with each level and the experience levels necessary to conduct the different levels vary substantially.

The most complete and time-consuming evaluations are done only when preliminary information indicates that there is or soon will be a significant emission problem.

Level I inspections

The **Level I** inspection is a field surveillance tool intended to provide relatively frequent but very incomplete indications of source performance. No entry to the plant grounds is usually necessary and the inspection is never announced in advance. The inspector makes visible emission observations on all stacks and vents which are visible from the plant boundary and which can be properly observed given prevailing meteorological conditions. Odor conditions are noted both upwind and downwind of the facility. General plant operations are observed to confirm that these conform to permit requirements. Unusual conditions provide the stimulus for an in-plant inspection in the near future. If the visible emission observations and/or other observations will probably result in the issuance of a notice of violation, the information should be transmitted to source management personnel immediately.

Level II inspections

The **Level II** inspection is a limited "walk through" evaluation of the air pollutant source and/or the control device. Entry to the facility is necessary. The inspection can be performed either in a co-current or countercurrent fashion depending on the anticipated types of problems. In either case, the inspection data gathered are limited to that which can be provided by on-site, permanently-mounted instrumentation. An important aspect of this type of inspection is the evaluation of the accuracy of the data from this instrumentation.

When control devices are not in service during the plant inspection, the Level II inspections can include checks on the internal conditions. This is particularly useful for the evaluation of fabric filter performance. The inspection involves observations from access hatches and under no circumstance includes entry into the collector by the inspector.

Level III inspections

The more detailed and complete Level III inspection may be conducted when the Level I data and/or the preliminary observations during Level II inspections indicate problems. Where necessary, portable gauges provided by the inspector are used to measure certain operating parameters. The types of instruments generally used include:

- static pressure gauges;
- thermocouples and thermometers;
- oxygen and carbon dioxide monitors;
- pH meters; and
- pitot tubes.

The Level III inspection includes a detailed evaluation of stack effluent characteristics, CEM monitoring data, control device performance parameters, and process operating conditions. Raw material and fuel analyses may be reviewed and samples of the scrubber liquor may be obtained for later evaluation. Failed bags or electrostatic precipitator discharge electrodes may be obtained to confirm that the plant has correctly identified the general type of problem(s). In some cases, the Level III inspection will include an evaluation of the internal portions of an air pollution control device. This is done simply by observing conditions from an access hatch and under no circumstances should include entry of the inspector into the control device. The internal checks are included only when the unit is locked off line or when one or more compartments can be safely and conveniently isolated for evaluation.

Level IV inspections

The Level IV inspection, identical in scope to the Level III procedures, is done explicitly to gather baseline information for use later in evaluating the performance of the specific sources at a given facility. This type of inspection should be done jointly by a senior inspector and the Agency personnel who will be assigned responsibility for the plant. Such inspections are done in conjunction with stack tests of major sources such as large electrostatic precipitators, scrubbers, and fabric filters. With smaller sources which are rarely tested, the Level IV inspection is done during a period when source personnel believe that the source is in compliance and the control device is working properly.

An important part of the Level IV inspection is the preparation of general process and control device flowcharts. These should be prepared in accordance with published guidelines. As a starting point, the inspector should request the block flow diagrams or drawings for the portions of the plants which are of interest. Specific flowcharts should be prepared so that all of the important information concerning process flow streams, measurement ports, locations of vents and bypass stacks, and locations of all control devices is clearly shown.

1.5 LEVEL II SOURCE INSPECTIONS

Introduction

A Level II inspection involves an on-site evaluation of the control system and relies on plant instrumentation for the values of any inspection parameters.

Since this is the type of inspection most commonly conducted by Agency personnel, additional information is provided in this, and subsequent sections.

General information

- The scope of the Level II inspection should be limited to absolutely essential operating parameters and conditions necessary to evaluate compliance status and/or to evaluate progress toward compliance.
- The Level II inspection should require a maximum of 4 hours on site. Small sources should require less time.
- The inspection form should be identical to the inspection report form. Preparation of the report should require less than 1 hour even for major sources.
- While on site, it should be possible for inspectors to compare inspection data against site-specific baseline data and industry "norms". The inspection form should help inspectors determine the follow-up information needed to evaluate the adequacy of source operation.
- The inspection procedures and inspection form should include a checklist to help inspectors conduct a complete and consistent inspection. However, the form must allow for flexibility so that inspectors can exercise professional judgement while performing the inspection.

- Evaluation of the accuracy of certain on-site instruments must be completed before data from the instruments is recorded in the inspection notes and report.
- Safety considerations**
- Nothing should be done which jeopardizes the health and safety of the inspector and/or the plant personnel.
 - Under no circumstances should a regulatory agency inspector enter any air pollution control device or any process equipment.
- Limitations**
- The inspection is intended to evaluate progress toward compliance and to identify abnormal operating conditions which **may** be indicative of excessive emissions. It is **not** intended to provide a definite measure of the pollutant emission rate. This can only be determined by means of the promulgated reference method test.
 - Due to the complexity of interrelated performance variables and the lack of on-site inspection time, it is generally impractical for the inspector to positively identify the specific operating problem causing excess emissions. The inspection is inherently limited to the determination of the general type of problem or problems which exist.
 - The inspection does not provide a specific list of repairs and/or modifications necessary to achieve compliance with applicable emission regulations.
 - The Level II inspection is limited to the observations which can be made by the inspector and any data which can be obtained for plant instruments. These instruments can include permanently mounted gauges on the plant equipment or portable instruments used by plant personnel while the inspector is present.

1.6 COMPONENTS OF THE CONTROL SYSTEM

Introduction

Control of air pollution emissions usually involves a system that employs several components to accomplish its task. The system begins with the collection of contaminants from the area of generation and continues through ductwork and assorted system components until the cleaned gas stream is discharged through a vent or stack to the outdoor air.

Components

An air pollution control system includes the following:

- Contaminant capture (hoods)
- Transport (ductwork)
- Gas stream cleaning (control devices)
- Air moving (fan)
- Instrumentation (controls and monitors)
- Other activities (gas cooling, chemical feeding, waste disposal, etc.)

The components of a control system are usually divided into two groups: (1) the air pollution control device, and (2) its ancillary equipment.

Figure 1-1 illustrates a typical air pollution control system

Contaminated air is captured by a series of hoods located over operations which are the source of contamination. The captured contaminants are conveyed through a branched ductwork system to the control device. Dampers control the flow from each hood. The fan draws the gas flow through the hoods, ductwork and control device and discharges it into a stack and on to the atmosphere.

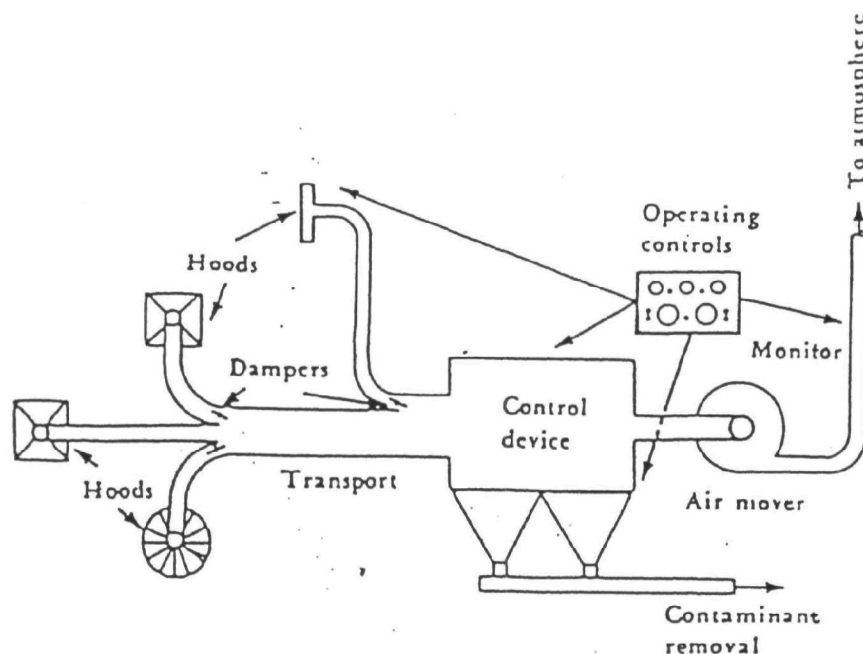


Figure 1-1. Typical air pollution control system

1.7 ANCILLARY COMPONENTS

Containment capture

The objective of this system component is to effectively capture (with minimum air flow into the system and minimum pressure loss on entry) the contaminants being released from a source. Optimization of both air flow and pressure loss reduces fan horsepower and operating costs and the size and cost of the control device and its ancillary equipment.

Level II inspection points

- *Capture efficiency:* visual evaluation of fugitive losses as indicated by escaping dust or refraction lines.
- *Physical condition:* hood modifications or damage that could affect performance; evidence of corrosion.
- *Fit of "swing-away" joints:* evaluation of gap distance between hood system and duct system on movable hoods.
- *Hood position/cross-drafts:* location of hood relative to point of contaminant generation; effect of air currents on contaminant capture.

Transport

The duct system transports the contaminated gas stream between other components in the control system. The design objective is to select duct and fitting sizes that provide optimum conveying velocities while minimizing friction and turbulence losses.

Level II inspection points

- *Physical condition:* indications of corrosion, erosion or physical damage; presence of fugitive emissions.
- *Position of emergency dampers:* emergency by-pass dampers should be closed and not leaking.
- *Position of balancing dampers:* a change in damper positions will change flow rates; mark dampers with felt pen to document position for later inspections.
- *Condition of balancing dampers:* damper blades can erode and change system balance; remove a few dampers to check their condition.

Air moving

The purpose of the fan is to move the gas stream through the air pollution control system. To do this, the fan must be sized for the proper air flow and must be able to overcome acceleration and entrance losses at the hoods and friction losses in the ductwork, the control device and other system components.

The fan may be positioned upstream or downstream of the control device. A downstream fan position creates a negative pressure at the control device, drawing air in through any cracks or openings and minimizing leakage of contaminants. However, if the openings are excessive, in-leakage may diminish the required capture velocity at the source, allowing emissions to escape. When the fan is located upstream of the control device, a positive pressure is created that permits contaminants to escape through cracks or holes in the casting or connecting ductwork.

Level II inspection points

- *Physical condition:* indications of corrosion.
- *Vibration:* indications of balance problems due to material build-up or wheel erosion or corrosion; severely vibrating fans are a safety hazard.
- *Belt squeal:* squealing belts under normal operation indicate a loss of air volume.
- *Fan wheel build-up/corrosion:* internal inspection of non-operating fans.
- *Condition of isolation sleeves:* check vibration isolation sleeves for holes.
- *Rotation direction:* check rotation direction with direction marked on fan housing.

Instrumentation

Operating controls are important to the function of the air pollution control system and may directly affect its performance. For example, changing the timing cycle on a fabric filter cleaning system may cause pressure loss to increase, reducing the air flow from the fan and allowing emissions to escape at the source.

Level II inspection points

- *Physical condition:* indications of excessive wear, obvious signs of failure or disconnected controls.
- *Set-point values:* changes in set-point values for temperature, pH, rapping intensity, air pressure and other controllers may affect system performance.

- *Timer settings:* check for changes in cleaning cycle, chemical delivery cycle and other timer settings.
- *Emission monitors:* evaluate general condition and siting; have operator check zero and span values; review historical data.

Other components There can be many other components in an air pollution control system, including such items as chemical feed systems and catalyst regeneration units. A component found with all of the dry collection devices is a dust handling system. This component is responsible for removing the collected particles from the control device and conveying them to the final disposal site. Common to such systems are a collection hopper, a dust transfer valve and the piping or conveying equipment.

Many control systems capture gases that are too hot to introduce directly to the control device. In these systems, a component for cooling the gases will be found. This cooling may be accomplished by diluting the hot gases with cooler air, by evaporating water into the hot gas stream or by radiation and convection to the atmosphere.

Level II inspection points

Solids handling:

- *Physical condition:* indications of hopper corrosion or physical damage; condition of level detectors, heaters, vibrators, insulation, etc.
- *Discharge valve:* check for presence and operating status and indications of air leakage.
- *Solids discharge rate:* rate of solids discharge should be reasonable.

Gas cooling:

- *Physical condition:* indications of corrosion, erosion or physical damage; presence of fugitive emissions.
- *Outlet temperature:* observe plant instruments to determine cooler effectiveness; if controller is used, compare to set-point value.
- *Spray pattern/nozzle condition:* indications of effective atomization on evaporative coolers.

- *Water flow rate:* observe plant flow meters or pressure gauges to evaluate changes in water flow rate on evaporative coolers.

1.8 CLASSIFICATION OF AIR POLLUTION CONTROL DEVICES

Control devices:

- Separate contaminants from a gas stream and then remove them without re-entrainment, either continuously or intermittently, to a disposal system; or
- Change the contaminant from offensive to inoffensive; or
- Both separate and remove, and change contaminants from offensive to inoffensive.

Control devices can be classified according to the contaminants they are typically used to remove:

- Particles only
 - Settling chamber
 - Fabric filter
 - Electrostatic precipitator
 - Cyclone
- Gases only
 - Wet collector
 - Adsorber
 - Incinerator
- Vapors only
 - Condenser
 - Incinerator
- Particles, gases and vapors
 - Wet collector
 - Incinerator

1.9 FABRIC FILTERS

General information

Fabric filters remove particles by passing the contaminated gas stream through a woven or felted fabric, usually in a cylindrical configuration. Depending on the direction of gas flow, particles are deposited on either the inside or outside of the cylindrical "bag". Initially, such forces as impaction, diffusion and electrostatic attraction are primarily responsible for particle capture by the fabric fibers. However, as the dust coats the filter and increases in thickness, direct sieving begins to dominate.

As the thickness of the dust-cake increases, so does the pressure lost in moving the gases across the filter. To keep pressure loss reasonable, it is necessary to periodically clean the fabric. The three most popular cleaning methods are shaking, reversing air flow direction and pulsing with compressed air.

Cleaning methods

Shaker-cleaning

A typical **shaker-cleaning collector** is shown in Figure 1-2. The dirty gas stream enters the hopper area and then moves across a tube-sheet to the inside of the filter tubes. The gas stream passes through the filter, depositing the particles on the inside. When it is time to clean the fabric, the collector is isolated from air flow and the bag shaken by moving the supports from which the bags are hung. The dust drops into the hopper where it is removed through a dust discharge valve.

Reverse-air-cleaning

The **reverse-air-cleaning collector** (Figure 1-3) is nearly identical in appearance to the shaker, except the bags are hung from rigid supports. Cleaning is accomplished by isolating the collector from the dirty gas flow and introducing clean gas flow in the reverse direction. This reverse flow dislodges the dust which falls into the hopper. At this point the cleaning air is quite dirty, so it is ducted to an operating unit for cleaning. Thus, a reverse-air collector requires a minimum of two units.

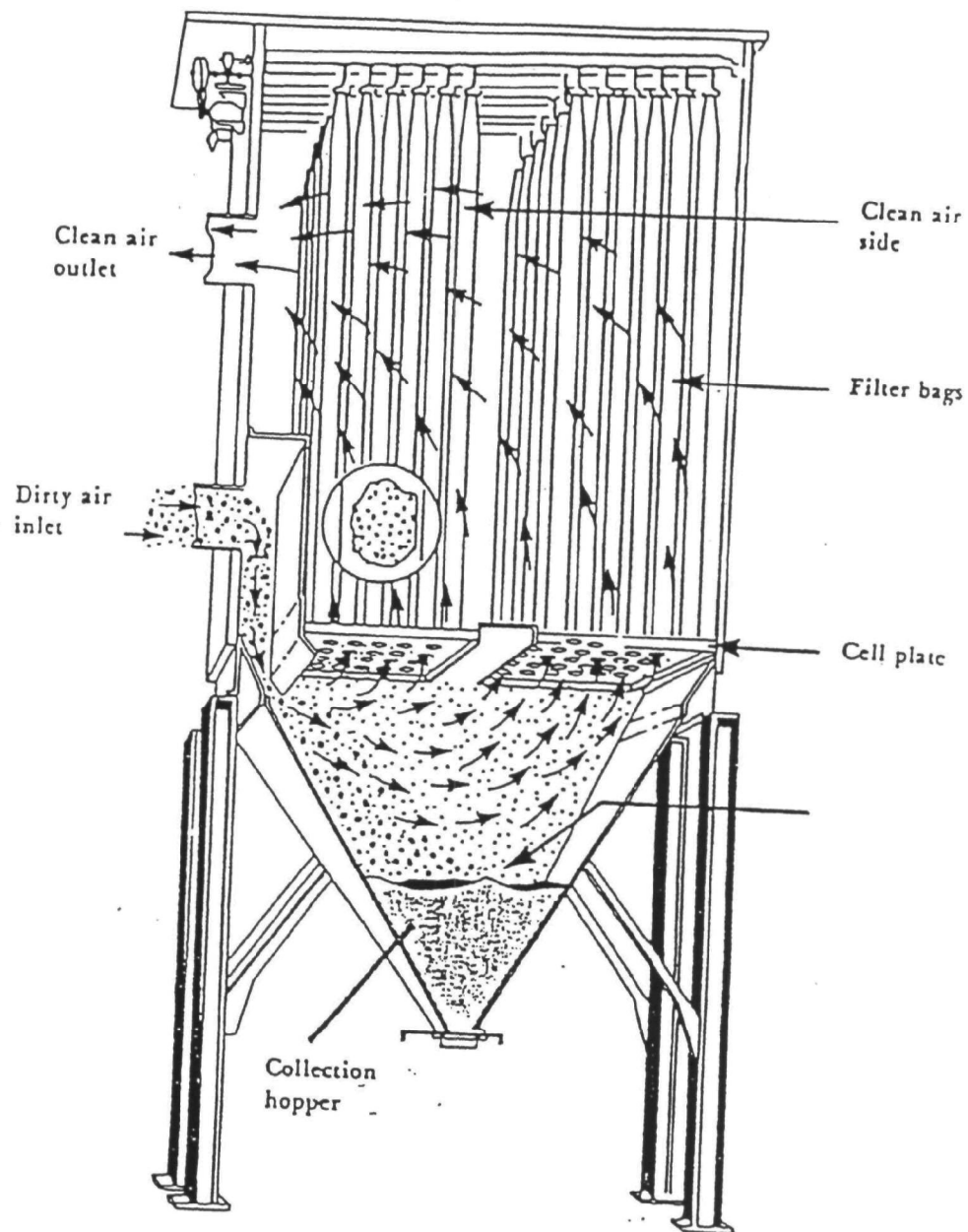


Figure 1-2. Shaker-cleaning fabric filter

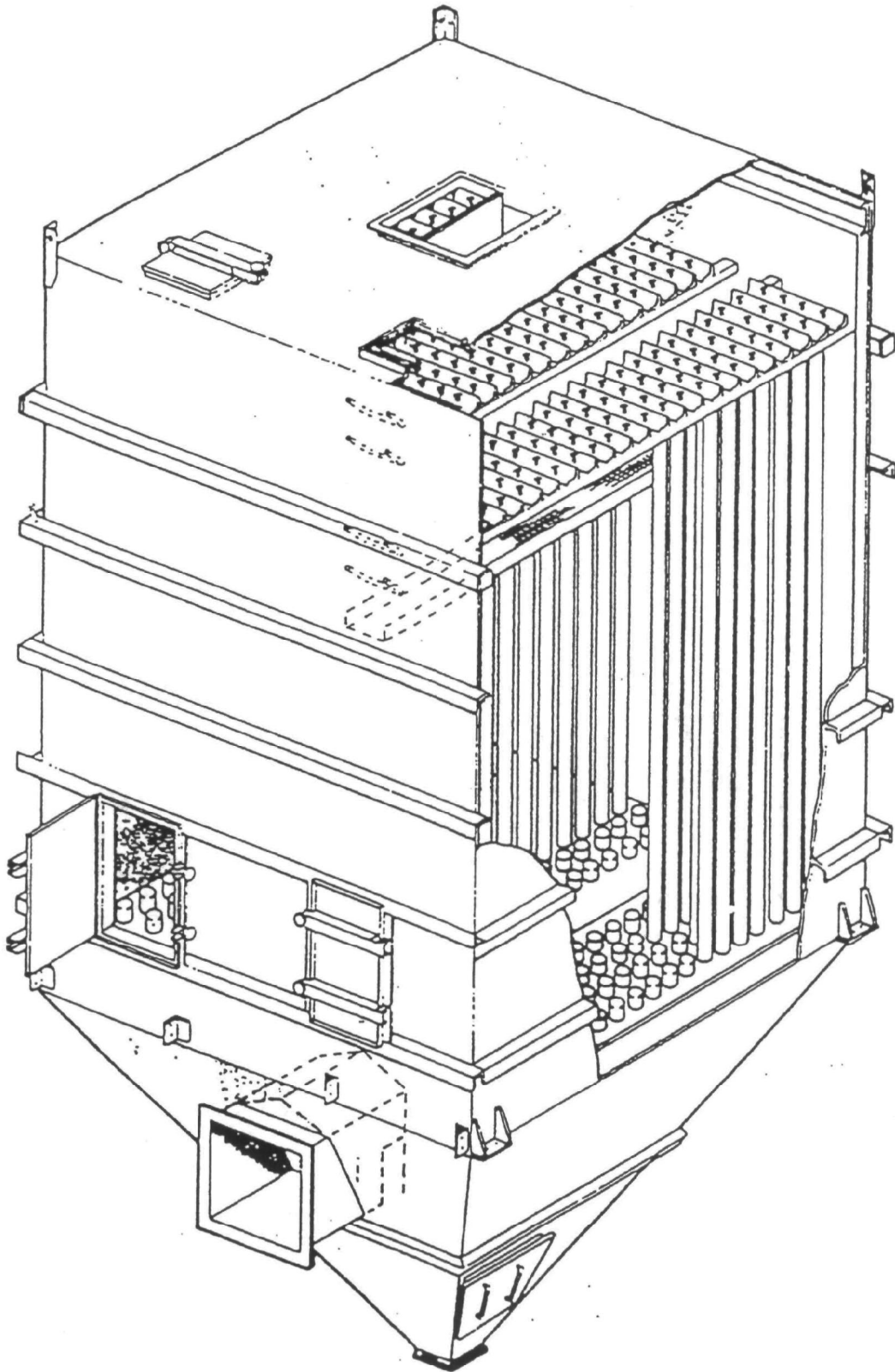


Figure 1-3. An example of a large reverse-air fabric filter (Courtesy of MikroPul Corporation).

Pulse-cleaning

Figure 1-4 shows a typical **pulse-cleaning collector**. Cylindrical bags are suspended from a tube-sheet located near the top of the collector, and the dirty gas flow is directed through the outside of the bags and up through the center to the clean gas discharge. Metal cages are placed inside the bags to prevent collapse. Cleaning is accomplished by directing a pulse of compressed air into the top of the bag and against the dirty gas flow. This pulse momentarily dislodges the dust from the outside of the bag and slowly works it down toward the hopper. Bags are usually cleaned one row at a time without isolating the collector from the dirty gas flow.

Level II inspections

Inspection activities

- Method 9 observation of the baghouse discharge.
- Method 9 observation of fugitive emissions from baghouse solids handling operation (if reentrainment is occurring).
- Method 9 observation of fugitive emission from process equipment.
- Counterflow checks of audible air infiltration into fan, baghouse (solids discharge valve, access doors, shell) and ductwork. Also check physical condition and location of hoods.
- Static pressure drop across baghouse using on-site gauge; compare with baseline data.
- Comparison of compressed air pressures at baghouse reservoir with baseline values. Check for audible leaks of compressed air at fittings.
- Check operation of diaphragm valves, record number of valves which do not appear to be working properly.
- Check inlet gas temperatures using on-site gauge.
- Observe and describe corrosion of baghouse shell and hoppers.
- Evaluate bag failure records, gas inlet temperature records, pressure drop data, and other maintenance information.

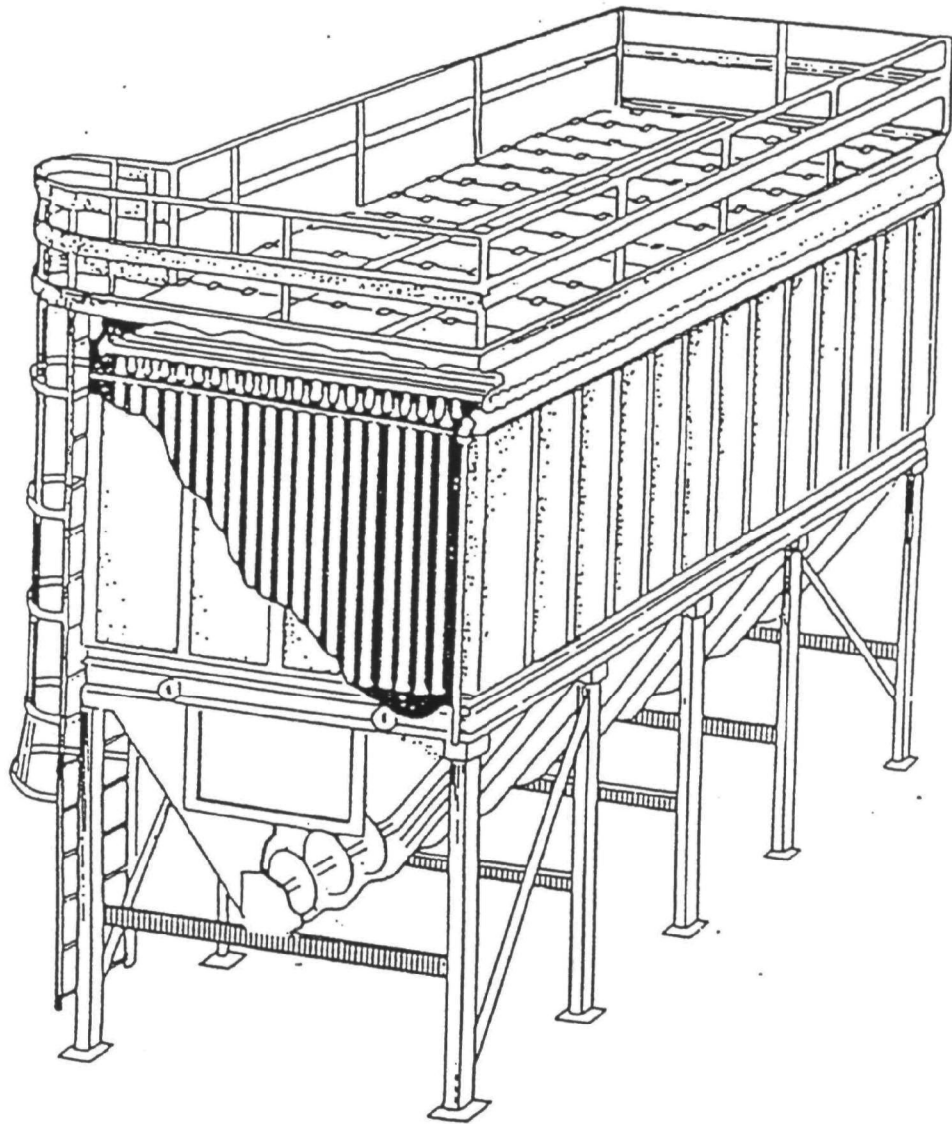


Figure 1-4. Pulse-cleaning fabric filter

***Performance
evaluation***

- Visible emissions greater than 10% from the baghouse indicate poor performance. Inspection should include evaluation of bag problems, including but not limited to abrasion, chemical attack, ember damage, high temperature damage, and improper cleaning. A rip test should be done on failed bags unless quantitative fabric tests have been performed. If conditions appear to be severe, a Level III inspection (primarily clean side checks) is warranted.
- Fugitive emissions from all process sources should be carefully documented. Reasons for poor capture should be investigated, including, but not limited to, air infiltration, poor hood condition or location, fan belt slippage (listen for squeal), fabric blinding and poor cleaning effectiveness. The static pressure drop data and cleaning system performance checks (compressed air pressures, conditions of diaphragm valves and frequency of cleaning) are very important.
- The counterflow check of the entire system for air infiltration is very important since this can generally lead to severe problems.

Safety considerations

- The Level II inspection involves some climbing and close contact with the pulse jet baghouse. Check the integrity of all supports and ladders. Climb ladders properly. Avoid contact with hot ducts and roofs. Avoid downward pointing gas discharge points.
- Since the inspector must enter the facility to make a Level II inspection, all normal safety precautions apply.

1.10 ELECTROSTATIC PRECIPITATOR'S (ESPs)

**General
information**

Electrostatic precipitators remove particles from a contaminated gas stream by employing the principle of attraction of opposite charges. The particles are charged in a high voltage electric field created by a corona discharge electrode and are then attracted to a collection plate of opposite charge (see Figure 1-5). When the particles reach the collection plate they slowly lose their charge through conduction, ideally retaining just enough charge to hold the particles to the plate but not so much that it inhibits further deposition or makes removal difficult. Periodically, the plate is vibrated or rapped and the dust drops into the hopper.

The electric field is powered by direct currents supplied from transformer-rectifier (T-R) sets mounted on the roof. Each T-R set serves one or two fields or electrical sections. Efficiency of collection is usually highest when the voltage is highest. Most industrial ESPs operate with a negative corona because of its stability under high voltage conditions. Peak performance is indicated by the beginning of sparking from electrode to plate.

The plates are generally rapped by hammer mechanisms mounted outside on top of the housing. In some designs the rappers are located inside the housing and cannot be seen by the inspector. Also located on top of the housing will be vibrator units for keeping the discharge electrodes clean.

The electrostatic precipitator looks very much like a fabric filter, i.e., a large box-shaped structure with hoppers beneath it. However, the ESP is distinguished by the rapping mechanisms and transformer-rectifier sets mounted on top of the housing and by inlet/outlet locations that are generally on the ends (see Figure 1-6).

Level II inspections

Inspection Activities

- Method 9 observation of the stack discharge.
- Timing, duration and pattern of intermittent puffs.
- Characteristics of any detached, condensing or reactive plumes.
- Physical conditions of transmissometer transmitter and retroreflector.
- Transmissometer zero and span values, status of window lights.
- Transmissometer strip chart data
- Precipitator electrical set data, including plots of the secondary voltages, secondary currents, and spark rates for each chamber starting with the inlet field and proceeding to the outlet field.
- Process operating data.
- Transmissometer strip chart records and electrical set records.

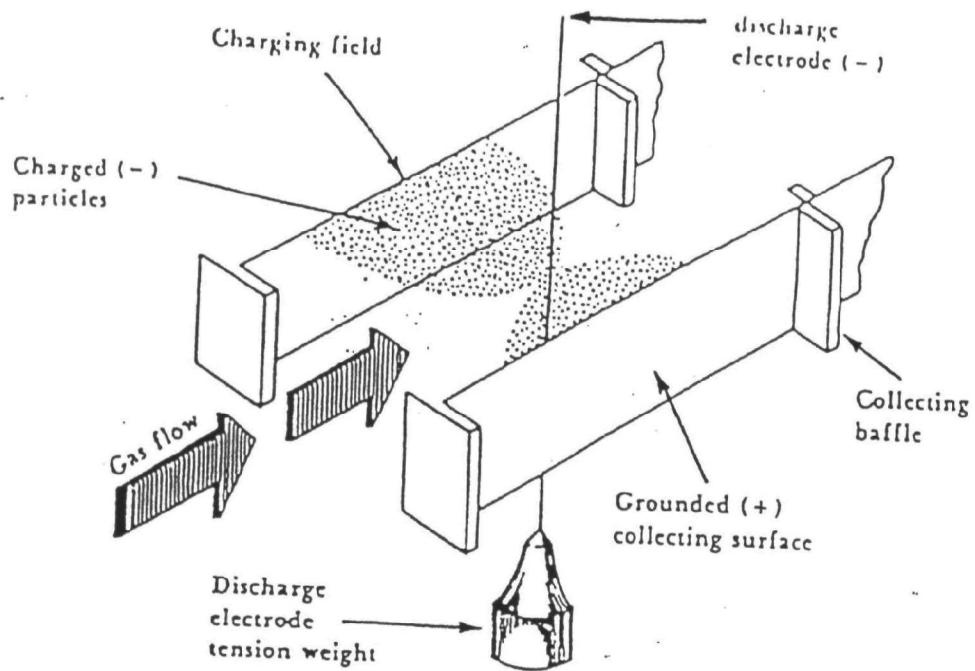


Figure 1-5. ESP collection schematic

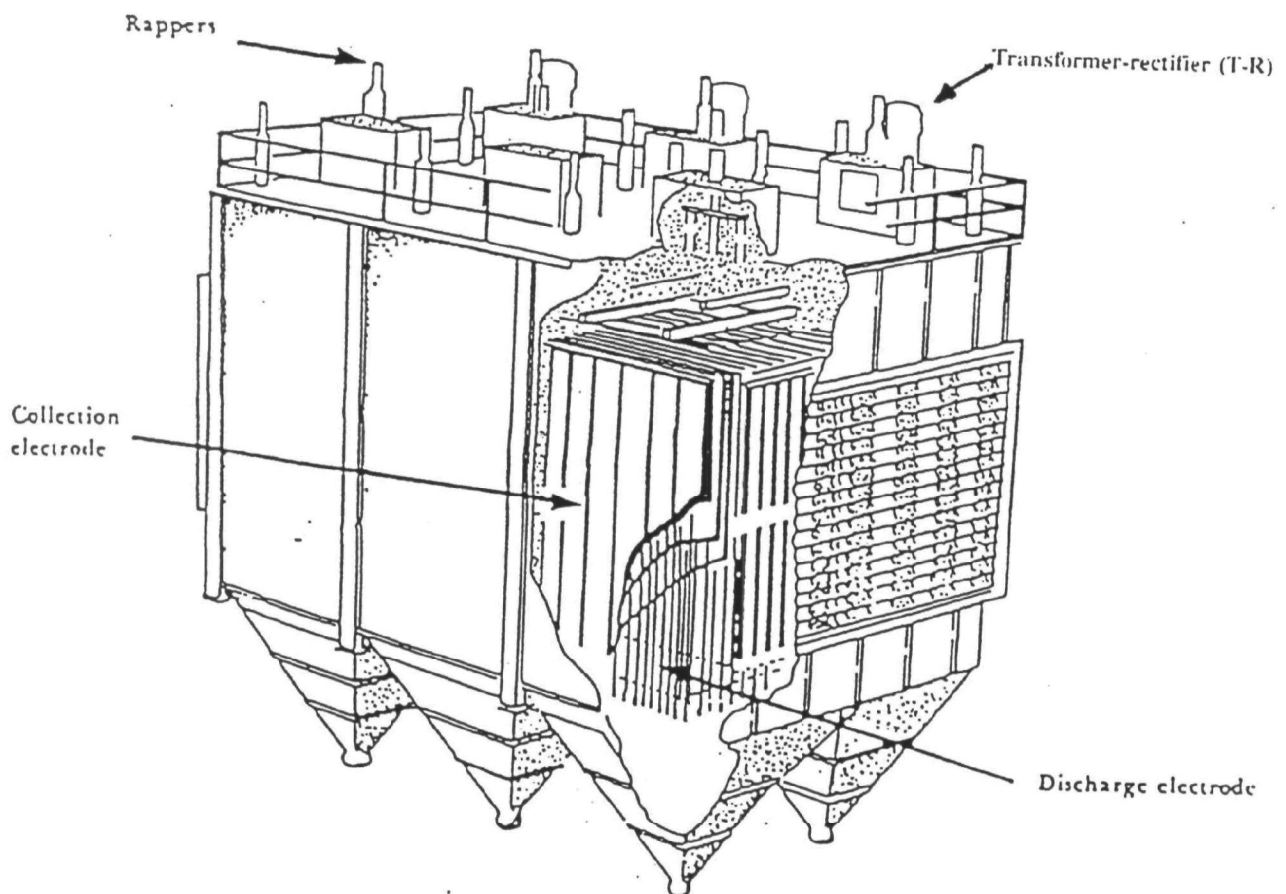


Figure 1-6. Electrostatic precipitator

Performance evaluation

- An increase of more than 5% opacity in the visible emission since the baseline period or visible emission within 5% opacity of the regulatory limit warrant a Level III inspection.
- If the data indicate the unit is operating in moderate or high resistivity conditions, the power input should be computed and compared against the baseline values.
- The secondary (or primary) voltages should be compared with the baseline values.
- The field-by-field electrical data plots should be compared with baseline plots.
- The transmissometer strip charts should be analyzed for characteristic patterns of operating problems.

Safety considerations

- Inspectors should be trained in safety procedures prior to using stack elevators to reach transmissometers mounted on stacks.
- All ladders and platforms should be checked before use. Safe ladder-climbing practices are necessary.
- Poorly ventilated areas around expansion joints, flanges and other areas must be avoided.

1.11 CYCLONES/MULTI-CYCLONE COLLECTORS

General information

In a cyclone, the dirty gas stream is directed into a cylindrical shell, either through a tangential entry or through turning vanes. The result is a confined vortex in which centrifugal forces drive the entrained particles toward the outside wall. Particles successfully deposited slide down the wall and into the hopper from which they are removed through a dust discharge valve.

Cyclones

Single cyclones

Cyclones can be constructed in either single or multiple configurations. **Single cyclones** are generally characterized as either high efficiency or high throughput (see Figure 1-7). High efficiency cyclones have a narrow inlet opening in order to attain high inlet velocity, a long body

length relative to its diameter and a small outlet diameter/body diameter ratio. High throughput cyclones, which are inherently less efficient, have larger inlet openings, a shorter body length and larger gas exits.

Multi-cyclones

Multi-cyclones have numerous small diameter (typically 15-23 cm (6"-9")) cyclone tubes in parallel inside a single housing (see Figure 1-8). Each cyclone is mounted into a lower "tube-sheet" which separates the in-coming dirty gas stream from the hopper level below. The outlet tube from each cyclone extends up through the in-coming dirty gas stream and into an upper tube-sheet that separates the dirty gas from the cleaned gas.

Cyclone efficiency is very sensitive to particle size, with performance deteriorating rapidly for particles less than about 2-5 μm diameter. When particle size distribution and gas flow rate are relatively constant, changes in pressure drop across a cyclone provide a good indicator of changes in collection efficiency.

Level II inspections

Inspection activities

- Method 9 observation of the stack for a sufficient period to fully characterize conditions during normal process cycles.
- Method 9 observation of any fugitive emissions from process equipment, material handling operations, and stockpiles.
- Air infiltration sites on collector shell, hopper, solids discharge valve, and inlet ductwork.
- Static pressure drop across collector as indicated by on-site gauge.
- Inlet gas temperature as indicated by on-site gauge.

Performance evaluation

- If the visible emissions have increased more than 5% opacity since the baseline period or if the visible emissions are within 5% of the regulatory limit, a Level II or Level III inspection is necessary.
- Fugitive emissions from the process area can be at least partially due to air infiltration into the ductwork or collector. The process area and ductwork should be checked in any subsequent Level II or III inspections.

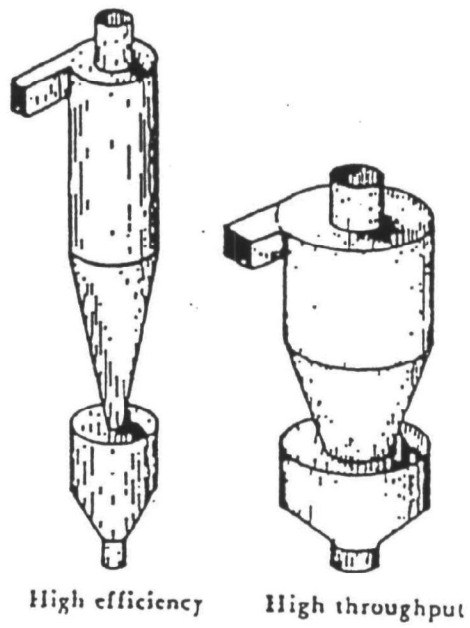


Figure 1-7. Single cyclone collectors

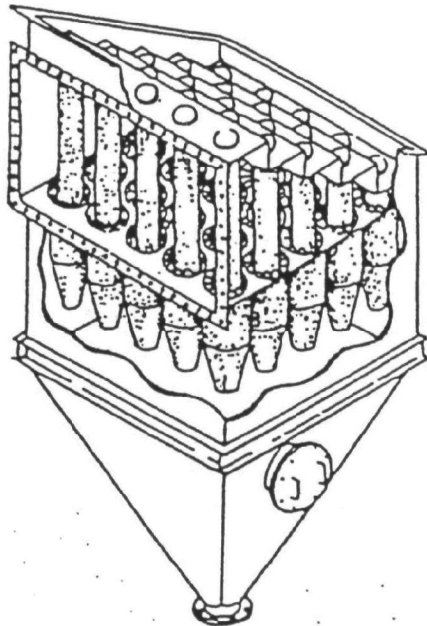


Figure 1-8. Multi-cyclone

- The static pressure provides an indication of the flow rate and the resistance of gas flow. The static pressure should be checked against baseline static pressure drops for similar process operating rates. If the present value is higher, then pluggage is possible. If the static pressure drop is now lower, erosion of outlet tubes and gasket problems are likely.

- Safety considerations**
- Position selected for the Method 9 observations should be secure from moving vehicles such as cars, trains, and moving machinery.
 - There must be secure footing. Stockpiles are not acceptable.
 - All climbing and walking safety procedures are very important. Some horizontal structures may not be able to withstand the load of accumulated solids and several people.
 - Contact with hot surfaces must be avoided.
 - Many multi-cyclone collectors are located in hot areas. Heat stress should be avoided by limiting the time spent in the area (moderate heat conditions) or by not entering the area (high heat areas).
 - Poorly ventilated areas must be avoided.

1.12 WET SCRUBBERS

General information

Wet collectors remove contaminants from a gas stream by transferring them to some type of scrubbing liquid. For particles larger than about 1 μm , the dominant separation mechanism is impaction onto liquid droplets or wetted targets. For sub-micron particles and gases, the dominant mechanism is diffusion to liquid surfaces. Because of incompatible requirements, wet collectors are generally designed to perform as either a particle or a gas collector. Simultaneous collection of both particles and gases is usually possible only when the gas has a very high affinity for the scrubbing liquid.

Contacting the contaminated gas stream with the scrubbing liquid is only the first stage of a wet collector. Because the contact phase usually results in liquid entrained in the gas stream, the second stage is some type of liquid-gas separator. Common entrainment separators include chevron baffles, mesh pads and single-pass cyclones. Contactors producing large droplets may require only a little low-velocity head-space to allow the droplets time to settle back into the unit.

Wet collectors

The almost endless variety of wet collectors makes it difficult to include all types and varieties in one discussion. To illustrate the range of designs and performance levels, four types of scrubbers will be briefly described: (1) a spray tower, (2) a tray scrubber, (3) a countercurrent packed tower and (4) a venturi scrubber.

Spray tower

A simple **spray tower** is illustrated in Figure 1-9. The dirty gas stream enters at the bottom of the scrubber and flows upward at velocities between 0.6 and 3.0 meters (2 and 10 feet) per second. The liquid enters at the top of the unit through one or more spray headers, so that all of the gas stream is exposed to the sprayed liquid. A spray tower has only limited particle removal capacity, and is generally selected for applications where the particles are larger than about 5 μm . Spray towers can be effective gas absorbers if the contaminant has a moderate affinity for the liquid.

Tray scrubber

A **tray scrubber** (see Figure 1-10) can also be used for both particle and gas collection. The gas stream again enters at the bottom and passes upward through holes in the trays. The liquid enters at the top and cascades across one tray and then flows down to the next. An overflow weir is used to maintain a liquid level on each tray. Variations in tray design include the placing of assorted "targets" above each hole to enhance the scrubbing action. The tray scrubber is an effective collector of particles larger than about 1 μm and can be an effective gas absorber when the contaminant has a moderately low affinity for the liquid.

Packed tower

Packed towers are used primarily for gas absorption because of the large surface area created as the liquid passes over the packing material. The beds can be either vertical or horizontal. The most efficient arrangement is the vertical countercurrent packed tower shown in Figure 1-11. The gas stream again enters at the bottom and passes upward through the packing. The liquid is sprayed from the top and flows downward in a thin film over the surface of the packing. The packed tower is an effective gas absorber when the contaminant has a low affinity for the liquid.

Venturi scrubber

A conventional **venturi scrubber** is shown in Figure 1-12. The dirty gas stream enters a converging section and is accelerated toward the throat by approximately a factor of ten. The liquid is injected into the scrubber just beyond the entrance to the throat, where the liquid is shattered into droplets by the high velocity gas stream. Particles are collected primarily by being impacted into the slower moving drops. Following the contactor is usually a single-pass cyclone for entrainment separation. The venturi scrubber is an effective collector of particles down to the sub-micron range, comparable in performance to the fabric filter or ESP, and can be an effective gas absorber when the contaminant has a moderately high affinity for the liquid.

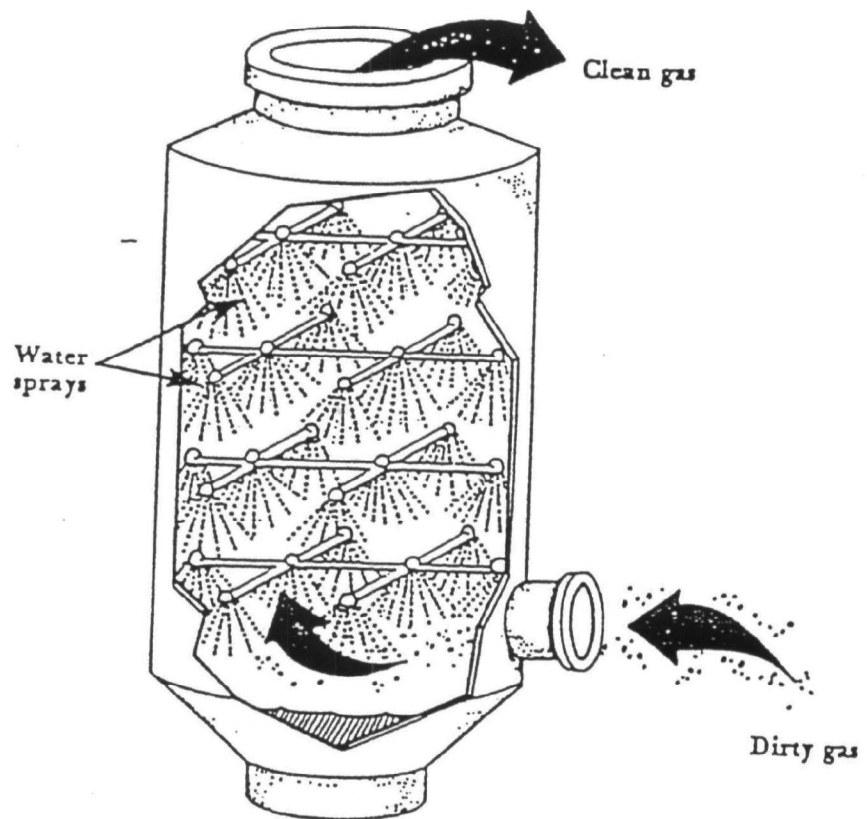


Figure 1-9. Simple spray chamber

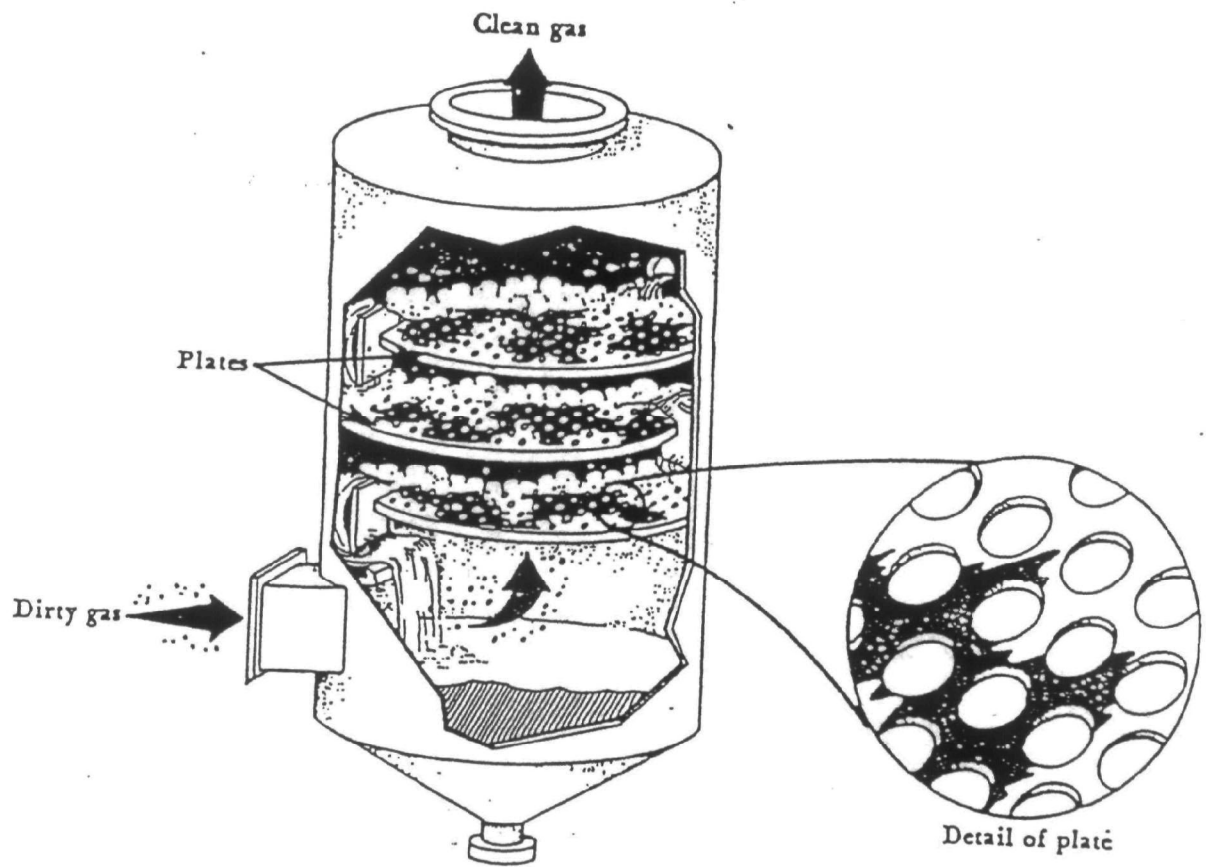


Figure 1-10. Tray scrubber

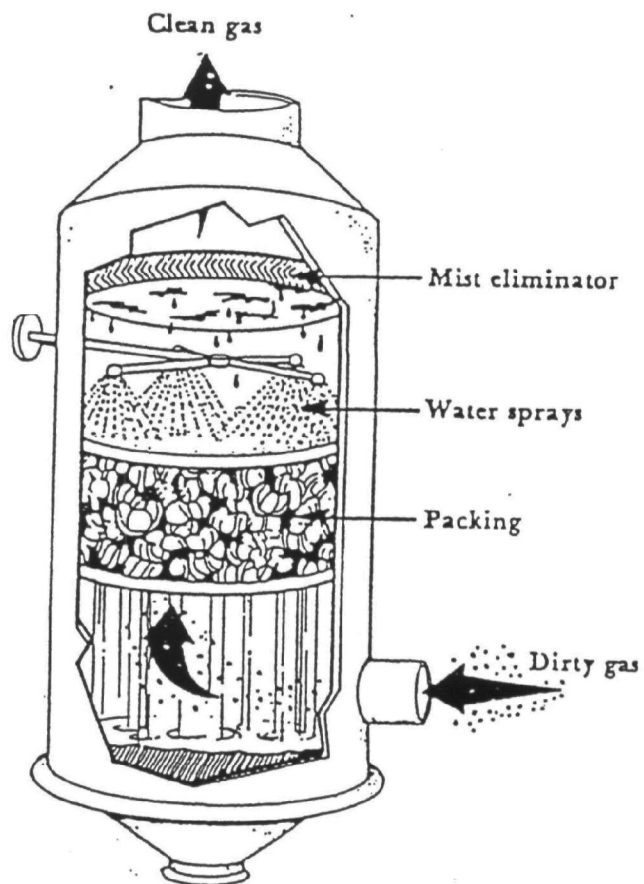


Figure 1-11. Countercurrent packed tower

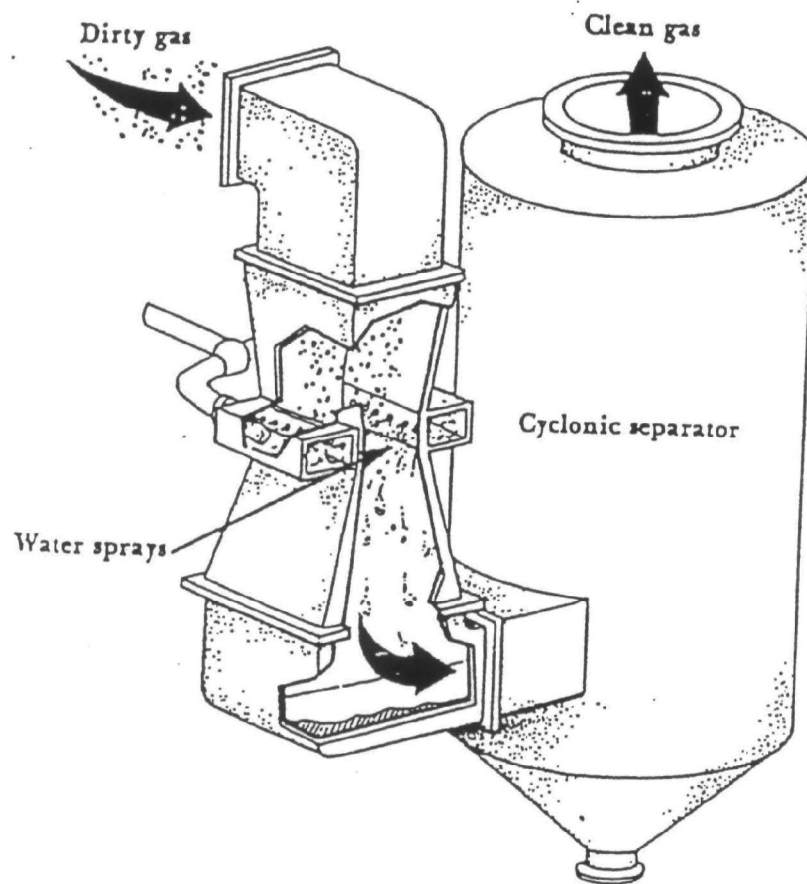


Figure 1-12. Conventional venturi scrubber

Level II inspections

Inspection activities

- Method 9 observation of the stack for a period of not less than 6 minutes. Average opacity should be calculated. Cycles in the average opacity should be described.
- Method 9 observation of all bypass stacks and vents. Method 9 observations of any fugitive emissions from process equipment.
- Presence of rainout close to the stack or mud lips at the discharge point.
- Presence of fan vibration.
- The liquor flow rate indicated by on-site gauge.
- Physical condition of shell and ductwork.
- Recirculation pond layout and pump intake position.
- Physical condition of nozzles observed through access hatch.
- Means used to dispose of purged liquor should be noted.

Performance evaluation

- A shift in the average opacity may be due to a decrease in the particle size distribution of the inlet gas stream. A co-concurrent inspection of the process operation is often advisable.
- Anything which affects the nozzles will reduce performance. The liquor turbidity is related to the vulnerability to nozzle pluggage and erosion.
- Shell and ductwork corrosion is often caused by operation at pH levels which are lower than desirable. The liquor pH should be measured using in-plant instruments if available.
- The performance of a spray tower scrubber is dependent on the liquor flow rate. Any problems which potentially reduce the flow rate should be fully examined.

Safety considerations

- All ladders and platforms should be checked before use. Safe climbing and walking practices are important, especially in cold weather.
- Poorly ventilated areas should be avoided.
- Hot duct and pipes should not be touched.

- The inspection should be terminated if a severely vibrating fan is noted in the general vicinity of the scrubber.
- Under no circumstances should the inspector attempt to look inside an operating wet scrubber.
- Visible emissions observations should be made only in secure areas.

1.13 CARBON BED ADSORBERS

General information

Adsorbers remove gaseous contaminants from an air stream by transferring them to the surface of some high-surface-area solid adsorbent. In air pollution control systems, adsorbers which use activated charcoal as the adsorbent are typically employed to remove volatile organic compounds. Adsorption is most effective when the system temperature is about 24°C (75°F) and the compounds have molecular weights between about 45 and 200.

The most popular cleaning method is to introduce low-pressure steam into the bottom of the bed to raise its temperature and cause the contaminants to desorb from the carbon. The mixed stream of organic vapor and steam coming from the bed is condensed and the solvent recovered by decanting or distillation. Following desorption, the bed is allowed to cool and dry before being put back on line.

A typical multi-bed adsorption system is shown in Figure 1-13. Here, the left two beds are on line and contaminated gas is passing vertically down through each unit. As the system continues to operate, the on-line beds approach saturation with the contaminants and must be taken off line for cleaning to prevent breakthrough of the organic contaminant. This condition is represented in the right hand corner.

Level II inspections

Physical condition

- Indications of corrosion or physical damage.

Adsorption/de-sorption cycle times

- An increase in the interval between bed cleanings could mean breakthrough is occurring.

Steam pressure/temperature during desorption

- A decrease in steam pressure/temperature could indicate insufficient steam flow for regeneration.

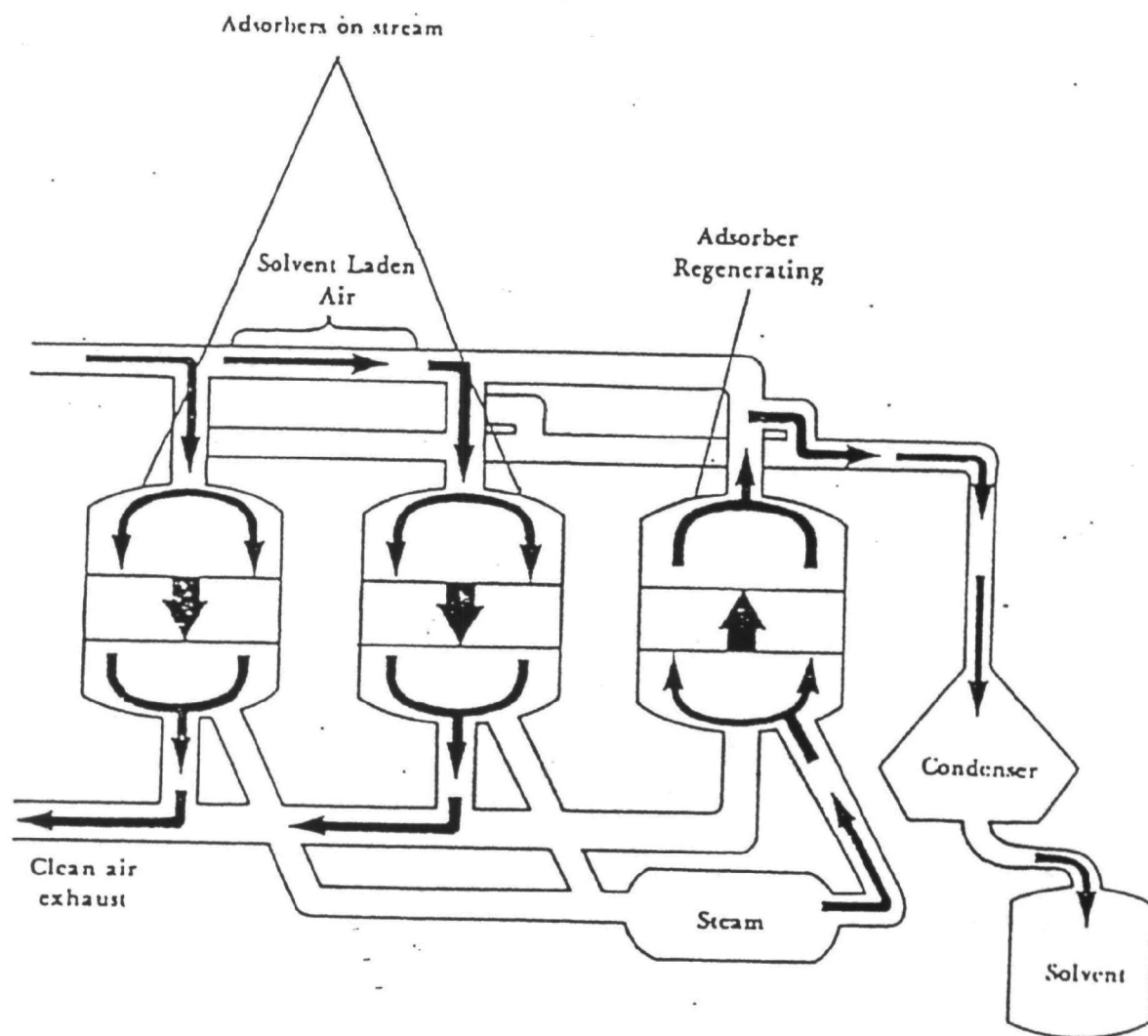


Figure 1-13. Activated carbon adsorber

1.14 INCINERATORS

Incinerators remove gaseous contaminants from an air stream by oxidizing them to compounds not considered to be contaminants. The two most common types of incinerators are:

- **Direct-fired or thermal units**, which are refractory-lined chambers with a gas or oil burning apparatus plainly visible (see Figure 1-14).
- **Catalytic units**, which have the appearance of a duct heater and are more highly instrumented (see Figure 1-15).

In both thermal and catalytic units, the principal parameter for indicating efficiency is temperature, the value of which is dictated by the characteristics of the contaminant to be oxidized. In thermal units, the recommended minimum outlet temperature is 704°C (1300°F); most systems operate in the 816-982°C (1500-1800°F) range. Catalytic units are generally designed for a bed inlet temperature of 371-482°C (700-900°F).

Level II inspections

| | |
|---------------------------|---|
| <i>Physical condition</i> | <ul style="list-style-type: none">• Indications of corrosion or physical damage; indication of air infiltration. |
| <i>Outlet temperature</i> | <ul style="list-style-type: none">• Decreased outlet temperature may mean reduced VOC destruction efficiency. |
| <i>Temperature rise</i> | <ul style="list-style-type: none">• Decreased temperature rise across the catalyst bed may mean reduced VOC destruction efficiency. |

1.15 CONDENSERS

Condensers remove vaporous contaminants from a gas stream by cooling it and converting the vapor into liquid. In some instances, control of volatile contaminants can be satisfactorily achieved entirely by condensation. However, most applications require additional control methods. In such cases, the use of a condenser reduces the concentration load on downstream control equipment. The two most common types of condensers are:

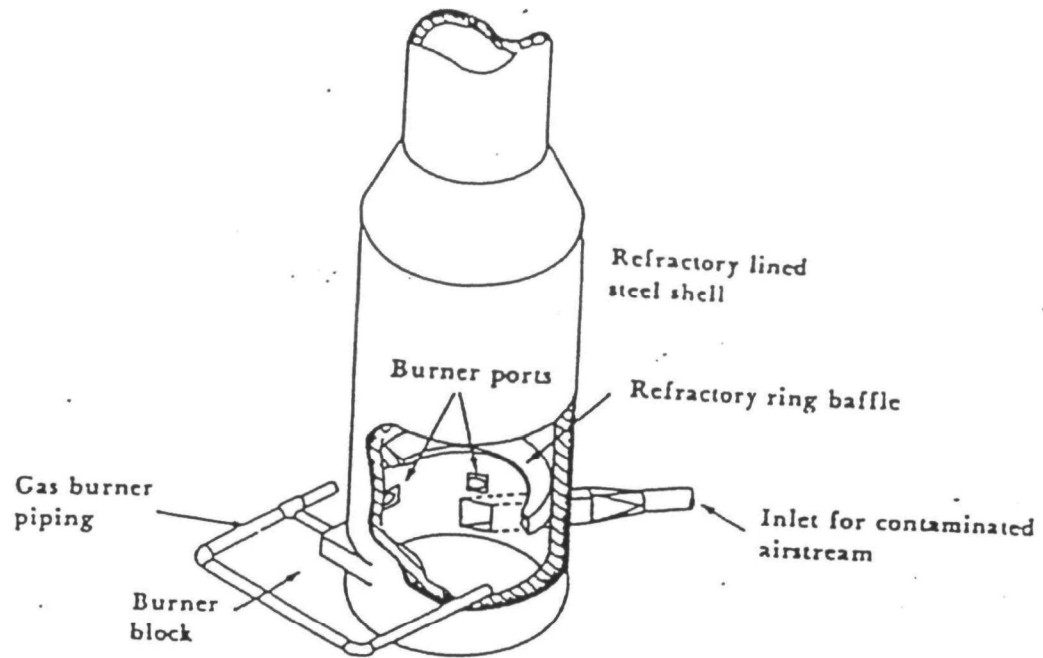


Figure 1-14. Direct-fired Incinerator

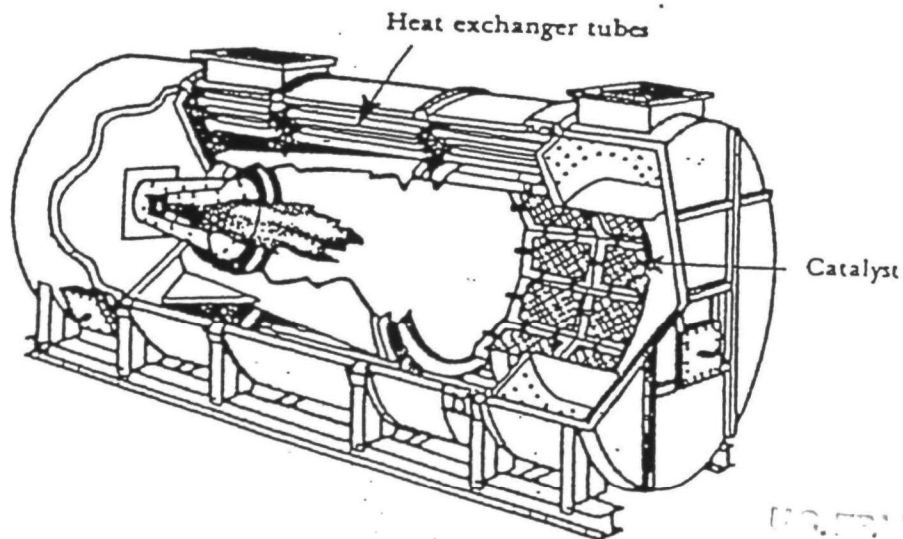


Figure 1-15. Catalytic Incinerator

- **Contact or barometric condensers**, where a direct spray contacts the vapors to cause condensation (see Figure 1-16). The liquid leaving the condenser contains the coolant plus the condensed vapors.
- **Surface condensers**, such as the shell-and-tube heat exchanger (see Figure 1-17). This device consists of a shell into which the vapor stream flows. Inside the shell are numerous small tubes through which the coolant flows. Vapors contact the cool surface of the tubes, condense and are collected without contamination by the coolant.

Level II inspections

- | | |
|--|---|
| <i>Physical condition</i> | • Indications of corrosion or physical damage. |
| <i>Outlet temperature</i> | • Provides an indirect indication of the liquid flow rate and nozzle condition; increases may indicate nozzle pluggage and lower coolant flow rates; decreases may indicate nozzle erosion and higher flow rates (contact-type only). |
| <i>Liquid turbidity/ settling rate</i> | • High settling rate indicates coarse solids that could plug nozzles (contact-type only) |
| <i>Droplet re- entrainment</i> | • Droplet rainout or a mud-lip on the stack indicates a significant demister problem. |

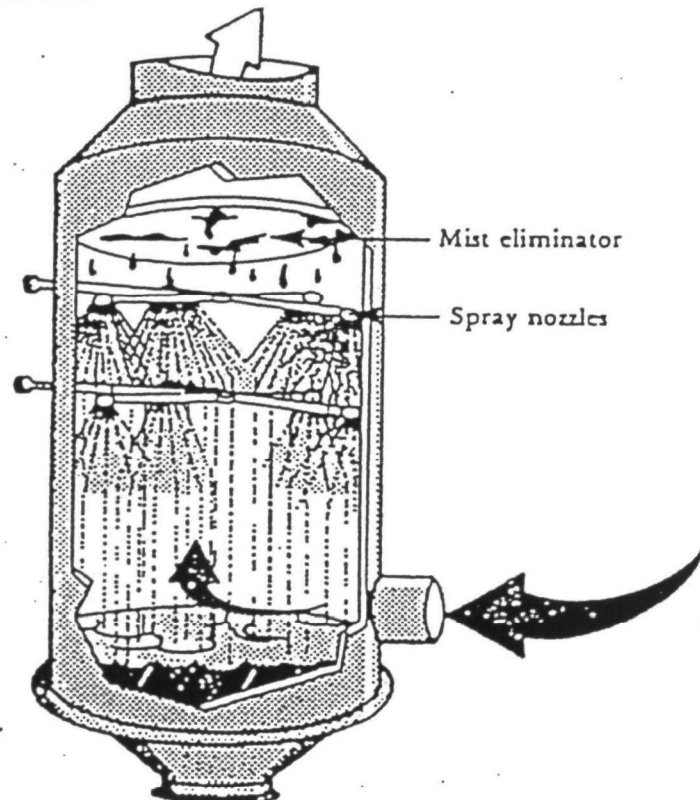


Figure 1-16. Contact condenser

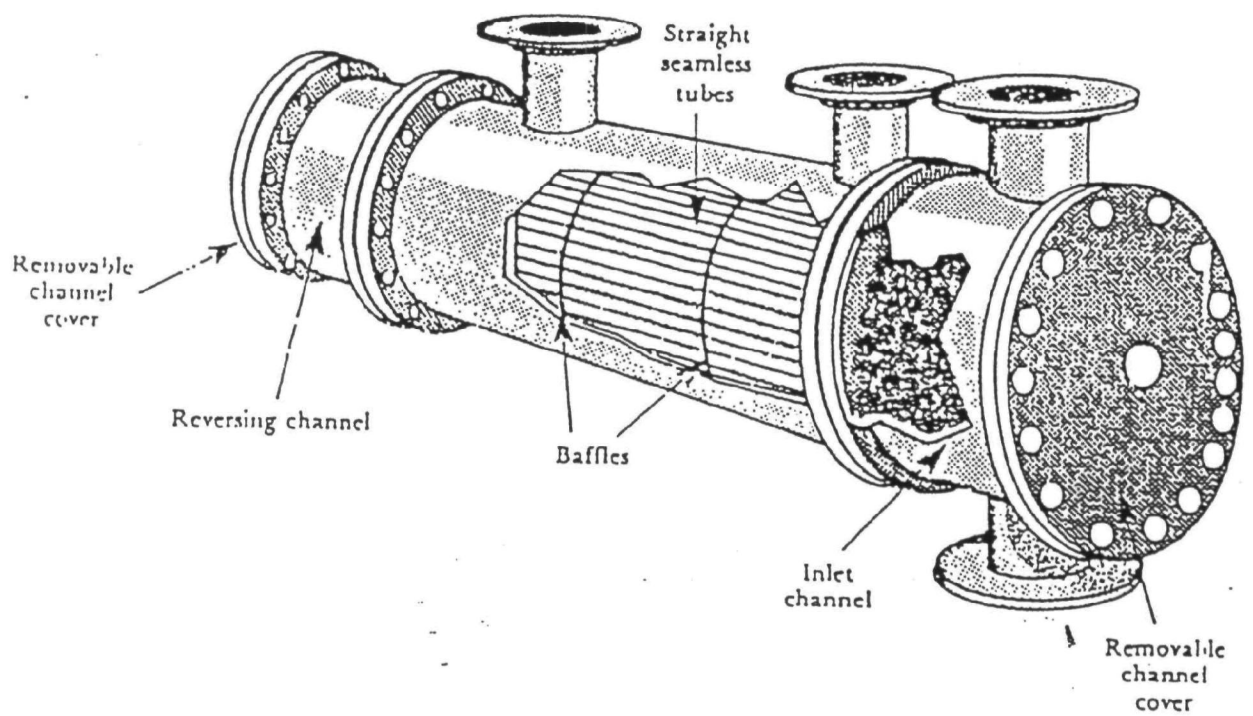


Figure 1-17. Surface condenser

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APPENDIX 1-A. SAFETY GUIDELINES

1. Do not do anything which you feel is dangerous. Do not ask plant personnel to do anything which either you or the plant personnel believe could be unsafe.
2. Interrupt the inspection immediately whenever you feel any of the symptoms of possible exposure to pollutants. These include, but are not limited to: headache, nausea, dizziness, drowsiness, loss of coordination, chest pains, shortness of breath, vomiting, and eye, nose, or throat irritation.
3. Conduct the inspection at a controlled pace. Do not hurry.
4. Avoid areas of possible risk during the inspection if the necessary personal protection equipment is not available.
5. Do not make internal inspections of air pollution or process equipment under any circumstance.
6. Do not wear contact lenses during the inspection unless specifically allowed by both agency and source safety personnel.
7. Avoid areas with potentially high pollutant concentrations which could exceed PEL levels and/or the capabilities of the available respirators. Such areas are common around positive-pressure equipment and areas with many process stacks and vents.
8. Use only intrinsically-safe portable instruments when inspection locations are classified as hazardous.
9. Exercise extreme caution when walking across roofs and elevated platforms. Weak spots are not always apparent. Walk behind plant personnel. Avoid roofs whenever possible.
10. Evaluate means for rapidly leaving elevated roofs or platforms in the event of sudden plume downwash or process fugitive emissions of high-temperature steam or toxic gases.
11. Do not smoke while conducting inspections.
12. Discard or wash contaminated work clothes separately from personal clothing.
13. Know the meaning of all plant warning sirens/codes and know the proper evacuation routes.

14. Avoid areas of dripping and/or splashing chemicals. Flush eyes for at least 15 minutes as soon as possible after contact. Get medical attention.
15. Remove all affected clothing and shower immediately for a period of at least 15 minutes if there is contact with chemicals. Get medical attention.
16. Exit areas around severely vibrating fans immediately. Notify plant personnel immediately of this condition.
17. Conduct plant inspections only in the company of a responsible plant representative.
18. Wear gloves whenever climbing ladders which are possibly hot, covered with small quantities of contaminants, or which have abrasive and/or sharp edges.
19. Do not climb unsafe ladders. Exercise care in climbing. Both hands must be free for holding the ladder. Grasping of the foot rungs rather than the side rails is normally recommended by industrial safety personnel.
20. Avoid all rotating equipment which is improperly shielded.
21. Use grounding and bonding cables when obtaining samples of flammable liquids. Comply with all regulations regarding flammable liquid sampling and shipping.
22. Stand clear when plant personnel are opening any hatches.
23. Ask plant personnel to obtain any samples needed.
24. Wear splash goggles whenever dripping chemicals are possible.
25. Comply with all plant and agency safety requirements.

APPENDIX 1-B. RECOMMENDED LIST OF INSPECTION EQUIPMENT

GENERAL EQUIPMENT

- Camera, film, and flash equipment
- Pocket calculator
- Tape measure
- Clipboard
- Waterproof pens, pencils and markers
- Locking briefcase
- Plain envelopes
- Polyethylene bags
- Wind meter or Admiral Beaufort wind scale
- Ruler (for use as scale in photos)
- Disposable towels or rags
- Flashlight and batteries
- Pocket knife
- Pocket tape recorder
- Level
- Range finder/optical tape measure
- Compass
- Stopwatch
- Square

SAFETY EQUIPMENT

- Safety glasses or goggles
- Face shield
- Coveralls, long-sleeved
- Hard hat
- Plastic shoe covers (disposable)
- Self-contained breathing apparatus
- Rubber-soled, metal toed, non-skid shoes
- Liquid-proof gloves (disposable if possible)
- Long rubber apron
- Respirators and cartridges

APPENDIX 1-B. (Continued)

PAPERWORK

- Proper identification
- Copy of facility's inspection file, permit, and monitoring schedule, including:
 - maps
 - photographs
 - enforcement actions
- Field data sheets
- Checklists
- Notebook
- Notice of inspection (if applicable)
- Chain of custody

EXHIBIT 1-C. BASELINE AIR POLLUTION QUIZ

1. True or false? The Baseline Inspection Technique involves detailed internal inspections of the control systems. 1. ____
2. True or false? Control systems designed by the same manufacturer and operated under similar conditions can be assumed to operate in a similar manner. 2. ____
3. If a canopy hood has a capture efficiency of 80 percent, the overall efficiency of the air pollution control system must be: 3. ____
 - a. less than 80 percent.
 - b. no greater than 80 percent.
 - c. unable to be calculated.
 - d. at least 75 percent.
4. If the fan is located after the air pollution control device, the static pressure plot should: 4. ____
 - a. show static pressure steadily becoming less negative with measurements taken closer to the fan.
 - b. remain essentially level.
 - c. reflect sharp changes in pressure depending on the direction of the ductwork.
 - d. become progressively more negative with measurements taken closer to the fan.
5. Bags in a reverse air unit are cleaned in the following manner: 5. ____
 - a. bag by bag.
 - b. row by row.
 - c. compartment by compartment.
6. True or false? Both very high and very low gas inlet temperatures can contribute to excess emissions and/or bag failure rates. 6. ____
7. In an ESP, ____ are used to control the strength of the electric field generated between the discharge and collection electrodes. 7. ____
 - a. rappers
 - b. transformers-rectifier sets
 - c. capacitors
 - d. adsorbers

8. Rappers are: 8. ____
- a. commonly used for removing dust from discharge and collection electrodes.
 - b. commonly used for removing dust from collection electrodes only.
 - c. a type of capacitor used to store discharge electrode voltage.
9. True or false? Increases in gas velocity result in more reentrainment of particles during rapping. 9. ____
10. Particle collection efficiency in a cyclone depends upon a number of factors including: 10. ____
- a. cyclone dimensions.
 - b. inlet gas velocity.
 - c. particle size.
 - d. dust concentration.
 - e. all of the above.
 - f. a, b, and c only.
11. Multi-cyclone collectors have a ____ static pressure drop than large-diameter cyclones. 11. ____
- a. higher
 - b. lower
12. Wet scrubbers are pollution control devices that use a liquid to remove ____ from an exhaust gas stream. 12. ____
- a. particles
 - b. pollutant gases
 - c. both a & b
 - d. none of the above
13. Symptoms of poor thermal incinerator burner performance include: 13. ____
- a. blue smoke generation.
 - b. higher than normal outlet temperatures.
 - c. lower-than-normal outlet temperatures.
 - d. lower-than-normal VOC outlet concentrations.
14. When complete combustion of a gas containing only organic compounds occurs, ____ are the products formed. 14. ____
- a. NO_x and SO_x
 - b. H_2O_2 and CO_2
 - c. NO_3 and H_2O
 - d. CO_2 and H_2O

CHAPTER 2

2.0 HAZARDOUS MATERIALS/HAZARDOUS WASTE INSPECTION PROCEDURES

2.1 INTRODUCTION

Purpose The primary purpose of this section is to provide procedural and technical guidance for performing inspections of those facilities which use hazardous materials or generate hazardous wastes. The procedures are general and are not intended to be prescriptive.

Inspector responsibilities Inspectors should be aware of all Federal, State, local, and international regulations a facility must meet in order to be in compliance. No matter what the reason for the inspection, it must be performed in a manner which is both technically and legally correct. Flaws in either the technical or legal conduct of an inspection may hamper, prevent, or invalidate the use of inspection results for enforcement purposes.

Two overriding criteria must guide the conduct of inspections to insure that inspections optimally fulfill their role in enforcement:

1. Technical accuracy and integrity

Inspections must be technically correct. Any measurements or other data collection and analysis must be thorough, technically proper, and appropriately documented.

2. Legal propriety

Legal requirements concerning the conduct of inspections must be scrupulously followed.

It is important for inspectors to know current enforcement priorities and develop the specific skills necessary to perform the inspections required under those priorities. They also need to be aware of changes in priorities and be flexible so such changes can be accommodated.

In accordance with contemporary program priorities, inspectors are frequently assigned to concentrate on inspections of a particular type of facility or waste management practice. As a result, inspectors will develop specialized skills in inspecting that type of facility or practice

through training, research and experience.

It is important, however, that inspectors also maintain a good general knowledge of the overall hazardous material/waste program so that they can respond to new enforcement priorities or changes in assignment which require them to inspect other types of facilities and practices. To maintain knowledge, inspectors should review:

- major new regulations as they are promulgated;
- new and existing guidance on inspecting other types of facilities and practices; and
- new and existing technical guidance that could provide quick background information on other types of facilities and practices.

2.2 INSPECTION PREPARATION

| | |
|-------------------|---|
| Purpose | Adequate preparation is critical to the effective performance of hazardous materials/waste inspections. Generally, inspectors will have only a relatively brief period of time on site in which to perform an inspection; therefore, it is important that the inspection be properly scoped and planned in order to use time on site as efficiently as possible and to insure that all aspects of the facility which should be evaluated are inspected. |
| Objectives | <p>When preparing for the inspection, inspectors should:</p> <ul style="list-style-type: none">• Determine the scope of objectives of the inspection.• Coordinate inspection activities with other regulatory or enforcement personnel as necessary.• Develop a thorough understanding of the technical, regulatory, and enforcement aspects of the facility.• Develop a plan or strategy for conducting the inspection consistent with inspection objectives.• Determine health and safety requirements and equipment needs. |

Activities the inspector should undertake to achieve these objectives are discussed in the following sections.

2.3 HEALTH AND SAFETY REQUIREMENTS

Planning the inspection

Although routine inspections generally do not involve activities in which inspectors must physically contact hazardous wastes (except inspections involving sampling, in which incidental contact with wastes may occur), there is always the potential for inspectors to be exposed to hazardous wastes or substances during the course of an inspection. Therefore, in planning the inspection, inspectors should:

- Determine the nature of the chemical hazards that may be encountered during the inspection (based on the types of materials handled on site, as identified in the file review).
- Identify and obtain proper safety equipment.
- Become familiar with the proper use of safety equipment (if not already familiar with its use), check equipment for proper function, and perform necessary maintenance on the equipment (if appropriate and within the technical abilities of the inspector).
- Obtain and become familiar with all applicable safety guidance and practices.
- Determine any facility-specific safety requirements by contacting the facility (only in cases where the facility is being notified of the inspection) or by review of previous inspection notebooks.

Special considerations

In some cases, the inspector will have limited information on the facility, or may be inspecting an uncontrolled site. The inspector should be prepared to encounter the worst conditions in such cases. **Inspectors should never proceed with inspections involving site conditions for which they are not prepared and do not have the proper safety equipment.**

2.4 INSPECTION EQUIPMENT

- Select equipment** The kind of equipment that the inspector takes into the field is dependent on the kind of inspection to be performed and the type of facility to be inspected. Inspectors should use their knowledge of the facility, understanding of inspection objectives, training, and experience to decide which equipment is necessary for a particular inspection. Inspectors may wish to consult with other inspection personnel or their supervisor in determining equipment requirements. Inspection requirements, the availability of certain equipment, and Regional or State policies and conditions should also be considered when selecting equipment during inspection planning.
- Appendix 2-A provides a list of equipment that is commonly used in performing inspections. Inspectors may not need all of the equipment listed for every inspection; however, inspectors may need additional equipment for some inspections. The list is divided into four categories of equipment: general equipment, safety equipment, sampling equipment, and paperwork.
- Ensure proper functioning** The inspector should identify and obtain the equipment necessary to perform the inspection from the appropriate source. The inspector should check inspection equipment to insure that it is in good working order prior to going into the field, and should perform, or have performed by the appropriate agency personnel, any needed maintenance or repairs. The inspector should also insure that he or she is familiar with the use of the equipment; generally, the use and operation of most of the standard inspection equipment listed is apparent.
- Consider additional equipment** Special circumstances may require the use of additional equipment such as fireproof clothing or self-contained breathing apparatus. The inspector should determine whether such additional equipment is necessary in conjunction with his or her supervisor, and, if appropriate, the facility's owner/operator or plant manager.

2.5 OPERATIONS, WASTE HANDLING, AND RECORD REVIEW

- Initial interview** The inspector should have the facility representative describe facility operations and waste management practices following the opening discussion. In general, the inspector should be familiar with the facility through previous review of the facility's file. Therefore, the

purpose of this discussion will be to:

- Obtain a more detailed understanding of operations.
- Answer any questions the inspector may have on waste generation, waste flow, and waste management activities.
- Identify any changes in operating and/or waste management practices.
- Identify and reconcile any discrepancies between the operations described by the facility representative and those described in the facility file.

During the discussion, the inspector should prepare waste information sheets on each waste managed at the facility.

Record review

After discussing facility operations and waste handling practices, inspections usually proceed to the record review. The record review provides the inspector with the opportunity to become thoroughly familiar with the facility (e.g., through review of the operating record) and formulate specific questions to be investigated during the visual inspection of the facility. However, the record review does not have to occur before the visual inspection. In some cases, inspection objectives may be best served if the visual inspection occurs before the record review. The visual inspection may be performed first for other reasons as well (e.g., availability of facility personnel or weather conditions).

The regulated community must address administrative requirements for manifests, recordkeeping, and reporting; and hazardous waste facilities must comply with technical requirements mandating plans for waste analysis, training, contingency procedures, groundwater monitoring, and closure.

2.6 GENERAL INSPECTION PROCEDURES

Follow inspection plan/strategy

In general, the visual inspection of the facility should proceed in accordance with an inspection plan or strategy developed by the inspector during inspection planning. This plan should lay out, in the level of detail considered appropriate by the inspector (which may vary according to individual preferences), the operations the inspector intends to inspect and the tentative order in which the inspection will proceed. The inspector may, however, determine that it is appropriate

to modify the plan based upon information obtained during the record review or other factors, such as the availability of specific personnel for interviewing or the scheduled operations of waste management units to be inspected. Inspectors should be flexible in changing their planned approach to suit conditions encountered at the facility. Step-by-step procedures for visually inspecting a facility will vary according to the type of facility and the objectives of the inspection.

When planning and performing the visual inspection, it is generally desirable that the inspection proceed in a way which allows the inspector to evaluate and understand the waste flow within the facility and to determine the compliance status of each segment of the facility's waste management system. For example, in a plant which generates hazardous waste, stores waste for off-site disposal, and treats some waste on-site, the inspection could proceed as follows, in brief:

Maintain control

Inspectors should not allow facility representatives to hurry the inspection, direct the route of the inspection, or prevent them from asking pertinent questions of facility personnel. Inspectors should ask relevant questions of both the facility representative guiding them through the facility and of other personnel. Questioning diverse personnel may identify inconsistencies in explanations of procedures or operations that could indicate possible non-complying conditions that should be further investigated, and can also give the inspector an indication of the adequacy of the personnel training program. Answers to questions and observations that are not reported on checklists should be recorded in a field log or notebook.

Remain oriented

Inspectors should be careful to remain oriented during the tour of the facility so that they can accurately note locations of waste management areas, possible releases, potential sampling locations, etc. At larger facilities, inspectors should carry a map or plot plan in order to note locations and maintain their orientation.

2.7 INSPECTION CHECKLISTS

Pre-inspection activities

As previously discussed, the inspector should complete as much of the applicable checklist(s) as possible in the facility office, generally during the record review, prior to visually inspecting the facility (unless the objectives of the inspection or other reasons dictate that the visual inspection occur before the record review). The inspector should leave blank those sections of the checklist(s) which cannot be answered without visual inspection.

| | |
|------------------------------|--|
| Inspection activities | During the visual inspection, the inspector should complete these sections. However, completing these sections is not the sole purpose of the visual inspection, and it is critical that the inspector not limit the visual inspection to only completing the checklist. Inspectors should be aware of, and investigate, all relevant waste generation and management activities throughout the facility, and be alert to what is happening around them as they tour the facility. If inspectors conduct visual inspections in ways which allow them to understand how wastes are generated, transported, and managed at the facility (as previously discussed), they should be able to complete the applicable checklists easily during the inspection. |
|------------------------------|--|

2.8 WASTE SAMPLING

| | |
|------------------------------------|--|
| Reasons for sampling | Sampling is generally conducted to verify the identity of a waste or to identify potential releases of hazardous wastes or constituents to the environment. |
| Inspection planning | If sampling is to be conducted during an inspection, the need to sample will be determined or made known to the inspector during inspection planning. The inspector should refer to sampling manuals during inspection planning to obtain information on preparing sampling plans, taking samples, preserving samples, splitting samples with the owner/operator, and completing chain-of-custody requirements. |
| On-site activities | In most cases, sampling will not be performed during routine inspections. However, the inspector should be aware of, and identify, potential sampling requirements that may need to be fulfilled in future inspections, particularly in cases where the inspector has identified potentially non-complying conditions or criminal activity during the course of the inspection. In these cases, it is possible that case development inspections will be performed at the facility, and it is helpful when planning these inspections to have the results of previous inspections in which potential sampling locations and needs have been identified based on observed conditions at the facility. |
| Reasons for future sampling | <p>There are many possible conditions or activities which may lead the inspector to determine that future sampling will probably be necessary. Examples of some of these conditions include situations in which:</p> <ul style="list-style-type: none"> • The owner/operator is handling a potentially hazardous waste as a non-hazardous waste. |

(Sampling may be required to verify that the waste is hazardous or non-hazardous.)

- In-plant waste handling practices indicate that mislabeling/misidentification of waste is likely to occur, or that wastes may vary significantly in characteristic over time and be mismanaged as a result.

(Sampling may be required to demonstrate that the facility is mislabeling or misidentifying wastes.)

- There is visible or other observable evidence of possible releases of hazardous wastes from waste management units, satellite storage areas, waste generating areas, etc.

(Sampling media and wastes may be required to demonstrate that a release has occurred or is occurring.)

- Wastes may be being managed improperly, i.e., in an inappropriate treatment or disposal unit.

(Sampling may be required to verify that the correct wastes are being managed in the facility's various waste management units.)

**Useful information
for future
inspections**

Whenever such condition/activities are encountered, the inspector should identify the media or wastes to be sampled, the physical locations to sample (e.g., the location of a possible release), the steps within a treatment process to sample, the physical characteristics of the medium to be sampled (e.g., sludge, granular solid), and other relevant information that would be helpful in developing a sampling plan for a future inspection.

2.9 DOCUMENTATION

**General
information**

Documentation refers to all printed and mechanical media produced, copied or taken by the inspector to provide evidence of suspected violations. It is strongly recommended that the inspector record information collected during the inspection in only the following types of records: field notebooks, checklists, photographs, maps, and drawings. Recording information on other loose papers is discouraged; loose papers may be easily misplaced and the information on them discredited during hearings. Proper documentation and document control are crucial to the enforcement

system, as the Government's case in a formal hearing or criminal prosecution often hinges on the evidence gathered by the inspector. Therefore, it is imperative that each inspector keep detailed records of inspections, investigations, photocopies, photographs taken, etc., and thoroughly review all notes before leaving the site.

Document control The purpose of document control is to assure the accountability of all documents for the specific inspection when that inspection is completed. Accountable documents include items such as logbooks, field data records, correspondence, sample tags, graphs, chain-of-custody records, bench cards, analytical records, and photos. To ensure proper document control, each document should bear a serialized number and should be listed, with the number, in a project document inventory assembled upon completion of the inspection. Water-proof ink should be used to record all data on serialized, accountable documents.

2.10 FIELD NOTEBOOK

In keeping field notes, it is strongly recommended that each inspector maintain a legible daily diary or field notebook containing accurate and inclusive documentation of all inspection activities, conversations, and observations. Field notes should include any comments, as well as a record of actual or potential future sampling points, photograph points, and areas of potential violation. The diary or field notebook should contain only facts and observations because it will form the basis for later written reports and may be used as documentary evidence in civil or criminal hearings. Notebooks used for recording field notes should be bound and have consecutively numbered pages. **A separate notebook should be used for each facility inspected.**

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APPENDIX 2-A. HAZARDOUS MATERIALS/HAZARDOUS WASTE SAMPLING EQUIPMENT

- Bucket auger
- Bucket
- Containers
 - jars
 - plastic (for metals)
 - organic sample containers
- Bailers
- Pumps
- Rope
- Glass tubes
- Ice
- Scoops
- Trowels
- Tape
 - labeling
 - duct
 - electrical
- Conductivity meter
- Thermometer
- Dissolved oxygen meter
- Steel tape measure
- Sampling safety equipment (in addition to Appendix 1-B items)
 - Tyvek suit
 - booties
 - gloves
 - harnesses
 - chemical-resistant suit
 - Organic Vapor Analyzer (OVA)
- Decontamination equipment
 - buckets
 - Alconox
 - brushes
 - grate
 - deionized water
 - solvents for equipment cleaning
 - steam cleaning machine
 - plastic bags

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APPENDIX 2-B. GENERAL SITE INSPECTION INFORMATION FORM

A. Site Name

B. Street (or other identifier)

C. City

D. State

E. Site Operator Information

1. Name

2. Telephone Number

3. Street

4. City

5. State

F. Site Description

G. Type of Ownership

1. Federal___

2. State___

3. Municipal___

4. Private___

H. Site classification

1. Generator___ 2. Transporter___ 3. Treatment___ 4. Storage___ 5. Disposal___

I. Inspector information

1. Principal Inspector

2. Organization

3. Title

4. Telephone No.

J. Inspection Participants

1.

6.

2.

7.

3.

8.

4.

9.

5.

10.

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APPENDIX 2-C. WASTE INFORMATION WORKSHEET

(To be filled out for each facility waste)

1. Waste Name: _____

2. Process generating the waste: _____

3. Waste classification

Hazardous _____ (Waste code: _____)

Non-Hazardous _____

4. How has the facility made this determination?

Testing _____

Process knowledge _____

5. Are any test results available?

Yes _____ (if so, look at)

No _____

6. Waste generation rate: _____

7. Disposal procedure:

Current _____

Past _____

8. Have manifests been used for off-site shipment?

Yes _____ (if so, look at)

No _____

9. Is waste subject to land disposal restrictions? Yes _____ No _____

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APPENDIX 2-D. CONTAINERS CHECKLIST

A. USE AND MANAGEMENT

1. Are containers in good condition? Yes ___ No ___

B. COMPATIBILITY OF WASTE WITH CONTAINER

1. Is container made of a material that will not react with the waste which it stores? Yes ___ No ___

C. MANAGEMENT OF CONTAINERS

1. Is container always closed while holding hazardous waste? Yes ___ No ___
2. Is container handled so that it will not be opened, handled, or stored in a manner which may rupture it or cause it to leak? Yes ___ No ___

D. INSPECTIONS

1. Does owner/operator inspect containers at least weekly for leaks and deterioration? Yes ___ No ___

E. CONTAINMENT

1. Do container storage areas have a containment system? Yes ___ No ___

F. IGNITABLE AND REACTIVE WASTE

1. Are containers holding ignitable and reactive waste located at least 15m (50 ft) from facility property lines? Yes ___ No ___

APPENDIX 2-D. (Cont.)

G. INCOMPATIBLE WASTE

1. Are incompatible wastes or materials placed in the same containers? Yes ____ No ____
2. Are hazardous wastes placed in washed, clean containers which previously held incompatible waste? Yes ____ No ____
3. Are incompatible hazardous wastes separated from each other by a berm, dike, wall, or other device? Yes ____ No ____

H. CONTINGENCY PLAN AND EMERGENCY PROCEDURES

1. Is a contingency plan maintained at the facility? Yes ____ No ____
If yes, does contingency plan include:
 - a. arrangements with local emergency response organizations? Yes ____ No ____
 - b. emergency coordinators' name, phone numbers, and addresses? Yes ____ No ____
 - c. list of all emergency equipment at facility and description of equipment? Yes ____ No ____
 - d. evacuation plan for facility personnel? Yes ____ No ____
2. Is there an emergency coordinator on site or on call at all times? Yes ____ No ____

APPENDIX 2-E. WASTE PILES CHECKLIST

A. DESIGN AND OPERATING REQUIREMENTS

1. Is the pile containing hazardous waste protected from wind? Yes ___ No ___
2. Does waste pile have a liner and leachate collection system? Yes ___ No ___
3. Is run-on diverted around active portion? Yes ___ No ___
4. Is runoff collected and controlled? Yes ___ No ___
5. Are collection and holding facilities emptied after storms? Yes ___ No ___

B. WASTE ANALYSIS

1. Is a representative sample of waste from each incoming shipment analyzed before the waste is added to the pile to determine the compatibility of the wastes? Yes ___ No ___
2. Does the analysis include a visual comparison of color or texture? Yes ___ No ___

C. CONTAINMENT

1. Is the leachate or runoff from the pile considered a hazardous waste? Yes ___ No ___

If yes, is the pile managed with the following:

- a. an impermeable base compatible with the waste? Yes ___ No ___
- b. run-on diversion? Yes ___ No ___
- c. leachate and runoff collection? Yes ___ No ___
- d. periodic emptying of collection and holding facilities? Yes ___ No ___

OR

- e. protection from precipitation and run-on by some other means? Yes ___ No ___

APPENDIX 2-E (Cont.)

D. MONITORING AND INSPECTION

1. Are liners and covers inspected for damage during construction? Yes ___ No ___
2. Are waste piles inspected weekly for deterioration, run-on and runoff controls, wind dispersal control, and proper function of leachate collection system? Yes ___ No ___

E. IGNITABLE OR REACTIVE WASTES

1. Are ignitable or reactive wastes placed in the pile? Yes ___ No ___

If yes,

- a. Does the addition of the waste result in the waste or mixture no longer meeting the definition? Yes ___ No ___

(Use narrative explanation sheet to describe procedure)

OR

- b. Is the waste protected from sources of ignition or reaction? Yes ___ No ___
 1. If yes, use narrative explanation sheet to describe separation and confinement procedures.
 2. If no, use narrative explanation sheet to describe sources of ignition or reaction.

F. INCOMPATIBLE WASTES

1. Are incompatible waste placed together in the pile? Yes ___ No ___
2. Are incompatible waste separated from each other by a dike, berm, or wall? Yes ___ No ___
3. Is there evidence of fire, explosion, gaseous emissions, leaching, or other discharge? (Use narrative explanation sheet.) Yes ___ No ___

**INTRODUCTION TO
POLLUTION PREVENTION**

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CHAPTER 1

1.0 INTRODUCTION TO POLLUTION PREVENTION

Pollution Prevention is generally defined as any in-plant process that reduces, avoids, or eliminates the use of toxic materials and/or the generation of pollutants and wastes so as to reduce risks to human health and the environment and to preserve natural resources through greater efficiency and conservation. The goal of pollution prevention is to minimize environmental risks by reducing or eliminating the source of risk (rather than reactively through treatment and disposal of wastes generated).

There are significant opportunities for industry to reduce or prevent pollution at the source through cost-effective changes in production, operation, and raw materials use. The opportunities for source reduction are not often realized because existing environmental regulations, and the industrial resources they require for compliance focus upon treatment and disposal, rather than source reduction. Source reduction is different and more desirable than waste management and pollution control.

A logical waste management hierarchy would be based on the principal that pollution should be prevented or reduced at the source wherever feasible, while pollutants that cannot be prevented should be recycled in an environmentally safe manner. In the absence of feasible prevention or recycling opportunities, pollution should be treated. Disposal or other release into the environment should be used as a last resort. This hierarchy is described in more detail in the next section.

1.1 WASTE MANAGEMENT HIERARCHY

In this section, a waste management hierarchy was developed as an approach to prioritize pollution control methods. This hierarchy assesses four types of pollution control methods based on their effectiveness in reducing the risks to human health and the environment from pollution.

Source Reduction

The most desirable option of the hierarchy and the most effective way to reduce risk is through source reduction. Source reduction is defined as any method that reduces or eliminates the source of pollution entirely. This includes any practice that:

- Reduces the amount of hazardous substances, pollutants, or contaminants entering a waste stream or otherwise released into the environment prior to recycling, treatment, or disposal; and
- Reduces hazards to public health and the environment associated with the release of such substances, pollutants, or contaminants.

The term source reduction includes equipment or technology modifications, process or procedure modifications, reformulation or redesign of products, substitution of raw materials, and improvements in housekeeping, maintenance, training, or inventory control. It is important to note that the term source reduction does not include any practice which alters the physical, chemical, or biological characteristics, or the volume of a hazardous substance, pollutant, or contaminant through a process or activity which itself is integral to, and necessary for, the production of a product or the provision of a service.

Recycling

Where pollution cannot be prevented through source reduction methods, the wastes contributing to the pollution should be recycled. Recycling is the use, reuse, or reclamation of waste after it has been generated (e.g., recycling spent solvents).

Treatment

Wastes that cannot be feasibly reduced at the source or recycled should be minimized through treatment in accordance with environmental standards and regulations that are designed to reduce both the hazard and volume of waste streams (e.g., adsorption of organic vapors onto activated carbon).

Disposal

Finally, any residues remaining from the treatment of waste should be disposed of safely to minimize their potential for release into the environment. Disposal involves the transfer of a pollutant to the environment in either air, solid waste, or water (e.g., landfilling metal scrap wastes).

Pollution control techniques include all four choices in the hierarchy. Pollution prevention techniques include only source reduction or closed-loop recycling, the first two choices in the hierarchy. Implementation of pollution prevention methods is the best way to reduce or control pollution considering their potential environmental and economic advantages which include:

- Energy and resources conservation;
- Raw material losses reduction;
- Treatment and disposal cost reductions;
- Reduction of long-term liabilities associated with environmental waste or cleanup;

- Improved worker health and safety; and
- Reduced regulatory requirements.

The waste management hierarchy establishes a set of guidelines to follow rather than a fixed set of rules. Practices such as treatment and proper disposal can be protective of the environment when performed properly. Industries can be expected to balance the costs and benefits when evaluating pollution control strategies. Specific factors which must be evaluated will be discussed in detail in a later section.

Many countries that are adopting pollution prevention as a national environmental program rely on voluntary efforts by industries and government to implement pollution prevention methods. These voluntary efforts have been quite successful due to several factors including the increasing costs of treating wastes, the increasing costs of transferring wastes to landfills, treatment plants, and hazardous waste management facilities; financial liabilities; and public pressure. These non-regulatory incentives are causing industries to realize the economic and environmental benefits gained from adopting pollution prevention control methods.

1.2 SOURCE CONTROL METHODS

Source control (pollution prevention) techniques can be grouped in numerous ways (as evidenced in the many manuals and guides prepared by EPA and other U.S. agencies). For this presentation, the techniques are grouped into the following eight classifications:

1. Process Changes
2. Material Substitution
3. Material Inventory and Storage
4. Waste segregation
5. Good housekeeping/Preventive Maintenance/Employee Education
6. Product changes
7. Water and energy conservation
8. Recycling/waste exchange

Process Changes

Process changes consist of changing one or more processes used by the facility, or changing the equipment used in the process(es). The changes can result in both reduced volume and/or toxicity of the waste generated. Process changes may not necessarily be extensive or costly to implement.

Some examples of potentially simple and inexpensive process changes which are considered pollution prevention techniques include:

- Reducing drag-out (transfer) of pollutants from process solutions by slowing withdrawal speed of metal parts and allowing sufficient drainage time over process tanks (or over drip tanks). These procedures, along with other drag-out reduction techniques can reduce the waste of expensive chemicals, the quantity of pollutants in rinse waters, the toxicity of waste waters, and the quantity of sludge generated.
- Adjusting production schedules or dedicating process equipment to reduce the quantity of cleanup wastes generated (e.g., use of dedicated tanks in the paint formulating industry to eliminate intermediate washing).
- Use of still rinse techniques to reduce the volume of waste water generated in electroplating processes. Still rinses are static (no inflow or outflow) and are used to rinse metal parts after plating processes. When constituent concentrations become unacceptably high within the rinse tank, rinse waters may be used to replenish the upstream plating bath. Evaporative equipment may be used to concentrate rinse waters prior to replenishing the plating baths.

Material Substitution

Changes in the raw materials used in a process can result in pollutant source reduction by reducing or eliminating the hazardous materials that enter the production process. Examples of pollution prevention using material substitution techniques include:

- Substituting organic polyelectrolytes in place of traditional coagulation and flocculation agents (e.g., lime, alum) to reduce quantities of sludge generated;
- Substituting alkaline cleaners or citric acid cleaners for organic solvents; and
- Replacing environmentally hazardous hexavalent chromium electroplating solutions with trivalent chromium.

Material Inventory and Storage

Proper material inventory and storage refers to the purchasing, tracking, storage, and handling of hazardous materials. There are two facets of material inventory and storage:

- Using good inventory and tracking procedures of hazardous materials help minimize overstocking and contamination and reduces the need to dispose of expired or contaminated materials.

These procedures should ensure that raw materials are purchased only when needed and in appropriate quantities. Expiration dates of materials should be tracked and a "first-in, first-out" (FIFO) policy (older materials used first) should be adopted.

- Developing procedures and obtaining appropriate equipment to prevent and respond to all potential sludge discharges including spills, leaks, bypasses, and upsets (e.g., utilizing secondary containment around tanks and containers of hazardous materials and process equipment to prevent discharge of hazardous materials and to reduce the quantity of waste generated from cleanup of spills or leaks).

Waste Segregation

Segregation of different types of wastes can be a simple and effective pollution prevention technique applicable to a wide variety of waste streams and industries. By segregating wastes at the source of generation and by handling hazardous and non-hazardous wastes separately, waste volume and management costs may be reduced. Additionally, uncontaminated or undiluted wastes may be reusable in the production process or may be sent off-site for recovery. Practices for segregating wastes include the following:

- Isolating hazardous waste from nonhazardous waste. Blending such waste makes all the waste hazardous and increases treatment or disposal costs.
- Segregating different types of solvents, particularly halogenated solvents from non-halogenated solvents, and aromatic solvent from aliphatic solvents. Solvents are harder to recycle and reuse.
- Avoiding contamination of wastes with water. Solvents and oils that are contaminated with water are harder to recycle and reuse. In addition, wastes and waste water that are mixed with large amounts of storm water require additional treatment steps and costs.

**Good
Housekeeping/Pre-
ventive Main-
tenance/Employee
Education**

These procedures are generally simple and inexpensive to implement and effectively reduce pollution at its' sources.

Good Housekeeping

Some examples of such procedures include:

- Reducing dripping and splashing from parts being dipped in process and rinse tanks. This prevents this waste water from entering drains to the sewer or waste water treatment system.
- Maintaining adequate distances between different chemicals to prevent cross contamination; and
- Keeping containers closed except when material is being removed.
- Providing funnels and other transfer equipment to reduce loss of material during transfer.

***Preventive
Maintenance***

Preventive maintenance reduces malfunctions and leaks and can also reduce the quantity of waste generated. Preventive maintenance consists of regular inspection, cleaning, testing, and lubrication of process, storage, handling, monitoring and treatment equipment. A master preventive maintenance file which documents all maintenance work should be kept. Also, any parts that are worn or broken should be replaced before a problem occurs (e.g., regular replacement of seals and gaskets to prevent leaks from pumps, joints, valves, etc.).

Employee Education

Employee education may be the most basic pollution prevention technique and yet it is often overlooked. Pollution prevention education should be an integral part of the training normally given to employees when they begin a job and during regular refresher training. Two of the most important aspects of training include:

- Educating employees to know and understand the company's pollution prevention goals. It is important for employees to know and understand the benefits of reducing hazardous materials being handled and generated. To accomplish this task, many companies establish a facility-wide training program to educate employees on pollution prevention techniques used by the facility.
- Ensuring that all employees know and practice proper and efficient use of tools and supplies. This is especially important for cleaning operations.

Product Changes

Product changes that are considered pollution prevention techniques

include any changes in the composition or use of an intermediate or end product which results in reducing waste from the manufacture, use, or ultimate disposal of the product. A life-cycle assessment of a product can be used as an objective tool to identify and evaluate opportunities to reduce the environmental impacts associated with its manufacture, use, or disposal. The three components of the assessment include:

- Inventory analysis—Identification and quantifying of energy and resource use and waste emissions;
- Impact Analysis—Assessment of the consequences those wastes have on the environment; and
- Improvement Analysis—Evaluation and implementation of opportunities to effect environmental improvements.

Water and Energy Conservation

Water and energy conservation should be considered as part of an overall pollution prevention strategy. Benefits to reducing water and energy use include reduced waste water generation and associated treatment/disposal costs and reduced pollution associated with producing potable water and the generation of energy. Examples of water and energy conservation techniques include:

- Employing timed automatic shutoff valves on equipment using water such as rinses on a metal finishing line. This technique is relatively inexpensive, but can result in substantial decreases in water use and waste water generated.
- Recirculating cooling waters through a cooling tower. Water used in cooling heavy machines, quenching hot metals, molding and forming processes, etc. should be recirculated to significantly reduce water use.
- Utilizing heat exchangers on high temperature discharges to heat incoming water. This practice is employed at many industrial laundries (including those at hospitals), chemical manufacturing, and power generating facilities.

Recycling/Waste Exchange

Recycling can be used where further source reduction techniques cannot be implemented. Recycling involves the use of a waste as an effective substitute for a commercial product or as a raw material in the manufacture of a product.

On-site Recycling

Recycling the waste on-site by returning the waste back to the process or another process (e.g., the use of waste acids and bases for pH adjustment in waste water treatment systems or the use of a small On-site still to purify degreasing solvents for subsequent reuse).

***Off-site Recycling/
Reclamation***

Recycling waste off-site by sending it to a recovery/reclamation facility for processing (e.g., sending metal-bearing sludges from industrial waste water treatment processes to Off-site reclamation facilities).

Waste Exchange

Advertising the sale or the availability of wastes through a private- or government-funded organization. Waste exchanges can help bring together generators of waste with companies that can use the waste in their production process.

1.3 IMPLEMENTATION OF POLLUTION PREVENTION TECHNIQUES

When industries are deciding whether to implement pollution prevention techniques in their facilities, several items must be examined.

First, it must be determined if the pollution prevention technique will result in cross medium transfer of pollutants. It is important to avoid transfer of pollutants from one media to another. The three types of media are air, land, and water. Most treatment or disposal methods transfer pollutants from one media to another. For example, wastewater treatment that uses coagulation and sedimentation to remove metals generates a sludge which is usually disposed in landfills. In this case, the metal pollutants are transferred from the waste water to the sludge placed in the landfill. Another example is the use of air stripping to remove volatile organic compounds (VOCs). In this case, the volatile organic compounds are removed from the waste water and released to the air.

Pollution prevention strategies can substantially decrease pollutant loads to the environment without transferring pollutants from one medium to another. An example includes substituting powder paints for water-based and solvent-based paints for example, eliminates cleanup wastes and emissions of VOCs.

A second consideration is worker health and safety. For example, the substitution of a coagulant chemical which generates less sludge in a pretreatment system may be more hazardous to workers handling it.

Finally, any pollution control technique utilized must comply with all applicable Federal, State and local laws and regulations. Some pollution prevention strategies may require obtaining a permit or license or making a special notification to the appropriate regulatory agency.

1.4 SELECTED POLLUTION PREVENTION CASE STUDIES

The United States Environmental Protection Agency has established a voluntary pollution prevention program initiative called, the 33/50 Program. The program derives its name from its overall goals--an interim goal of 33% in 1992 and an ultimate goal of a 50% reduction by 1995 in releases and transfers of 17 high-priority toxic chemicals, using 1988 Toxic Release Inventory (TRI) reporting as a baseline. During 1988, 1.48 billion pounds of the target chemicals were either released to the environment on-site or transferred off-site to waste management facilities. The aim of the 33/50 Program is to reduce this amount by at least 50%-743 million pounds-by 1995, with an interim reduction target of more than 490 million pounds by 1992.

The Program is part of a broad group of EPA activities designed to encourage pollution prevention as the best means of achieving reductions in toxic chemical emissions. More than 16,000 facilities have reported 33/50 Program chemicals to the Agency since 1988. By contacting the chief executives of the parent companies of TRI facilities that report 33/50 Program chemicals, the Program seeks to instill a pollution prevention ethic throughout the highest echelons of American businesses.

In an effort to recognize companies making significant progress in reducing chemical releases and transfers, Company Profiles have been developed to provide detailed information about the reduction efforts companies have undertaken. The following case summaries represent 14 companies, of the more than 1200 companies participating in the Program, that have added to the success of the 33/50 Program.

PRINTED CIRCUIT BOARDS

HADCO Corporation is a manufacturer of custom printed circuit boards and backplanes for use in electronic components. Approximately 60% of the boards produced are used in computers, and an additional 30% are used in telecommunications equipment. The remaining 10% find end uses in various types of instrumentation, principally in medical devices and the automotive industry. HADCO is headquartered in Salem, New Hampshire, and operates six facilities.

From July, 1989 through August, 1990 the company implemented a \$1.7 million process conversion and emission control project at its Derry facility. The project's goals were to eliminate use or minimize air emissions of chemicals used in the facility's manufacturing operations.

The cornerstone of the project was implementation of new aqueous-based chemicals in the cleaning and dry film processes. The dry film process was modified to include carbonate based developers instead of 1,1,1-trichloroethane, and hydroxide solutions instead of dichloromethane. A screen cleaning use of dichloromethane was also replaced with an aqueous cleaning solution at the Owego, NH facility.

HADCO's conversion project has resulted in the following source reduction of chemicals:

- Significant reduction in dichloromethane through conversion of six of the eight dry film and cleaning processes to water based chemistry;
- Elimination of 1,1,1-trichloroethane through conversion of the cleaning and dry film processes to water based chemistry; and,
- Elimination of methyl ethyl ketone as an additive to dichloromethane in cleaning (its only use at the facility).

Certain circuit board processes could not be replaced with this new water-based technology, however, because of user specifications. To reduce emissions of these chemicals, HADCO also installed a dual-bed activated carbon adsorption recovery system at its Derry, NH facility, which reduced remaining emissions of the three solvents by over 99%.

As an alternative to a recovery system, HADCO replaced both 1,1,1-trichloroethane and dichloromethane with a terpene solvent at its Owego, NH facility.

The recovery system was installed to further reduce air emissions. However, HADCO's process conversion and emission control program achieved significantly greater reductions than required by New Hampshire Air Toxics Regulations (adopted April, 1990). HADCO's state permit for dichloromethane allows emissions of no more than one pound per hour; however, the company estimates that its emissions level has been reduced to 0.3 pounds per hour. In addition, the State law did not require control of methyl ethyl ketone or 1,1,1-trichloroethane at the Derry site. Thus, HADCO has reduced air emissions by more than 270,000 pounds over the state requirements.

HADCO's efforts in pollution prevention and solvent recovery allowed the company to achieve its goals two years ahead of schedule. Company-wide releases and transfers of its' major solvents chemicals decreased 95% between 1988 and 1992, reflecting a reduction of almost 2.2 million pounds. In addition, according to company officials, the company achieved additional reductions in 1993 that have brought its total reductions to 99.5%.

STEEL PRODUCTS

Acme Metals Incorporated, based in Riverdale, Illinois, is the parent company of an integrated steelmaker and three steel fabricating subsidiaries. Although interrelated, each subsidiary is responsible for its own environmental programs.

Acme Steel Company, an integrated producer of steel products, operates coke and ironmaking facilities in Chicago, IL and a steelmaking plant in Riverdale, IL. Acme Packaging Corporation, a manufacturer of steel strapping tools, operates facilities located in Riverdale, IL, Leeds, AL, New Britain, CT, and Pittsburg, CA. These two subsidiaries are responsible for virtually all releases and transfers of selected chemicals and are the focus of this profile.

Acme Metals Incorporated reduced annual releases and transfers of selected chemicals by more than 833,000 pounds by 1992 from 1988 levels.

Acme achieved an 89% reduction in releases and transfers of these chemicals from 1988 to 1992, surpassing its pledged reduction of 70% by 1995.

Since 1988, Acme has implemented several programs aimed at further reducing releases and transfers of these chemicals. Acme has completed the following projects at its Chicago Coke plant:

- **Replace cooling system.** Acme replaced its contact gas cooling system with a non-contact, wet surface air cooler in the coke byproducts recovery process. The replacement of the cooling system resulted in reductions of releases of approximately 143,000 pounds of benzene, 276,000 pounds of cyanide, 28,000 pounds of toluene, and 6,000 pounds of xylene, as well as 1,450,000 pounds of ammonia, and 10,000 pounds of naphthalene.
- **Install emission collector headers.** Acme installed emission collector headers to remove volatile chemicals, such as benzene, toluene, and xylene, from the headspaces of process units and storage tanks. This process uses steam moving under negative pressure to sweep the volatile chemicals into the byproduct recovery system. Emission collector headers were installed at the light oil storage tank, the wash oil decanter, and the wash oil circulation tank and resulted in a 14,000 pound reduction in releases of benzene, as well as smaller reductions of toluene and xylene.

In addition, at Acme Packaging's Riverdale facility, spent lead dross from the steel strapping production process is now sent to an off-site recycler. Previously, the lead was landfilled. The increased recycling of lead resulted in a reduction of approximately 333,000 pounds of releases and transfers of lead. Small components of lead are still landfilled as a component of nonhazardous sludge generated from pollution control activities.

Acme reduced releases and transfers of other selected chemicals by nearly 2,600,000 pounds (75 %) between 1988 and 1992.

HEALTH CARE PRODUCTS

Johnson & Johnson is the world's largest health care company, with over 80,000 employees and manufacturing and sales locations in more than 50 countries. The company manufactures toiletries and baby care products, medical supplies, and pharmaceutical products.

To reduce releases and transfers of selected chemicals, Johnson & Johnson has undertaken several projects at its various facilities:

- Eliminating the use of methyl ethyl ketone, methyl isobutyl ketone, and xylene at the Consumer Products plant in North Brunswick, NJ. These chemicals were used in the manufacturing process for the company's Band-Aid™ Brand adhesive bandages. Vinyl extrusion and the use of a water-based emulsion has been substituted in the manufacturing process, resulting in a decrease of over 380,000 pounds in releases and transfers of these three solvents between 1988 and 1992.
- Equipment and procedure changes in several processes at the Noramco facility in Wilmington, DE, resulting in a combined reduction in releases and transfers of dichloromethane and toluene of over 131,000 pounds between 1988 and 1992. These changes by Noramco include: using dichloromethane and toluene as the seal fluid in liquid ring vacuum pumps, instead of water, thereby reducing wastewater transfers; implementing a leak detection and repair program to reduce fugitive emissions; and eliminating one product recovery step, further reducing dichloromethane transfers in wastewater. This facility has achieved reductions of 52% in releases and transfers of all these chemicals between 1988 and 1992.
- Material substitution at Ethicon plants in Somerville, NJ and San Angelo, TX, as well as the Advanced Materials facility in Gainesville, GA and the Vistakon plant in Jacksonville, FL, resulting in a decrease of over 66,500 pounds (73%) in releases and transfers of 1,1,1-trichloroethane between 1988 and 1992. A biodegradable cleaner was substituted for 1,1,1-trichloroethane.

As a result of Johnson & Johnson's pollution reduction efforts, releases and transfers of selected chemicals decreased 63% (469,981 pounds) between 1988 and 1992. The largest reductions were for xylene and methyl ethyl ketone, which decreased by 93% and 80% respectively. These reductions were due principally to the conversion of the adhesive carrier to aqueous emulsion in the Band-Aid™ manufacturing process.

Releases and transfers of 1,1,1-trichloroethane also fell by 74% (66,580 pounds), in conjunction with the company's goal of eliminating the use of this chemical and other ozone depleting substances.

Johnson & Johnson has stated that participation in a Pollution Prevention (P2) program has helped significantly in formulating reduction initiatives and in obtaining corporate support for their implementation. The requirement of reporting releases and transfers of hazardous chemicals to EPA initially made the company aware of the extent of its emissions and off-site transfers. The company began to develop strategies for reducing releases and transfers of hazardous chemicals as figures were first compiled company-wide. The P2 focus on a distinct set of chemicals then helped Johnson & Johnson to develop and choose among specific source reduction projects for these targeted chemicals.

METAL AND PLASTIC HARDWARE

Aladdin Industries Inc. is a manufacturer of metal and plastic hardware for consumer and industrial use. Located in Nashville Tennessee, Aladdin produces a wide variety of products such as lunch kits, thermos bottles, hospital trays, coffee cups, lamps, and coolers.

Although Aladdin is a relatively small generator of toxic chemical emissions, the company has stated that, as a corporate citizen, it feels an obligation to reduce *any* emissions generated. Aladdin's ultimate objective is to eliminate the emissions of toxic chemicals completely, primarily through source reduction methods. However, in cases where source reduction is not possible, Aladdin is looking to other means of reducing emissions such as treatment and recycling.

In order to meet its goals, Aladdin designed in-house projects focusing on each of the chemicals to be eliminated, controlled, or replaced. For each of these projects, one staff member was appointed project leader and had primary responsibility for ensuring the project's completion. For each project, a goal, target implementation date, base year, and method for completion were articulated.

To date, Aladdin has completed the following projects:

- All trichloroethylene usage was eliminated during 1993. Trichloroethylene was required to remove petroleum oils from metal parts during metal forming processes. Synthetic lubricants are now used in place of petroleum oils and are removed from parts with an aqueous alkaline cleaner. The water from the alkaline cleaning process is treated on-site.
- Dichloromethane use was completely eliminated from the facility as of 1993 by replacing the polystyrene used in trays with polypropylene. Previously, the polystyrene trays were cut from a sheet and blemishes around the edges were removed using dichloromethane. Since the polypropylene trays are now injection molded, there are no blemishes to remove.
- Toluene and methyl isobutyl ketone were completely eliminated from the Aladdin facility as of 1993 by replacing a thinner containing toluene and methyl isobutyl ketone with a thinner containing 25% toluene and 75% 1,1,1-trichloroethane. This thinner was later replaced with a thinner containing acetone in place of the toluene. The company is currently investigating options to eliminate the 1,1,1-trichloroethane from this formulation.
- Aladdin eliminated all releases and transfers of chromium, along with phosphoric acid and sulfuric acid -- as of 1992. Using a newly installed on-site waste treatment facility, Aladdin removes toxic materials from a water mixture containing chromium, phosphoric acid, and sulfuric acid. Fifty percent of the water is recycled, while the remainder is of sufficient quality to discharge to the sanitary sewer. The sludge is of sufficient quality to be considered nonhazardous and is disposed of in a landfill. Prior to the installation of the on-site treatment facility, all of these wastes were transferred off-site for treatment or disposal.
- Aladdin eliminated its lacquer painting process by switching to a dry powder coating, thereby eliminating the use of lead, xylenes, and ketones. Small quantities of lead, xylenes, and ketones were previously used at Aladdin in its painting process for thermos bottles.

RUBBER-COATED FABRICS

Aldan Rubber Company is a manufacturer of rubber-coated fabrics that are used in a wide variety of applications, including protective clothing for fire fighting, flexible duct connectors, convertible tops, and baby products. Aldan is located in Philadelphia, Pennsylvania.

Aldan conducted a survey to identify areas in the manufacturing process where significant emissions were taking place. This allowed the company to focus reduction efforts on the largest emission sources. The survey followed the "solvent trail" through the entire manufacturing process, from unloading of solvent from tank trucks to post-manufacture disposal of rubber scrap. After completing the facility survey and evaluating the results, Aldan identified five major activities that would significantly reduce chemical emissions:

- **Totally enclose the rubber spreader.** In its 1976 project, Aldan installed a hood to capture solvent emissions over part of its spreader. The captured solvent was then routed to a recovery unit. Aldan recently enclosed the entire spreader so that all solvent emissions are captured and recycled, rather than just those under the partial hood.
- **Renovate the solvent recovery system.** In order to improve the efficiency of its solvent recovery system, Aldan renovated the system put in place in 1976. As part of the renovation, the recovery unit received a complete overhaul, including replacement of the carbon recovery media, cooling coils, and old seals and valves. Aldan reported the solvent recovery unit's efficiency at 98% - 99% after the renovation, an increase of approximately 20% from the previous efficiency level.
- **Use an alternative cleaner for machinery clean-up.** Aldan traditionally used toluene in a hand-wipe application to clean its equipment on a periodic basis. This cleaning removes excess rubber, dirt, and other contaminants from production machinery. To eliminate this use of toluene, Aldan now uses a d-limonene cleaner in a similar hand-wipe application, with reduced but satisfactory performance, and somewhat higher but still acceptable cost.
- **Institute an employee awareness program.** Aldan recognized that a significant quantity of solvent emissions could be eliminated simply by improving the handling of process materials. An employee awareness program, mandatory for all employees who handle solvents, was implemented to achieve this goal. During the program, Aldan explained to workers the environmental problems associated with the solvent emissions and made suggestions for reducing emissions. Company officials believe that the employee awareness program has been a great success.
- **Improve management of rubber scrap.** Aldan developed a proprietary process by which it is able to reduce solvent emissions from rubber scrap. This process is one in which the scrap is processed to remove excess solvent prior to scrap disposal. Aldan has found that, not only does the process reduce emissions of solvent to the air, but it also renders the rubber scrap nonhazardous. The scrap can then be disposed of in a municipal landfill.

As a result of the efforts described above, by 1992 Aldan Rubber had reduced releases and transfers of selected chemicals by 73% from the 1988 baseline, almost reaching its goal of an 80% reduction. Reductions for toluene alone accounted for more than 1,000,000 pounds.

SPECIALTY FENCING PRODUCTS

Anchor Fence, Inc. is a manufacturer of high quality chain link fencing systems, gates, and specialty fencing products. The company has one facility located in Baltimore, MD, employing approximately 85 workers.

The company has undertaken the following activities to reduce releases of selected chemicals:

- Releases of methyl ethyl ketone have been reduced 93% (113,000 pounds) through substitution of water based formulations of primers for pipes and fittings. This action accounts for all of the observed decrease in releases of this chemical. In addition, all solvent based paint applications are being strictly monitored to determine which can be converted to water based products in the future.
- Improvements in the operation of the company's waste water treatment system have resulted in a 50% reduction in releases of lead, nickel, and zinc compounds between 1988 and 1992. These improvements consist primarily of adjusting the pH of the system to increase efficiency of metals removal.
- Eliminating the use of dichloromethane at the plant by shifting the PVC stripping process for off-quality products to an off-site cleaning company that uses a hot salt bath PVC removal process. This change resulted in cost savings for the company.
- Examination of solvent based cleaning processes using toluene and methyl ethyl ketone to determine where solvent evaporation can be reduced. The company intends to install a water-cooled component cleaning tank to further reduce releases of the solvents.

By 1992, Anchor Fence had reduced release of these chemicals by 87% from 1988 levels. Virtually all of this reduction was a result of substitution of methyl ethyl ketone-based primers with a water-based formulation.

STAINLESS STEEL

Carpenter Technology Corporation manufactures stainless steel and other specialty metals for a variety of industries including aerospace, nuclear, and electronics. The company is headquartered in Reading, Pennsylvania and has four facilities that report emissions.

Its two largest facilities are in Reading, Pennsylvania and Orangeburg, South Carolina. The former produces a variety of bar wire and strip metal products while the latter produces fine wire. In addition, a small plant in Fryeburg, Maine and a plant in El Cajon, California also make metal products.

In 1988, as a first step in identifying source reduction opportunities, Carpenter set up a team dedicated to continuous environmental improvements. This team consisted of key staff from engineering, production, and research and development. The team identified several types of projects including solvent substitution, reduction in solvent emissions through process modifications, increased recycling of metal-bearing waste streams, and changes in operator procedures to reduce the amount of acid used for metal descaling.

Specific changes implemented by Carpenter to reduce solvent emissions include:

- Substituting mineral spirits (petroleum-based solvents) for trichloroethane for cleaning certain types of metal parts.
- Eliminating non-cleaning uses of 1,1,1-trichloroethane (e.g., as a lubricant).
- Improving vapor degreaser process control to minimize the amount of solvent needed to clean metal components, and reducing by 50% the number of vapor degreasers used.
- Improving process control to minimize the amount of waste acid generated and eliminate the need for sending acid bath wastes off-site for treatment.

Two additional changes resulted in the elimination of all releases of metals (1,608,250 pounds of chromium and nickel) to land and a significant reduction in the amount of metals transferred off-site for treatment:

- Improving sludge drying operations and recycling rolling mill sludges, resulting in a 400% increase in the amount of metal oxides that can be recycled. These wastes were previously transferred off-site for treatment.
- Adding chemical inhibitors to acid bath solutions to reduce the amount of dissolved metals being transferred to the acid waste streams.

In addition, for economic reasons, the company consolidated its operations in 1989 by closing the Bridgeport plant while maintaining similar company-wide production levels through operation of four other plants. Through this action, Carpenter was able to achieve a 35% reduction in releases and transfers of selected chemicals.

SHOES

Dexter Shoe Company is a manufacturer of shoes for men, women, and children. The company is headquartered in Dexter, Maine and has four facilities in Maine: two in Dexter, one in Skowhegan, and one in Milo.

Both the Headquarters and Skowhegan facilities are using a three-tiered approach to meet its reduction goals: reduction in chemical use, substitution with less hazardous chemicals, and solvent recovery.

The Skowhegan facility has had particular success in substitution and solvent recovery. The facility reports the following activities:

- Replacing two solvent-based waterproofing agents with aqueous-based products. These new products are more expensive than their solvent predecessors, but provide better coverage using less product.
- Replacing methyl ethyl ketone as a cleaning solvent with heptane. Because heptane still poses some risk, however, the company is continuing to investigate other alternatives.
- Employing solvent recovery for cleaning solvents, such as methyl ethyl ketone and heptane. Dexter uses solvent recovery both for reuse of individual solvents and for generalized recovery of mixed cleaning solvents. Some of the solvent recovery is done within the process for which the chemicals are used and, thus, can be considered source reduction.

A similar progress report from Dexter's Headquarters facility describes the following individual reduction accomplishments:

- Substituting solvents and cleaners containing methyl ethyl ketone, methylene chloride, and toluene with water-based products.
- Replacing a filler product containing 40% acetone with a cut insert material bonded to the upper part of the shoe with a hot melt adhesive.
- Installing a solvent recovery system for reuse of cleaning solvents.

Emissions of all reported chemicals at the company's two participating facilities have already decreased 47% from 1988 to 1992 through elimination of 209,471 pounds of emissions:

AUTOMOBILE AND TRUCK COMPONENTS (SEAT AND TRIM)

Douglas & Lomason Company is a manufacturer of automobile and truck components, primarily seat and trim parts. The company is headquartered in Farmington Hills, Michigan and operates 16 manufacturing facilities located in Alabama, Arkansas, California, Georgia, Iowa, Maryland, Mississippi, Missouri, Nebraska, Tennessee, and Texas.

To meet its reduction goals, Douglas & Lomason has undertaken a number of source reduction activities, primarily product and process reformulation. The company has completed projects to reduce chemical use in both the molding and painting processes.

- **Implementing a new mold-release agent formulation.** The Havre-de-Grace, MD, facility manufactures foam seat pads using a molding process. This process involves applying a wax mold-release agent to the mold to facilitate the removal of the finished molded product. Douglas & Lomason's traditional mold-release agent, which contained 1,1,1-trichloroethane as a solvent, was replaced with a water-based formulation. This substitution completely eliminated the use of 1,1,1-trichloroethane, a reduction of 350,000 pounds.
- **Using "high-solids" paint formulations.** At one facility, Douglas & Lomason manufactures metal trim parts which are painted. The amount of solvent, such as toluene, xylene, and methyl ethyl ketone, used in these paints was reduced through the use of reformulated "high-solids" paint. "High-solids" paint uses a reduced percentage of solvent in formulating the paint, thereby increasing the percentage of solids. This approach resulted in achieving reductions at the Phenix City, AL, facility.
- **Using water-based paint.** At several facilities, Douglas & Lomason manufactures metal seat frames which are painted for rust protection. The use of solvents in the paint has been eliminated by using water-reducible paints, in which the solvents (in this case toluene and xylene) are replaced with ethylene glycol. This approach was used at the Columbus, NE, facility, contributing to reductions of 86,454 pounds of toluene and xylene releases between 1988 and 1992.
- **Eliminating the use of paints.** Solvent use has also been reduced or eliminated through the implementation of two new processes that eliminate the need to paint certain parts. First, the spray-application of rust inhibitors has eliminated the need for painting, thereby reducing and in some cases eliminating the use of solvents. A second process implemented by Douglas & Lomason involves the chemical application of a coating to metal parts using a process that requires no solvents. The Red Oak, IA, facility used this process to eliminate releases and transfers of 61,000 pounds of toluene and xylene.

As a result of these and other efforts, Douglas & Lomason has made outstanding progress in reducing its releases and transfers of selected chemicals, including surpassing its 1995 reduction goal several years early. Douglas & Lomason succeeded in reducing its releases and transfers by 88% between 1988 and 1992, a reduction of 525,285 pounds. This reduction in releases and transfers was achieved despite an increase in production between 1988 and 1989.

As part of Douglas & Lomason's efforts, the Havre-de-Grace, MD, Red Oak, IA, and Columbus, NE facilities have completely eliminated their use of selected air toxic and other chemicals. The company as a whole has completely eliminated the use of 1,1,1-trichloroethane.

SPECIALTY CHEMICALS AND METALS

Olin Corporation is a Fortune 200 company, headquartered in Stamford, CT, with 29 facilities nationwide in 15 states. The company manufactures a wide variety of products, including specialty chemicals, metals, and other materials, as well as products for the defense, aerospace and sporting ammunition industries. Examples of significant projects at Olin facilities that have successfully reduced the emissions of these chemicals to the environment include:

Olin Corp., Rochester, NY. Olin's Rochester facility produces over 60 different types of specialty chemicals – relatively low volume products tailored to the specific needs of individual customers, including biocides (zinc or sodium pyrithione), aniline dyes, and pharmaceutical ingredients. In 1988, the facility reported air emissions of 11,540 pounds of carbon tetrachloride, which is used as a non-reactive diluent. In order to recover carbon tetrachloride from air vents, the plant installed a scrubber and additional process vent collection equipment, and now reuses the reclaimed material in several of the facility's production processes. 1992 air emissions of carbon tetrachloride were reduced to 3,437 pounds at this facility, a reduction of 70%. This facility is also investigating the substitution of carbon tetrachloride and other chemicals with non-toxic raw materials.

Olin Ordnance, Red Lion, PA. The Red Lion facility produces various munitions for the military. In 1988, this facility reported air emissions of 122,535 pounds of 1,1,1-trichloroethane. This chemical is used as a multi-purpose cleaner and degreaser. The Red Lion facility took a number of steps to reduce the use of this chemical, including: restricting access and requiring employees to justify their use of the material; identifying material substitution options for products not required to use the chemical (e.g., by military procurement specifications); and modifying the chiller on a solvent degreaser to enhance vapor capture. As a result of these efforts, air emissions of 1,1,1-trichloroethane were reduced to 21,700 pounds in 1992, a reduction of over 80% from 1988 levels. The facility is currently investigating two additional actions to further reduce the use of 1,1,1-trichloroethane: installing a parts washer which will use water-based cleaners instead of chlorinated solvents, or altering the overall production process to completely eliminate the cleaning process.

Bridgeport Brass Co., Indianapolis, IN. In 1988 this facility reported air emissions of 37,000 pounds of 1,1,1-trichloroethane and dichloromethane, which were used as degreasers. By 1990, the facility had completely eliminated its use of these two chlorinated solvents by switching to the use of water-based soaps and hot water rinsing in its metal processing and maintenance operations.

Main Plant Facility, East Alton, IL. Olin's East Alton Main Plant facility used to landfill large quantities of lead wastes (off-site disposal of 815,853 pounds in 1988), primarily from bullets test-fired into sand traps at the Winchester sporting ammunition plant. The facility used to screen as much lead as possible out of the sand for reuse in their own production processes, and landfill the remaining lead-contaminated sand off-site. The facility began selling unscreened material to a battery manufacturer, and more recently began selling it to a lead smelter. The sand/lead mixture is used directly as a recycled raw material in the smelting process. The landfilling of lead wastes has thus been dramatically reduced to 39,673 pounds in 1992, for an overall reduction of 95%.

Between 1988 and 1992, Olin reduced its releases and transfers of selected chemicals by 67%, a reduction of 1,367,614 pounds. Much of this reduction was the result of eliminating or capturing 473,114 pounds of air emissions from solvents. In addition, Olin reduced off-site chemical disposal 876,904 pounds between 1988 and 1992, including shifting 776,180 pounds of lead from off-site disposal in a landfill to off-site recycling – an action that represents a move up the pollution prevention hierarchy.

MOTION CONTROL PRODUCTS

Parker Hannifin Corporation manufactures a broad array of motion control products for industrial and aerospace applications. The company is headquartered in Cleveland, OH and employs nearly 26,000 individuals worldwide at 143 manufacturing plants and 87 administrative and sales offices, company stores, and warehouses. Parker's Industrial segment, which accounts for 75% of the company's sales, is comprised of five groups: Fluid Connectors, Motion & Control, Automotive & Refrigeration, Seal, and Filtration. The company's Aerospace segment is a single group with several divisions that account for the remaining 25% of Parker's sales.

To reduce releases and transfers of selected chemicals at its facilities in the United States, the company undertook the following activities between 1988 and 1992:

- Eliminated 756,000 pounds of releases and transfers of dichloromethane, tetrachloroethylene, 1,1,1-trichloroethane, and trichlorethylene by switching to aqueous cleaning systems for degreasing operations. Because the aqueous cleaning process requires agitation of the parts, part of the conversion involved redesigning the racks used to hold parts during cleaning to accommodate agitation.
- Eliminated 453,000 pounds of releases and transfers of methyl ethyl ketone and toluene by substituting water-based solutions for solvent solutions used to carry cements in the manufacture of rubber hoses. This substitution required the addition of a drying step because of the relatively slow evaporation rate of water.
- Eliminated 109,000 pounds of releases and transfers of carbon tetrachloride, methyl isobutyl ketone, and xylene by substituting water-based adhesives and paints for solvent-based adhesives and paints.
- Eliminated 30,000 pounds of releases and transfers of chromium and chromium compounds used in coloring processes that are part of the metal finishing operations. This reduction was achieved through waste minimization techniques such as counter-current rinsing, reduced drag-out rates, and improved quality control.
- Reduced releases and transfers of cadmium and cadmium compounds by 15,000 pounds by substituting zinc plating for all of the cadmium plating process carried out in metal finishing operations. Cyanide releases and transfers associated with the cadmium plating operations have increased. This increase is due to the fact that the company switched approximately 50% of its cyanide treatment from on-site to off-site. (Waste treated on-site is reported only for quantities not destroyed or removed, while the full quantity treated off-site is reported as a transfer). Parker estimates, however, that releases and transfers of cyanide will be eliminated by 1994 when the conversion to zinc plating will be complete at all of its facilities.

In addition to these activities, Parker is working with steel suppliers to minimize emissions of metals during machining operations by developing raw material steel with a low or zero lead content. This effort is currently in the development stage, but promising results are expected in the future. In the meantime, Parker achieved reductions in metal emissions through improved scrap recovery and control methods. However, because these reductions are relatively small, they are not measured by the company and therefore cannot be quantified.

As a result of Parker's pollution prevention efforts, releases and transfers of selected chemicals decreased by more than 1,350,000 pounds between 1988 and 1992. This reduction of 71% exceeds the company's Program goal of a 50% reduction more than three years ahead of schedule.

PRINTED CIRCUIT BOARDS

Printed Circuit Corporation, located in Woburn, Massachusetts, is a manufacturer of printed circuit boards. The company provides its products to companies in the electronics, instrumentation, telecommunication, and automotive industries.

In order to meet its program goals, Printed Circuit adopted a two-step approach. First, the company focused its efforts on eliminating all use of dichloromethane in its operations. To accomplish this goal, the company implemented a process that uses a water-based cleaner to strip away excess polymer from the etched circuit boards. In addition, Printed Circuit switched all solvent cleaning operations to 1,1,1-trichloroethane. These changes eliminated all use of dichloromethane at Printed Circuit by the end of 1991. As a result of the process change, the company also was able to minimize its use of methanol.

Although the switch to 1,1,1-trichloroethane for all solvent cleaning operations caused releases of the chemical to increase between 1990 and 1991, Printed Circuit showed an overall reduction in releases of selected chemicals between the two years. The company believed that by focusing its efforts on one chemical at a time, it would be able to make more rapid progress toward reducing emissions than if it were addressing several chemicals simultaneously.

To eliminate the use of 1,1,1-trichloroethane, the company undertook an evaluation of potential replacements. Printed Circuit worked with six vendors nationwide over a two-year period to identify replacements that would:

- be compatible with other chemicals and materials used in production;
- comply with environmental standards; and
- be economically feasible.

As a result of the study, the company has replaced its use of 1,1,1-trichloroethane as a developing agent with a water-based sodium carbonate solution. In addition, Printed Circuit now uses a mild detergent with water for the final cleaning of completed circuit boards, in place of dichloromethane and 1,1,1-trichloroethane.

As a result of these efforts, Printed Circuit Corporation reduced total releases of selected chemicals by 87% from 1988 to 1991 after the elimination of dichloromethane. Furthermore, the company completely eliminated releases of all 17 selected chemicals by 1993 after the elimination of 1,1,1-trichloroethane, far surpassing its goals.

AIRCRAFT, RESIDENTIAL AND COMMERCIAL APPLIANCES

Raytheon Company is a diversified organization whose major interests include manufacturing of aircraft, residential and commercial appliances (including refrigeration, cooking, and laundry equipment), electronics (including guidance systems, guided missiles, printed circuit boards, and communications equipment), and energy/environmental services (including power, transportation, logistics support, and road building equipment). Raytheon is headquartered in Lexington, Massachusetts and had twenty five facilities in the United States that reported releases and transfers of chemicals in 1988.

Raytheon's reductions of selected chemicals were achieved as a result of several on-going projects.

- Eliminate or reduce solvents in cleaning operations. Dichloromethane, 1,1,1-trichloroethane, tetrachloroethylene, trichloroethylene, and CFC-113 were all targeted by Raytheon's ODS and suspected carcinogen phaseout goals. In 1988, these solvents were used at 18 facilities for electronics cleaning and metal degreasing, and as general solvent cleaners.

Terpene-based cleaners and mildly alkaline aqueous solutions were identified as alternatives to these solvent cleaners. Raytheon has successfully eliminated its use of dichloromethane, tetrachloroethylene, and CFC-113, and has significantly reduced its use of 1,1,1-trichloroethane and trichloroethylene as a result of the development of these alternate cleaners.

- Eliminate the use of dichloromethane for paint stripping applications. At the Wichita facility, dichloromethane was used to strip paint from aircraft. Raytheon implemented a dry media (wheat starch) blasting system for paint stripping that completely eliminated the need for dichloromethane at this facility.
- Reduce 33/50 Program chemicals in painting and soldering applications. Lead, chromium, toluene, and xylene are used at Raytheon facilities in painting and soldering operations. Raytheon has identified and implemented a powder paint system in some facilities which has resulted in a reduction of releases and transfers of these chemicals. For applications in which powder painting is not technically feasible, Raytheon is working with its coating suppliers to reduce the amount of solvent used in its coatings.

As a result of these and other efforts, Raytheon's releases and transfers of selected chemicals decreased over 2.5 million pounds between 1988 and 1992 — a 65% reduction from 3,883,820 pounds to 1,360,658 pounds. The major components of this reduction were the elimination of dichloromethane and tetrachloroethylene, and the significant reduction of releases and transfers of 1,1,1-trichloroethane and trichloroethylene.

The phaseout of the use of dichloromethane and tetrachloroethylene resulted in a reduction of 706,701 pounds of releases and transfers of these chemicals between 1988 and 1992. These reductions account for approximately 28% of total reductions of releases and transfers of these chemicals during that period. The replacement of 1,1,1-trichloroethane and trichloroethylene resulted in a reduction of 1,354,654 pounds of releases and transfers of these chemicals. This reduction accounts for approximately 54% of total reductions from 1988 to 1992.

INTEGRATED STEEL

U.S. Steel is a large, integrated steel manufacturer and also includes several smaller diversified businesses. USX Corporation also is involved in the oil and natural gas businesses through its Marathon Oil Group and Delhi Group. U.S. Steel has its headquarters in Pittsburgh, Pennsylvania, and operates six wholly-owned plants which report releases and transfers of chemicals. In addition, U.S. Steel is involved in several joint ventures including USS/POSCO Industries and USS/Kobe Steel.

Four of U.S. Steel's six facilities are in Pennsylvania: The Clairton Works (Clairton), and the Edgar Thomson (Braddock), Irvin (West Mifflin), and Fairless (Forest Hills) plants on the Mon Valley Works. The other plants are the Gary (Indiana) Works and the Fairfield (Birmingham, Alabama) Works.

U.S. Steel expected to achieve its reductions through material reuse/recycling, process modifications, and product changes. Based on its reported 1988 emissions data, the company's goal translates into an overall reduction of 2,250,952 pounds in total releases and transfers.

U.S. Steel achieved significant reductions in releases and transfers of selected Program chemicals through source reduction and recycling initiatives at several of its facilities. Examples of specific changes implemented by the company include:

- **Installation of inert gas blanketing systems.** These systems use nitrogen to confine air emissions of volatile toxic chemicals such as benzene, cyanide, toluene, and xylene. By maintaining a layer of inert gas over an open tank or container, toxic chemical vapors are unable to escape from the tank. U.S. Steel has installed blanketing systems on product and by-product storage tanks and decanters at both its Gary and Clairton plants.
- **Implementation of dust pelletizing process.** In the Steel making operations, pollution control dusts containing iron units and various metallic compounds are produced. Under normal circumstances, these dusts are landfilled. Because of the recoverable iron units in the dusts, the Edgar Thomson plant, U.S. Steel Mon Valley Operations has implemented a pelletizing operation. The pellets are recycled back into the steel making operations.
- **Modification of coke quenching process.** After the coke is removed from the Coke ovens, it must be cooled rapidly. Previously, the Clairton Works used contaminated water to quench the coke. Use of contaminated water, however, resulted in releases of 33/50 Program chemicals such as benzene and toluene. The facility switched to clean quench water 100% of the time, thus eliminating the releases of benzene and toluene from the quenching operations. The contaminated water is currently treated at the facility's waste water treatment plant where contaminants are removed to permitted levels.

As a result of these and a variety of other projects and initiatives, U.S. Steel has surpassed its goal of a 30% reduction in releases and transfers by 1992. The company successfully reduced its overall releases and transfers of selected chemicals by 6,582,277 pounds, amounting to a reduction of 88% from 1988 levels. In addition, although not an explicit part of U.S. Steel's goals, the company reduced annual releases and transfers of other selected chemicals by almost 14 million pounds from 20,148,876 pounds for a reduction of 69% since 1988.

Overall, U.S. Steel has reduced its annual releases and transfers of all chemicals by a remarkable 20,508,069 pounds since 1988. This represents a 74% reduction in all releases and transfers.

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INDUSTRIAL PROCESSES

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PETROCHEMICAL INDUSTRY

The petrochemical industry is a large and complex source category that is very difficult to define because its operations are "intertwined functionally or physically with the inorganic sector of the chemical industry, with downstream (manufacturing), fabrication or compounding activities, or with the petroleum refining industry. (This results in) mixing of vertical operating steps in official statistics". Petrochemical industries are involved in the production of several chemicals which fit into one or more of the following four categories:

1. Basic raw materials
2. Key intermediates
3. Minor intermediates
4. End products

The petrochemical industry also includes the treatment of hydrocarbon streams from the petroleum refining industry and natural gas liquids from the oil and gas production industry.

Some of the raw materials used in the petrochemical industry include petroleum, natural gas, ethane, hydrocarbons, naphtha, heavy fractions, kerosene, and gas-oil. Natural gas and petroleum are the main feedstocks for the petrochemical industry. That is why about 65 percent of petrochemical facilities are located at or near refineries.

The petrochemical industry produces solvents and chemicals of various grades or specifications which are used to produce industrial organic chemicals, including benzene, the butylenes, cresols and cresylic acids, ethylene, naphthalene, paraffins, propylene, toluene, and xylenes. Approximately 2500 organic chemical products are produced directly or indirectly from basic petrochemicals. The industrial organic chemicals produced from petrochemicals are employed in downstream industries including plastics and resins, synthetic fibers, elastomers, plasticizers, explosives, surface active agents, dyes, surface coatings, pharmaceuticals, and pesticides.

A. PROCESS DESCRIPTION

A process converts a raw material into products, by-products, intermediate products, or waste streams. The main processes conducted in the basic petrochemicals industry are separation and purification. Some chemical conversion processes such as cracking, hydrogenation, isomerization, and disproportionation are also carried out. Six groups of related processes, termed operations, are employed by the petrochemical industry:

1. Olefins production
2. Butadiene production
3. BTX production
4. Naphthalene production
5. Production of cresols and cresylic acids
6. Separation of normal paraffins

Each operation employs several varied process lines and procedures. The production of 1,3-butadiene will be used as an example of the types of processes used in the petrochemical industry.

1,3-butadiene is a high-volume, intermediate organic chemical used commercially to produce various types of rubber, resin, and plastics. 1,3-butadiene is involved in several different reactions, including addition, oxidation, and substitution reactions; however, its main use is for polymerization.

Producers of 1,3-butadiene typically generate the feedstock at the same location as the 1,3-butadiene production. Most 1,3-butadiene is used in synthetic elastomer production, and some is used in adiponitrile production, the raw material for nylon 6,6 production. The overall demand of 1,3-butadiene is expected to increase due to the growth of specialty uses for 1,3-butadiene.

1,3-butadiene is produced by one of two processes:

- (1) Recovery from a mixed hydrocarbon stream, and
- (2) Oxidative dehydrogenation of n-butenes.

1,3-butadiene production through recovery is by far the most common approach. In this process, a mixed hydrocarbon stream containing butadiene, coproduced in an olefins plant during cracking of large-molecule hydrocarbons to manufacture ethylene or other alkenes (Exhibit 1), is routed to a recovery unit where the butadiene is separated.

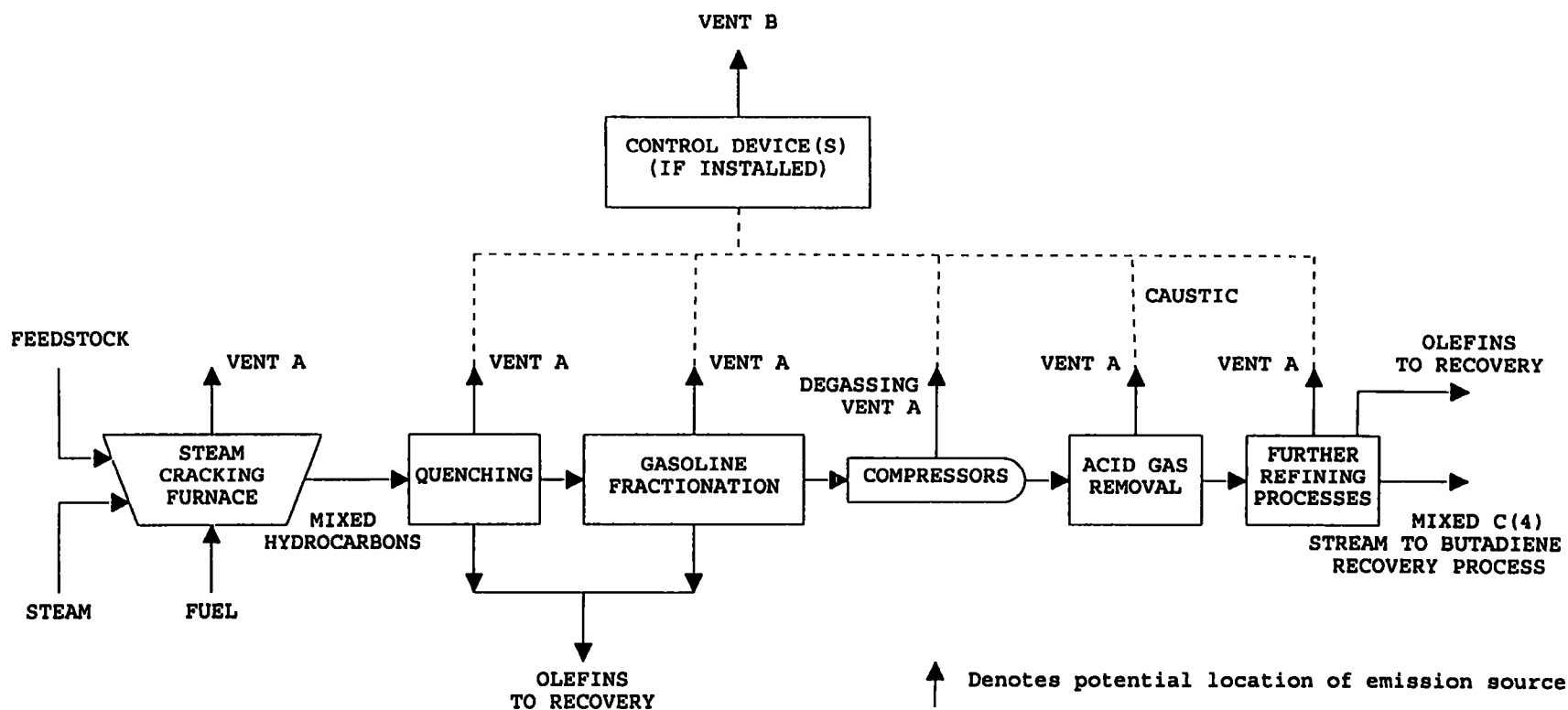
In an olefins plant a steam cracking furnace is used to crack the hydrocarbon feedstock. The heavy hydrocarbons are broken into two or more fragments, forming a stream of mixed hydrocarbons. The concentration of butadiene in this mixed hydrocarbon stream varies with the type of feedstock. The flue gas from the cracking furnace is vented to the atmosphere.

After the cracking step, the mixed hydrocarbon stream is cooled and, if naphtha or gas oils were the initial feedstock, the stream is sent to a gasoline fractionator. The fractionator is used to recover heavy hydrocarbons (C_5 and higher). For some olefins units the quenching step shown occurs after gasoline fractionation. The mixed stream is then compressed prior to removal of acid gas (hydrogen sulfide) and carbon monoxide. Acid removal usually involves a caustic wash step. The mixed hydrocarbon stream then goes through additional refining steps, where it is separated from olefins (C_3 and lower).

The mixed C_4 stream may be sent directly to butadiene recovery at the same plant. Olefins plants that do not produce finished butadiene use the by-product mixed C_4 streams in the following ways: (1) recover the crude butadiene from the stream and sell it to a butadiene producer, (2) recirculate the stream into the front of the ethylene process, and/or (3) use the stream to fuel the equipment (e.g., furnaces) in the ethylene process.

The second part of this butadiene production process involves recovering the butadiene from the mixed C_4 stream. The mixed C_4 stream is fed from pressurized storage tanks into a hydrogen reactor along with hydrogen to convert some of the unsaturated hydrocarbons such as acetylene to olefins. The product C_4 stream from the hydrogenator is combined with a

EXHIBIT 1:
Process Diagram for Production of a Mixed C(4) Stream Containing Butadiene



↑ Denotes potential location of emission source

A - Denotes process vent

B - Represents emissions after a control device

solvent (typically furfural) and fed into an extractive distillation operation. In this operation, most of the butanes and butenes are separated from butadiene, which is absorbed in the solvent along with residual impurities. A stripping operation is then used to separate the butadiene from the solvent.

The stream containing butadiene typically has a small amount of residuals. Some of these residuals are alkynes that were not converted to olefins in the hydrogenation reactor. These residuals are removed from the butadiene stream by distillation and are usually vented to an emission control device. The bottom stream exiting the acetylenes removal operation contains butadiene and residuals such as polymer and 2-butene. The residuals are removed in the butadiene finishing operation and sent to a waste treatment system or recovery unit. The finished butadiene is then stored in pressurized tanks.

In the dehydrogenation process, steam and air are combined with n-butenes and preheated, then passed through a dehydrogenation reactor. Hydrogen is removed from the butenes feed stream. Next, the stream is compressed and sent to a hydrocarbon absorption and stripping process. The product is then routed to a light-ends column for further separation. Finally, distillation and separation take place, with the finished butadiene sent to storage.

B. SOURCES OF POLLUTION

There are five main sources of pollutant emissions in the production of 1,3-butadiene:

- process vent discharges,
- equipment leaks,
- secondary sources,
- storage, and
- emergency or accidental releases.

Process vent discharges can be from reactor vessels, recovery columns, and other process vessels. Equipment leaks include pump seals, process valves, compressors, safety relief valves, flanges, open-ended lines, and sampling connections. Secondary sources include process and other waste streams. Emissions from storage vessels are assumed negligible since 1,3-butadiene is stored in pressure vessels with no breathing or working losses. There are no data available regarding emission amounts from emergency or accidental releases.

C. POLLUTANTS AND THEIR CONTROL

Exhibits 2 and 3 identify air pollutants and hazardous waste pollutants, respectively. Little information is available regarding amounts of pollutant emissions from the entire petrochemical industry, including 1,3-butadiene production. Many petrochemical processes are located at or near petroleum refining operations; therefore, many of the air pollutants and hazardous wastes generated by the petroleum industry are also present at petrochemical facilities. It is important to note that the Exhibits represent facility-wide pollution.

In general, the waste streams from the petrochemical industry are quite similar to those of the petroleum refining industry. Limited data are available, but almost all assume waste management operations and facilities are probably of the same degree of sophistication as those of the petroleum refining industry.

Wastewater, which is a basic source of emissions, can be categorized in five ways:

- (1) Wastes containing a principal raw material or product;
- (2) By-products produced during reactions;
- (3) Spills, leaks, washdowns, vessel cleanouts, or point overflows;
- (4) Cooling tower and boiler blowdown, steam condensate, water treatment wastes, and general washing water; and
- (5) Surface runoff.

Disposal of solid wastes is a significant problem for the petrochemical industry. Waste solids include water treatment sludges, ashes, fly ash and incinerator residue, plastics, ferrous and nonferrous metals, catalysts, organic chemicals, inorganic chemicals, filter cakes, and viscous solids. General methods of disposal are depicted in Exhibit 3.

Exhibit 2: Pollutant Profile of the Petrochemical Industry

| Pollutants | Control Device | Control Efficiency (%) |
|---|--|------------------------|
| Particulates VOC Hydrocarbons SO _x NO _x CO Chemicals used or produced (benzene, 1,3-butadiene, naphthalene) | <ul style="list-style-type: none"> • (For gases) <ul style="list-style-type: none"> - Gas recovery (boiler) - Flare - Incinerator | 99.9 98 98 |

U.S. Environmental Protection Agency
 1200 Pennsylvania Avenue, N.W.
 Washington, D.C. 20460

Exhibit 3: Hazardous Waste Generation From the Petrochemical Industry

| Pollutant | Amount | Disposal Method |
|--|---------------|---------------------------------|
| Hazardous solids | Not available | Land disposal |
| | | Incineration |
| | | Salvage & recycle |
| Hydrocarbons | Not available | Chemical & biological treatment |
| Any hazardous chemicals used or produced | Not available | |

D. REFERENCES

1. Federal Energy Administration (Office of Economic Impact). Report to Congress on Petrochemicals. Public Law 93-275, Section 23 (no date: circa 1974).
2. Industrial Process Profiles for Environmental Use. Chapter 5 - Basic Petrochemical Industry, EPA document 600/2-77-023, January, 1977.
3. Locating and Estimating Air Emissions from Sources of 1,3-Butadiene, EPA document 450/2-89-021, December, 1989.

CHEMICAL MANUFACTURING

A. PROCESS DESCRIPTION

Due to the broad expanse and complexity of the chemical manufacturing industry, **acrylonitrile manufacturing** has been selected as being representative of it; however, process procedures may vary somewhat between different chemical industries.

Nearly all of the acrylonitrile (ACN) produced in the world today is produced using the SOHIO process for ammoxidation of propylene and ammonia. The overall reaction takes place in the vapor phase in the presence of a catalyst. Exhibit 1 shows a typical simplified process flow diagram for an uncontrolled SOHIO process.

The primary by-products of the process are hydrogen cyanide, acetonitrile, and carbon oxides. The recovery of these by-products depends on such factors as market conditions, plant location, and energy costs. Hydrogen cyanide and acetonitrile, although they carry a market value, are usually incinerated, indicating that the production of these by-products has little effect on the economics of producing ACN.

In the process represented in Exhibit 1, by-product hydrogen cyanide and acetonitrile are routed to an incinerator. Variations within the SOHIO process may provide for purification, storage, and loading facilities for these recoverable by-products. Other variations of the SOHIO process include the recovery of ammonium sulfate from the reactor effluent to allow for biological treatment of a wastewater stream and variations in catalysts and reactor conditions.

In the standard SOHIO process, air, ammonia, and propylene are introduced into a fluid-bed catalytic reactor operating at 5-30 psig and $\sim 400\text{-}510^{\circ}\text{C}$ ($750\text{-}950^{\circ}\text{F}$). Ammonia and air are fed to the reactor in slight excess of stoichiometric proportions because excess ammonia drives the reaction closer to completion and air continually regenerates the catalyst. A significant feature of the process is the high conversion of reactants on a once-through basis with only a few seconds residence time. The heat generated from the exothermic reaction is recovered via a waste-heat-recovery boiler.

The reactor effluent is routed to a water quench tower, where sulfuric acid is introduced to neutralize any unconverted ammonia. The product stream then flows through a countercurrent water absorber-stripper to reject inert gases and recover reaction products. The operation yields a mixture of ACN, acetonitrile, and water and then is sent to a fractionator to remove hydrogen cyanide. The final two steps involve the drying of the ACN stream and the final distillation to remove heavy ends. The fiber-grade ACN obtained from the process is 99+ % pure.

Several fluid-bed catalysts have been used since the inception of the SOHIO ammoxidation process. Catalyst 49, which represents the fourth major level of improvement, is currently recommended in the process.

Emissions of ACN during start-up are substantially higher than during normal operation. During start-up, the reactor is heated to operating temperature before the reactants (propylene and ammonia) are introduced. Effluent from the reactor during start-up begins as oxygen-rich, then passes through the explosive range before reaching the fuel-rich zone that is maintained during normal plant operation. To prevent explosions in the line to the absorber, the reactor effluent is vented to the atmosphere until the fuel-rich effluent mixture can be achieved. The ACN emissions resulting from this start-up procedure have been estimated to exceed 4500 kg (10,000 lb)/h.

The absorber vent gas contains nitrogen and unconverted oxygen from the air fed to the reactor, propane and unconverted propylene from the propylene feed, product ACN, by-product hydrogen cyanide and acetonitrile, other organics not recovered from the absorber, and some water vapor.

The ACN content of the combined column purge vent gases is relatively high, about 50% of the total VOCs emitted from the recovery, acetonitrile, light ends, and product columns. The rest of the vent gases consist of noncondensibles that are dissolved in the feed to the columns, the VOCs that are not condensed, and, for the columns operating under vacuum, the air that leaks into the column and is removed by the vacuum jet systems.

For the ACN process illustrated in Exhibit 1, by-product hydrogen cyanide and acetonitrile are incinerated along with product column bottoms. The primary pollutant problem related to the incinerator stack is the formation of NO_x from the fuel nitrogen of the acetonitrile stream and hydrogen cyanide. Carbon dioxide and lesser amounts of CO are emitted from the incinerator stack gas.

Other emission sources involve the volatilization of hydrocarbons through process leaks (fugitive emissions) and from the deep well ponds, breathing and working losses from product storage tanks, and losses during product loading operations. The fugitive and deep well/pond emissions consist primarily of propane and propylene, while the storage tank and product loading emissions consist primarily of ACN.

B. SOURCES OF POLLUTION

Exhibit 2 presents an emissions profile for sources in an ACN manufacturing facility, along with pollution control options and their efficiencies. Seven points are included:

1. Absorber vent gas
2. Column purge waste gas
3. Fugitive emissions
4. Incinerator stack gas
5. Deep well/pond emissions
6. Storage tank emissions
7. Product transport loading facility vent

Wastewater for disposal is generated mainly from the wastewater and acetonitrile columns.

EXHIBIT 1:

Sources of Pollution at a Typical ACN Plant

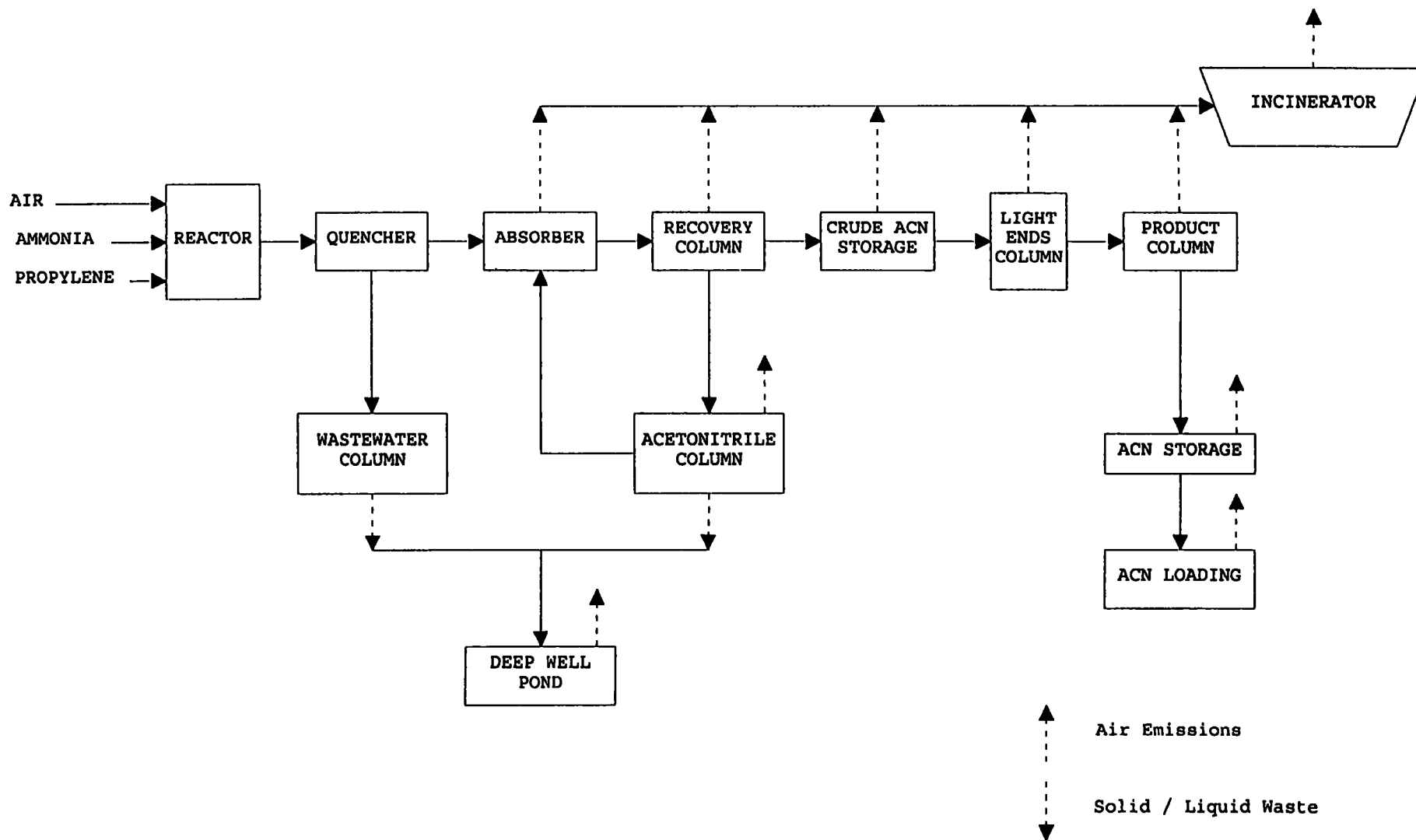


Exhibit 2: VOC and Acrylonitrile Emissions From ACN Manufacturing^a

| Emission Point | Emission Rate (kg/hr) | | Control Method | Control Efficiency (%) |
|----------------------|-----------------------|-----------|---|------------------------|
| | Acrylonitrile | Total VOC | | |
| Absorber Vents | 2.05 | 2050 | Thermal Incineration Catalytic Oxidation | 99.9 95-97 |
| Column Vents | 103 | 205 | Flare | 98-99 |
| Storage Tanks | 13.5 | 14.8 | Double Seal Floating Roof Water Scrubber | N/A 99 |
| Loading ^b | 3.44 | 3.98 | Flare Incinerator | 98-99 99 |
| Fugitive | 9.5 | 19.5 | Leak Detection/Maintenance | N/A |
| Incinerator Stack | | 7.4 | N/A | N/A |
| Deep Well/Pond | | 267 | Water Scrubber | N/A |

^a Model plant has an annual ACN capacity of 180 million kg, and is assumed to operate 8760 hours annually

^b Loading into tank cars, does not include loading into barges

C. POLLUTANTS AND THEIR CONTROL

1. Air Pollution

Absorber Vent Gas. The absorber vent gas stream contains nitrogen, oxygen, unreacted propylene, hydrocarbon impurities from the propylene feed stream, CO, CO₂, water vapor, and small quantities of ACN, acetonitrile, and hydrogen cyanide. Two control methods are used to treat this stream: thermal incineration and catalytic oxidation.

The thermal incineration units have demonstrated VOC destruction efficiencies of 99.9% or greater, while most catalytic units can achieve destruction efficiencies only in the 95-97% range. Destruction efficiencies in the 99% and greater range can be achieved with catalytic oxidizers, but these are not achieved on a long-term basis because of deactivation of the catalyst by a number of causes. The advantage of catalytic oxidation is low fuel usage, but emissions of NO_x formed in the reactors and not destroyed across the catalyst can pose problems.

Column Waste Purge Gas. Waste gas releases from the recovery column, light-ends column, product column, and the acetonitrile column are frequently tied together and vented to a flare. The estimated VOC destruction efficiency of the flare is 98-99% for all streams with a heat content of 300 Btu/scf or greater. The use of a flare is ideally suited for streams that are intermittent and having heating values of 300 Btu/scf.

Fugitive emissions. Fugitive emissions from piping, valves, pumps, and compressors are controlled by periodic monitoring by leak checking with a VOC detector and a directed maintenance program.

Incinerator Stack Gas. Staged combustion and ammonia injection are used to control the emissions of NO_x from the incinerator that treats the absorber off-gas vent, the crude acetonitrile waste gas stream, and the by-product liquid HCN stream. Staged combustion suppresses the formation of NO_x by operating under fuel-rich conditions in the flame zone where most of the NO_x is formed and oxygen-rich conditions downstream at lower temperatures where NO_x is not appreciably formed.

Ammonia injection reduces NO_x by selectively reacting ammonia with NO_x . The reaction occurs at temperatures in the range of 870-980°C (1600-1800°F) and, as such, the ammonia must be injected in the postflame zone of the combustion chamber. Residence times of 0.5-1.0 second are required for NO_x destruction efficiencies in the range of 80%, which is compatible with the residence time required for VOC destruction.

Deep Well/Pond Emissions. Emissions of acrolein and other odorous components in vents from wastewater treatment steps are controlled with water scrubbers. In some cases, pond emissions are controlled by adding a layer of a low-vapor-pressure oil on the surface of the pond to limit volatilization.

Storage Tank Emissions. Product storage tank emissions are controlled with double-seal floating roofs or, in some cases, water scrubbers. Field experience indicates that a removal efficiency of 99% can be achieved with water scrubbing.

Product Transport Loading. Emissions from product transport loading vents are gathered and sent to a flare or incinerator for VOC control. Destruction efficiencies of 98-99% are achieved using the flare and greater than 99% using incineration.

2. Solid/Liquid Waste

Wastes include salts of hydrogen cyanide, metal cyanide complexes, and organic cyanides (cyanohydrins) as solutions or solids. The wastewater from the wastewater column contains ammonium sulfate and heavy hydrocarbons, while the wastewater from the acetonitrile column mainly contains heavy bottoms. The wastewater from both these columns is typically discharged to a deep well pond (Exhibit 3). Other methods of waste treatment include alkaline chlorination in a recycle lagoon system, and incineration.

Exhibit 3: Potentially Hazardous Wastes Generated From Acrylonitrile Production

| Waste Source | Pollutant | Amount | Disposal Method |
|---------------------|--|--------|-----------------|
| Wastewater Column | Ammonium Sulfate Heavy Hydrocarbons | N/A | Deep well pond |
| Acetonitrile Column | Heavy Bottoms | N/A | Deep well pond |

D. REFERENCES

1. Wilkinsin, Gary R. The Manufacture and Use of Selected Inorganic Cyanides. Kansas City: Midwest Research Institute (for the U.S.EPA), April 2, 1976.
2. Air and Waste Management Association. Air Pollution Engineering Manual. New York: Van Nostrand Reinhold, 1992.

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SYNTHESIZED PHARMACEUTICAL MANUFACTURING PLANTS

A. PROCESS DESCRIPTION

The synthesis of medicinal chemicals may be done in a very small facility producing only one chemical or in a large integrated facility producing many chemicals by various processes. Most pharmaceutical manufacturing plants are relatively small. Organic chemicals are used as raw materials and as solvents. Nearly all products are made using batch operations. In addition, several different products or intermediates are likely to be made in the same equipment at different times during the year; these products, then, are made in "campaigned" equipment. Equipment dedicated to the manufacture of a single product is rare, unless the product is made in large volume.

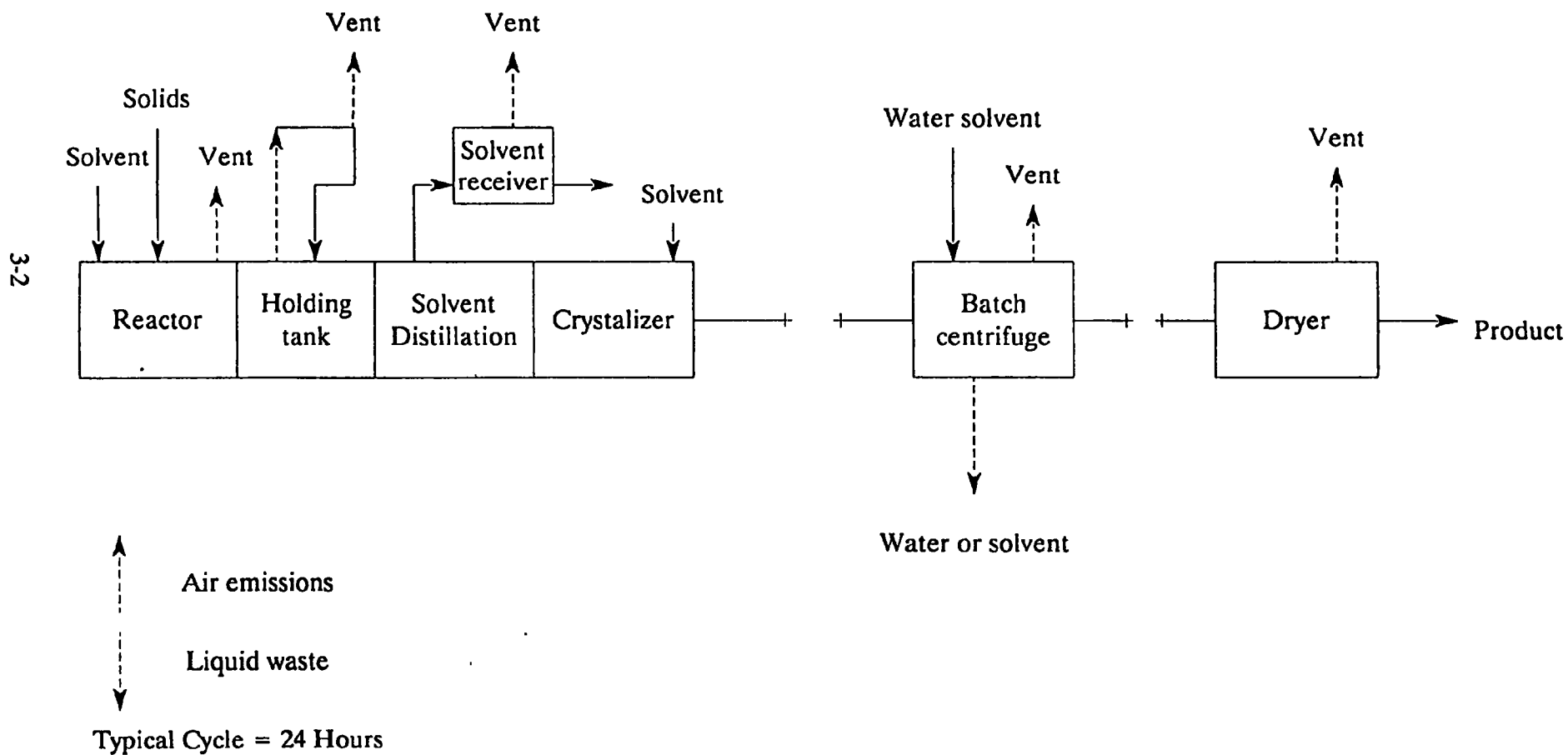
Production activities of the pharmaceutical industry can be divided into the following categories:

1. **Chemical Synthesis** - the manufacture of pharmaceutical products by chemical synthesis.
2. **Fermentation** - the production and separation of medicinal chemicals such as antibiotics and vitamins from microorganisms.
3. **Extraction** - the manufacture of botanical and biological products by the extraction of organic chemicals from vegetative materials or animal tissues.
4. **Formulation and Packaging** - the formulation of bulk pharmaceuticals into various dosage forms such as tablets, capsules, injectable solutions, ointments, etc., that can be taken by the patient immediately and in accurate amount.

Production of a synthesized drug consists of one or more chemical reactions followed by a series of purifying operations. Production lines may contain reactors, filters, centrifuges, stills, dryers, process tanks, and crystallizers piped together in a specific arrangement. Arrangements can be varied in some instances to accommodate production of several compounds. A very small plant may have only a few pieces of process equipment but a large plant can contain literally hundreds of pieces.

Exhibit 1 shows a typical flow diagram for a batch synthesis operation. To begin a production cycle, the reactor may be water washed and perhaps dried with a solvent. Air or nitrogen is usually used to purge the tank after it is cleaned. Following cleaning, solid reactants and solvent are charged to the glass batch reactor equipped with a condenser (which is usually water-cooled). Other volatile compounds may be produced as product or by-products. Any remaining unreacted volatile compounds are distilled off. After the reaction and solvent removal are complete, the pharmaceutical product is transferred to a holding tank. After each batch is placed in the holding tank, three to four washes of water or solvent may be used to remove any remaining reactants and by-products. The solvent used to wash may also be evaporated from the reaction product. The crude product may then be dissolved in another solvent and transferred to a crystallizer for purification. After

EXHIBIT 1: Typical Synthetic Organic Medicinal Chemical Process



crystallization, the solid material is separated from the remaining solvent by centrifugation. While in the centrifuge the product cake may be washed several times with water or solvent. Tray, rotary, or fluid-bed dryers may then be employed for final product finishing.

B. SOURCES OF POLLUTION

Exhibit 2 identifies pollutants from a typical pharmaceutical process. Volatile organic compounds may be emitted from a variety of sources within plants synthesizing pharmaceutical products. The following process components have been identified as VOC sources and will be discussed further: reactors, distillation units, dryers, crystallizers, filters, centrifuges, extractors, and tanks.

1. Reactors

The typical batch reactor is glass lined or stainless steel and has a capacity of 2,000 to 11,000 liters (500-3000 gallons). For maximum utility the tanks are usually jacketed to permit temperature control of reactions. Generally, each tank is equipped with a vent which may discharge through a condenser. Batch reactors can be operated at atmospheric pressure, elevated pressure, or under vacuum, and may be used in a variety of ways. Besides hosting chemical reactions, they can act as mixers, heaters, holding tanks, crystallizers, and evaporators.

A typical reaction cycle takes place as follows. After the reactor is clean and dry, the appropriate raw materials, usually including some solvent(s), are charged for the next product run. Liquids are normally added first, then solid reactants are charged through the manhole. After charging is complete, the vessel is closed and the temperature raised, if necessary, via reactor jacket heating. The purpose of heating may be to increase the speed of reaction or to reflux the contents for a period which may vary from 15 minutes to 24 hours. During refluxing, the liquid phase may be "blanketed" by an inert gas, such as nitrogen, to prevent oxidation or other undesirable side reactions. Upon completion of the reaction, the vessel may be used as a distillation pot to vaporize the liquid phase (solvent), or the reaction products may be pumped out so the vessel can be cooled to begin the next cycle.

2. Distillation Operations

Distillation may be performed by either of two principal methods. In the first method, the liquid mixture to be separated is boiled and vapors produced are condensed and prevented from returning to the still. In the second method, part of the condensate is allowed to return to the still so that the returning liquid is brought into intimate contact with the vapors on the way to the condenser. Either of these methods may be conducted as a batch or continuous operation.

Exhibit 2: Major Pollutants From Solvent Use in Pharmaceutical Production^a

| Pollutant (Solvent) | Ultimate Disposition (%) | | | | |
|------------------------|--------------------------|-------|--------------|----------------|---------|
| | Air Emissions | Sewer | Incineration | Solid Waste | Product |
| Acetic anhydride | 1 | 57 | | | 42 |
| Acetone | 14 | 22 | 38 | 7 | 19 |
| Amyl alcohol | 42 | 58 | | | |
| Benzene | 29 | 37 | 16 | 8 | 10 |
| Carbon tetrachloride | 11 | 7 | 82 | | |
| Dimethyl formamide | 71 | 3 | 20 | 6 | |
| Ethanol | 10 | 6 | 7 | 1 | 76 |
| Ethyl acetate | 30 | 47 | 20 | 3 | |
| Isopropanol | 14 | 17 | 17 | 7 | 45 |
| Methanol | 31 | 45 | 14 | 6 | 4 |
| Methylene chloride | 53 | 5 | 20 | 22 | |
| Solvent B (hexanes) | 29 | 2 | 69 | | |
| Toluene | 31 | 14 | 26 | 29 | |
| Xylene | 6 | 19 | 70 | 5 | |

^a Numbers are based on a survey of 26 U.S. manufacturers

3. Separation Operations

Several separation mechanisms employed by the industry are extraction, centrifugation, filtration, and crystallization.

Extraction is used to separate components of liquid mixtures or solutions. This process utilizes differences in solubilities of the components rather than differences in volatilities (as in distillation); i.e., solvent is used that will preferentially combine with one of the components. The resulting mixture to be separated is made up of the extract which contains the preferentially dissolved material and the raffinate which is the residual phase.

Centrifuges are used to remove intermediate or product solids from a liquid stream. Center-slung, stainless steel basket centrifuges are most commonly used in the industry. To begin the process, the centrifuge is started and the liquid slurry is pumped into it. An inert gas, such as nitrogen, is sometimes introduced into the centrifuge to avoid the buildup of an explosive atmosphere. The spinning centrifuge strains the liquid through small basket perforations. Solids retained in the basket are then scraped from the sides of the basket and unloaded by scooping them out from a hatch on the top of the centrifuge or by dropping them through the centrifuge bottom into receiving carts.

Filtration is used to remove solids from a liquid; these solids may be product, process intermediates, catalysts, or carbon particles (e.g., from a decoloring step). Pressure filters, such as shell and leaf filters, cartridge filters, and plate and frame filters are usually used. Atmospheric and vacuum filters have their applications too. The normal filtration procedure is simply to force or draw the mother liquor through a filtering medium. Following filtration, the retained solids are removed from the filter medium for further processing.

Crystallization is a means of separating an intermediate or final product from a liquid solution. This is done by creating a supersaturated solution, one in which the desired compound will form crystals. If performed properly and in the absence of competing crystals, crystallization can produce a highly purified product.

4. Dryers

Dryers are used to remove most of the remaining solvent in a centrifuged or filtered product. This is done by evaporating solvent until an acceptable level of "dryness" is reached. Evaporation is accelerated by applying heat and/or vacuum to the solvent-laden product or by blowing warm air around or through it. Because a product may degrade under severe drying conditions, the amount of heat, vacuum, or warm air flow is carefully controlled. Several types of dryers are used in synthetic drug manufacture. Some of the most widely used are tray dryers, rotary dryers, and fluid bed dryers.

5. Storage and Transfer

Volatile organic compounds are stored in tank farms, 233 liter (55 gallon) drums, and sometimes in process holding tanks. Storage tanks in tank farms range in size from about 2,000-20,000 liters (500-5,000 gallons). In-plant transfer of VOCs is done mainly by pipeline, but also may be done manually (e.g. loading or unloading drums). Raw materials are delivered to the plant by tank truck, rail car, or in drums.

C. POLLUTANTS AND THEIR CONTROL

1. Air Emissions

Solvents constitute the predominant VOC emission from production. Plants differ in the amount of organics used; this results in widely varying VOC emission rates. Therefore, some plants may be negligible VOC sources while others are highly significant. In addition, all types of equipment previously described have the potential to emit air pollutants.

a. Reactors

Reactor emissions stem from the following causes: (a) displacement of air containing VOC during reactor charging, (b) solvent evaporation during the reaction cycle (often VOC's are emitted along with reaction by-product gases which act as carriers), (c) overhead condenser venting uncondensed VOC during refluxing, (d) purging vaporized VOC remaining from a solvent wash, and (e) opening reactors during a reaction cycle to take samples, determine reaction end-points, etc.

Equipment options available to control emissions from reactors include surface condensers, carbon adsorbers, liquid scrubbers, and vapor incinerators (under certain conditions). Condensers are often included on reactor systems as normal process control equipment.

b. Distillation Operations

Volatile organic compounds may be emitted from the distillation condensers used to recover evaporated solvents. The magnitude of emissions depends on the operating parameters of the condenser, the type and quantity of organic being condensed, and the quantity of inerts entrained in the organic.

Emissions from distillation condensers can be controlled through the use of aftercondensers, scrubbers, and carbon adsorbers.

c. Separation Operations

1. Emissions from **batch extraction** stem mainly from displacement of vapor while pumping solvent into the extractor and while purging or cleaning the vessel after

extraction. Some VOCs also may be emitted while the liquids are being agitated. A column extractor may emit VOCs while the column is being filled, during extraction, or when it is emptied after extraction. Emissions occur not only at the extractor itself, but also at associated surge tanks. These tanks may emit significant amounts of solvent due to working losses as the tank is repeatedly filled and emptied during the extraction process.

2. A large potential source of emissions is the open-type **centrifuge** which permits large quantities of air to contact and evaporate solvents. The industry trend is toward completely enclosed centrifuges and, in fact, many plants have no open-type centrifuges. If an inert gas blanket is used, it can act as a transport vehicle for solvent vapor. This vapor may be vented directly from the centrifuge or from a process tank receiving the mother liquor. However, this emission source is likely to be small because the inert gas flow is only a few cubic feet per minute.
3. If **crystallization** is done mainly through cooling of a solution, there will be little VOC emission. In fact, the equipment may be completely enclosed. However, when the crystallization is done by solvent evaporation, there is greater potential for emissions. Emissions will be significant if evaporated solvent is vented directly to the atmosphere. It is more likely, however, that the solvent will be passed through a condenser or from a vacuum jet (if the crystallization is done under vacuum), thereby minimizing emissions.

Several add-on control technologies may be used on the separation equipment described above. Condensers, which can be applied to individual systems, are effective and may be the least costly option. Water scrubbers also have found wide usage in the industry. They are versatile and capable of handling a variety of VOCs which have appreciable water solubility. Scrubbers can be either small or quite large; thus, they can be designed to handle emissions from a single source or from many sources (via a manifold system). Carbon adsorbers can be and have been employed on vents from separation operations. Several vents may be ducted to an adsorber because it is likely that emissions from a single source would not warrant the expense of a carbon adsorption unit. Finally, in some instances, incinerators may be applicable. They may not be a good choice, however, since the expected variability from these emission sources might make continuous incinerator operation difficult.

4. Enclosed **pressure filters** normally do not emit VOCs during a filtering operation. Emissions can occur, however, when a filter is opened to remove collected solids. Emissions can also occur if the filter is purged (possibly with nitrogen or steam) before cleaning. The purge gas will entrain evaporated solvent and probably be vented through the receiving tank for the filtered liquid. The largest VOC emissions are from vacuum drum filters which are operated by pulling solvent through a precoated filter drum. Potential emissions are significant both at or near the surface

of the drum and from the ensuing waste stream. These filters can be shrouded or enclosed for control purposes.

d. Dryers

Dryers are potentially large emission sources. Emission rates vary during a drying cycle and are greatest at the beginning of the cycle and least at the end of the cycle. Drying cycle times can range from several hours to several days. Control options used for dryers include condensation, wet scrubbing, adsorption, and incineration.

1. Condensers are often the first control devices selected when dealing with air pollution from vacuum dryers. They can also be used by themselves or in series with another device. Condensers are not typically used on air dryers because the emissions are dilute.
2. Wet scrubbers have also been used to control many plant sources, including dryers. They can also remove particulates generated during drying. For water soluble compounds, VOC absorption efficiencies can be quite high (i.e. 98-99%).
3. Carbon adsorbers may also be used, especially following a condenser. Not only will overall efficiency increase but a longer regeneration cycle can be used in the adsorber.
4. Vapor incinerators might be viable controls although varying VOC flows to the incinerator may present operating problems.

e. Tanks

The vapor space in a tank will in time become saturated with the stored organics. During tank filling vapors are displaced, causing an emission or a "working loss." Some vapors are also displaced as the temperature of the stored VOC rises, such as from solar radiation, or as atmospheric pressure drops; these are "breathing losses." The amount of loss depends on type of VOC stored, size of tank, type of tank, diurnal temperature changes, and tank throughput.

Emissions from storage or process holding vessels may be reduced with varying efficacy through the use of vapor balance systems, conservation vents, vent condensers, pressurized tanks, and carbon adsorption.

2. Solid and Liquid Wastes

The manufacture of the following types of pharmaceutical products can generate hazardous wastes:

- Organic medicinal chemicals
- Inorganic medicinal chemicals
- Antibiotics
- Botanicals
- Medicinals from animal glands.

The largest quantities of hazardous waste are from the production of organic medicinal chemicals and antibiotics. Exhibit 3 identifies potential hazardous wastes from pharmaceutical production:

Exhibit 3: Potential Hazardous Wastes from Pharmaceutical Production

| Product or Operation | Potential Hazardous Wastes | Estimated U.S. Generation (dry metric tons/yr) ¹ |
|-------------------------------|---|--|
| Organic medicinal chemicals | <ul style="list-style-type: none">• Heavy metals• Terpenes, steroids, vitamins, tranquilizers• Ethylene dichloride• Acetone, toluene, xylene, benzene isopropyl alcohol, methanol, acetonitrile• Zinc, arsenic, chromium, copper, mercury | <div>1,700</div> <div>13,600</div> <div>3,400</div> <div>23,800</div> <div>2,700</div> |
| Inorganic medicinal chemicals | <ul style="list-style-type: none">• Selenium | 200 |
| Antibiotics | <ul style="list-style-type: none">• Amyl acetate, butanol, butyl acetate, MIBK, acetone, ethylene glycol, monomethyl ether | 12,000 |
| Botanicals | <ul style="list-style-type: none">• Ethylene dichloride, methylene chloride• Methanol, acetone, ethanol, chloroform, heptane, naphtha, benzene• Misc. organics | <div>100</div> <div>100</div> <div>700</div> |
| Medicinals from animal glands | <ul style="list-style-type: none">• Misc. organics | 800 |
| Biological products | <ul style="list-style-type: none">• Vaccines, toxoids, serum, etc.• Ethanol | <div>500</div> <div>300</div> |
| Misc. sources | Misc. solvents | 63,900 |

¹Hazardous waste amounts are for 1973 estimated total U.S. generation.

D. REFERENCES

1. Control of Organic Emissions from the Manufacture of Synthesized Pharmaceutical Products, Environmental Protection Agency, Research Triangle Park, NC, December 1978.
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METALLURGICAL INDUSTRIES

The metallurgical industries can be broadly divided into primary, secondary, and miscellaneous metal production operations. "Primary metals" refers to the production of metals from ore. "Secondary metals" refers to the manufacturing of alloys by utilizing metals from scrap and salvage, as well as ingots. "Miscellaneous metal" production encompasses industries with operations that produce or use metals for final products. Metallurgical industries include the following:

- | | |
|-------------------------|------------------------------|
| • Primary Aluminum | • Secondary Aluminum |
| • Metallurgical Coke | • Secondary Brass and Bronze |
| • Copper Smelting | • Melting Processes |
| • Ferroalloy Industry | • Iron Foundries |
| • Steel Industry | • Secondary Lead Smelting |
| • Primary Lead Smelting | • Steel Foundries |
| • Zinc Smelting | • Secondary Zinc |

As a representative industry within the metallurgical classification, iron foundries have been selected for discussion.

Method to control air pollution produced by iron foundries are selected based on the methods of melting, the handling of sand, the types of molten metals and other materials, and the cleaning of finished castings. Air pollutant characteristics are affected by a number of factors, including the type of melting unit, material-handling and hooding systems, and emission control systems. Air pollution is prevented by capturing the smoke, dust, and fumes at the furnace and other sources, and transporting these contaminants to suitable control devices.

A. PROCESS DESCRIPTION

1. Mold and Core Production

Molds are forms used to shape the exteriors of castings. The green sand mold, the most common type, consists of moist sand mixed with 3-20% clay and 2-5% water, depending on the process. To prevent casting defects materials such as seacoal (a pulverized high-volatility, low-sulfur bituminous coal), wood or corn flour, oat hulls, or similar organic matter may be added to the sand mixture. Cores are molded sand shapes used to form the internal voids in castings. They are made by mixing sand with various binders, shaping it into a core, and curing the core with a variety of processes.

2. The Melting Process

a. Electric Furnace (General)

In the electric furnace, the basic process operations are (1) furnace charging, in which metal, scrap, alloys, carbon, and flux are added to the furnace; (2) melting, during which the

furnace remains closed; (3) back-charging, which involves the addition of more metal and alloys; (4) refining and treating, during which the chemical composition is adjusted to meet product specifications; (5) slag removal; and (6) tapping molten metal into a ladle or directly into molds.

b. Induction Furnaces

Electric induction furnaces are either horizontal or vertical, cylindrical, refractory-lined vessels. Heating and melting occur when the charge is energized with a low-, medium-, or high-frequency alternating current. Induction furnaces also may be used for holding and superheating. Electric induction furnaces generally have lower emissions per ton of metal melted than the other furnace types. As a result, in spite of a generally lower unit capacity, induction furnaces have supplanted cupolas in many foundries.

c. Electric Arc Furnaces

Electric-arc melting furnaces are large, welded-steel cylindrical vessels equipped with a removable roof through which three carbon electrodes are inserted. The electrodes are energized by three-phase alternating current, creating arcs that melt the metallic charge material. Additional heat is generated by the electrical resistance of the metal to the current between the arc paths. The most common method of charging an arc furnace is by removing the roof and introducing the charge material directly. Alternatives include charging through a roof chute or side charging door. Once the melting cycle is complete, the metal is tapped by tilting the furnace and pouring the metal into a ladle.

d. Cupola

The cupola is a vertical, cylindrical shaft furnace which may use pig iron, scrap iron, scrap steel, and coke as the charge components. Melting is accomplished in the cupola by heat released from the combustion of coke (the reaction between oxygen in the air and carbon in the fuel) that is in direct contact with the metallic portion of the charge and the fluxes.

One of the advantages of using such a furnace is that counterflow preheating of the charge material can occur. In a cupola, upward flowing hot gases come into close contact with the descending burden, allowing direct and efficient heat exchange to take place. The running or charge coke, which replenishes fuel consumed, is also preheated before it reaches the combustion zone, thus enhancing the combustion process. Greater understanding of these features accounts, in part, for the continued popularity of the cupola as a melting unit. However, recent design improvements, such as cokeless, plasma-fired types that alter emission characteristics are now encountered.

3. Casting, Cooling, and Finishing

After melting, molten metal is tapped from the furnace and poured into a ladle or directly into molds. If poured into a ladle, the molten iron may be treated with a variety of alloying agents selected for their desired metallurgical properties. The molten material then is

ladled into molds which are allowed to cool in open floor space, or, (in larger, more mechanized foundries) are conveyed automatically through a cooling tunnel before separation of the casting from the mold (shakeout). Molding and core sand are separated from the casting(s) either manually or mechanically. In some foundries the cooled molds are placed on a vibrating grid to shake the mold and core sand loose from the casting. Used sand from casting shakeout is usually returned to the sand preparation area and cleaned, screened, and processed to make new molds. Because of process losses and potential contamination, additional makeup sand may be required.

When castings have cooled, any unwanted appendages such as sprues, gates, and risers are removed by an oxygen torch, abrasive saw, friction cutting tool, or hand hammer. The castings then may be subjected to abrasive blast cleaning and/or tumbling to remove any remaining mold sand or scale.

B. SOURCES OF POLLUTION

Exhibit 1 illustrates the operations of a typical iron foundry and emissions they generate. Processes which produce air emissions include melting (furnace or cupola), molding, core-making, pouring, casting shakeout, cooling/cleaning, and finishing. These are described in greater detail in the next section.

C. POLLUTANTS AND THEIR CONTROL

Exhibit 2 summarizes the pollutant emissions from the various processes in a typical iron foundry, and indicates appropriate types of control methods. The nature of emissions from each source is described in this section.

1. Emission Sources

a. Mold and Core Production

The major pollutants emitted in mold and core production operations are particulates from sand preparation, mold core forming, and curing. Volatile organic compounds (VOCs), carbon monoxide, and particulates also may be emitted during core and mold curing or drying.

b. Melting

The melting process begins with the handling of charge materials going into the melting furnace. Emissions from raw material handling are fugitive particulates generated from the receiving, unloading, storage, and conveying operations. Scrap preparation and preheating may emit one or more of the following: fumes, organic compounds, carbon monoxide, or coarse particulates. Scrap preparation with solvent degreasers may emit VOCs.

EXHIBIT 1: Emission Points in a Typical Iron Foundry

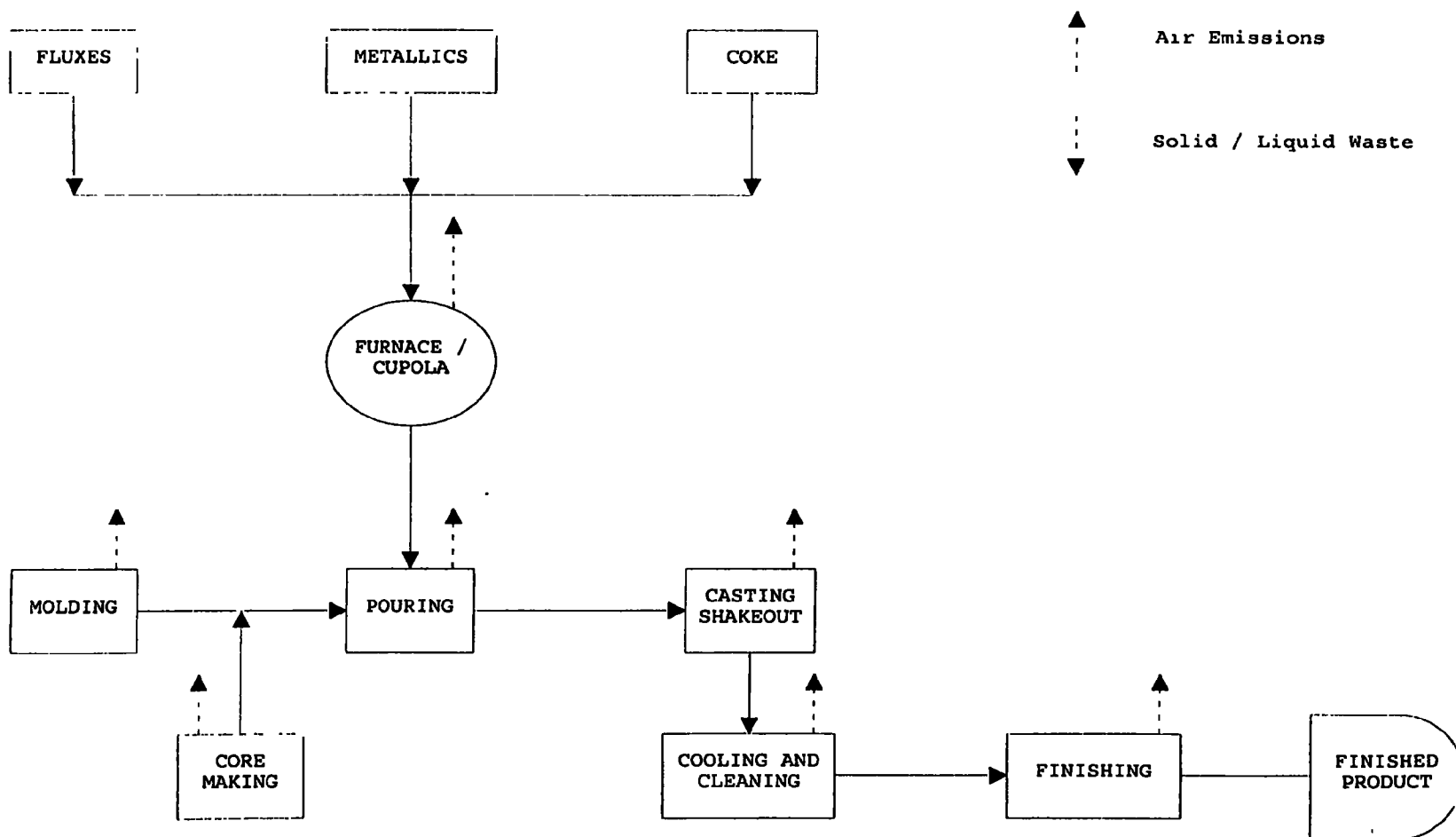


Exhibit 2: Emissions From Iron Foundry Processes

| Emission Point | Pollutants | Control Methods |
|---|---|---|
| Mold and Core Production | particulates VOCs carbon monoxide | <div>Wet Scrubbers</div> <div>Fabric Dust Collectors/Baghouses</div> <div>Afterburners</div> <div>Charcoal Absorption</div> |
| Melting | fugitive particulates fumes organic compounds carbon monoxide VOCs | |
| Induction and Arc Melting | particulates (metal oxides) organics | |
| Cupola Melting | dust consisting of: iron oxide silicon dioxide zinc oxide magnesium oxide manganese oxide calcium oxide lead cadmium gases: carbon monoxide sulfur oxides lead organic emissions | |
| Pouring, Casting, Cooling and Finishing | particulates magnesium oxides metallic fumes carbon monoxide organic compounds VOCs | |

c. *Induction and Arc Melting*

The highest concentrations of furnace emissions occur during charging, back-charging, alloying, slag removal, and tapping operations. These emissions are primarily particulates (metal oxides) and possibly organics, depending on the scrap quality and pretreatment. Typical dust loading from electric arc furnaces can range from 10 - 15 lb/ton melted. Electric induction furnaces, however, may emit particulates at one tenth of that value.

d. *Cupola Melting*

The quantity and composition of particulate emissions vary among cupolas, and even at intervals in the same cupola. Causes include changes in iron-to-coke ratios, air volumes per ton melted, stack velocity, and the quality of the scrap melted. Where oily scrap is charged, the raw emissions potentially will be greater in quantity and much more visible. Based on a survey, the average emission from an uncontrolled cupola was approximately 13 - 17 pounds of particulate per ton melted. Eighty-five percent of such emissions may be greater than 10 μ m in size.

Dust amount and composition vary from cupola to cupola. Each cupola has varying airflows at different phases in the melt process which affect the grains per standard cubic foot in emitted stack gases if all other factors are equal. The source of the raw charge materials also has a significant impact on dust composition and quantity. The dust can include some or all of the following materials:

- | | | |
|-----------------------|-----------------------|------------------|
| • Iron oxide | • Silicon dioxide | • Zinc oxide |
| • Magnesium oxide | • Calcium oxide | • Cadmium |
| • Manganese oxide | • Lead | |

In addition, other gases and organic compounds may be emitted as part of the melting process. These include carbon monoxide, sulfur oxides, lead, and organic emissions. Both sulfur and organic emissions are influenced by the amount of oil or grease on the scrap. The quantity of sulfur oxides generated may be large enough to cause corrosion of air pollution control equipment. There are a number of instances where rapid deterioration of dust collectors on cupolas occurred where corrosion protection was not considered. Where fluorspar is used as an additive, the fluorine driven off can cause a corrosion problem with dust collection equipment. Fluorine also has the potential to dissolve glass bags. Carbonic acid, formed when carbon dioxide reacts with water vapor, may cause corrosion problems as well.

e. *Pre-pouring, Pouring, Cooling, and Finishing*

Particulate emissions can be generated during the treatment and inoculation of molten iron before pouring. For example, the addition of magnesium to molten metal to produce ductile iron causes a very violent reaction accompanied by various emissions of magnesium oxides and metallic fumes, depending on the method of treatment. Some methods, such as the tundish method, result in significantly lower emissions than others. Emissions from pouring

consist of metal fumes, carbon monoxide, organic compounds, and particulates evolved when the molten iron contacts the mold and core materials. Emissions continue as the molds cool and during the shake-out operation, although at a much lower rate. Finishing operations, such as the removal of burrs, risers, and gates, and shotblast cleaning, also emit particulates, primarily iron, iron oxide, and abrasive media. The painting of castings also can lead to a variety of VOC emissions.

2. Air Pollution Control Measures

There are two primary collection methods for foundry particulates - wet and dry. Wet scrubbers include low- and high-energy types. Dry collection includes baghouses, mechanical collectors, and electrostatic precipitators. In addition, to control emissions of organic compounds, incineration or afterburners may be required. Air toxics merit special consideration, requiring careful selection of the emission control method.

a. Wet Scrubbers

For particulate collection, the mechanisms used in a wet-type collector are inertial impaction and direct interception. These are used either separately or in combination. In studying wet collector performance, independent investigators developed the contact power theory, which states that, for a well-designed wet-scrubber, collection efficiency is a function of the energy consumed in the air-to-water contact process and is independent of the collector design. On this basis, well-designed collectors operating at or near the same pressure drop can be expected to exhibit comparable performance. All wet collectors have a fractional efficiency characteristic -- that is, their cleaning efficiency varies directly with the size of the particle being collected. In general, collectors operating at a very low pressure loss will remove only medium to coarse particles. High-efficiency collection of fine particles requires increased energy input, which will be reflected in higher collector pressure loss.

In addition to particulates, gas scrubbers may be used to control odors and toxic and sulfur dioxide emissions. In this case, acids, bases, or oxidizing agents may have to be added to the scrubbing liquid. Disposal of this stream is subject to effluent guidelines for metal molding and casting.

b. Dry Collectors

The most frequently encountered equipment for the removal of solid particulate matter from an air stream or gas stream is the fabric dust collector or baghouse. With a mass median size of $0.5\ \mu\text{m}$, a collection efficiency of 98-99+ % can be expected. As the filter medium becomes coated in a fabric collector, the collection efficiency rises. However, as material continues to build on the bag surface, higher pressure drops occur, which result in a significant reduction in airflow. To maintain design flows, the bags must be cleaned periodically by mechanical shaking or with pulsed air.

Filter media are now available for hot corrosive atmospheres, such as furnace emissions. Operating inlet temperatures up to 500°F (260°C) are not uncommon. High humidity can

be a problem if no provision is included for the condensation of free moisture. Free moisture and acid dew point are the worst enemies of all fabric collectors. It is important to have the following design information in order to select the proper fabric and the quantity of bags required:

- Gas flow rate
- Temperature and dew point
- Acid dew point
- Particle size and distribution
- Concentration of solids
- Chemical and physical properties of solids

Teflon-coated, woven glass-fiber bags have been used on a large majority of cupola installations because of their high temperature resistance. If fluorspar is used, Nomex bags, which are acid-resistant, but combustible, are generally installed. The temperature of the gases entering the baghouse then must be reduced to a maximum of 400°F (204°C). Use of these lower-temperature bags creates a potential corrosion hazard because of the acid dew point problem. For reverse-air and mechanical shake collectors, air-to-cloth ratios range from 1.5-2.5:1.

Pulse-jet and cartridge collectors also can be used to collect pollutants from sand systems and casting cleaning operations. With either type of unit, care must be taken to select the proper air/cloth ratio (maximum of 25:1 with pulse jet and 1.5:1 with cartridge). In general, these types of collectors will have only marginal results with furnace and inoculation emissions. If considered, they should be employed at a very low air/cloth ratio. In addition, moisture introduced with compressed air may be significant and cause system failure.

c. Incineration

Afterburners may be used in some processes to control emissions, particularly when oily scrap or hydrocarbons in any form are charged into the furnaces or scrap preheat systems. Afterburning is required for below-the-door cupola emission systems. If afterburners are not used, carbon monoxide and oil vapors may be emitted through the discharge stack of the air pollution equipment. In order to achieve the required incineration, sufficient retention time (a minimum of 0.6 second) and ignition temperatures must be maintained.

In general, in the selection of collection devices for all processes, moisture, temperature, and the presence of corrosive materials must be considered. The temptation to operate at higher air/cloth ratios in baghouses must be avoided. Similarly, claims that lower pressure drops in scrubbers create high efficiencies have been proved to be false.

d. Absorption

Charcoal absorption has been used in conjunction with other control devices for VOC control.

3. Hazardous Air Pollutants From Other Metallurgical Industries

Hazardous Air Pollutants (HAPs) emitted from other metallurgical industries include both organic and inorganic substances. Exhibits 3 and 4 identify some HAPs from process operations at steel foundries and from aluminum production.

Exhibit 3: Hazardous Air Pollutants from Steel Foundries

| HAPs | Potential Emission Sources | Potential Fugitive Emission Sources |
|---|---|--|
| arsenic beryllium chromium copper lead manganese nickel zinc iron | furnaces foundry mold and core decomposition | converter/charging furnace tapping furnace charging metal casting |

Exhibit 4: Hazardous Air Pollutants from Aluminum Production

| HAPs | Potential Emission Sources | Potential Fugitive Emission Sources |
|--|--|---|
| fluorides chloride hydrogen chloride | calciner material handling furnaces material crusher and mills storage and handling areas reduction cells | furnace tapping furnace charging coke quenching |

D. REFERENCES

This report contains excerpts of information taken directly from the following source:

Air and Waste Management Association. Air Pollution Engineering Manual. New York: Van Nostrand Reinhold, 1992.

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TANNERIES

A. PROCESS DESCRIPTION

Tanning involves a complex combination of mechanical and chemical processes. The heart of the process is the tanning operation itself in which organic or inorganic materials become chemically bound to the protein structure of the hide and preserve it from deterioration. The substances generally used to accomplish the tanning process are chromium or extracts from bark of trees, such as chestnut. These tanning agents give rise to the two predominant types of tanning operations - chrome and vegetable tanning.

1. Chrome Tanning

Most leather produced is chrome tanned. Chrome tanning produces leather better suited for certain applications, particularly for the upper parts of boots and shoes, and requires less processing time than traditional vegetable tanning. The general steps required for chrome tanning of leather are shown in Exhibit 1 and described briefly below. No two tanneries are identical; each has its unique characteristics and subprocesses; some perform only some of the processes shown and ship their goods to another tannery to complete the processing.

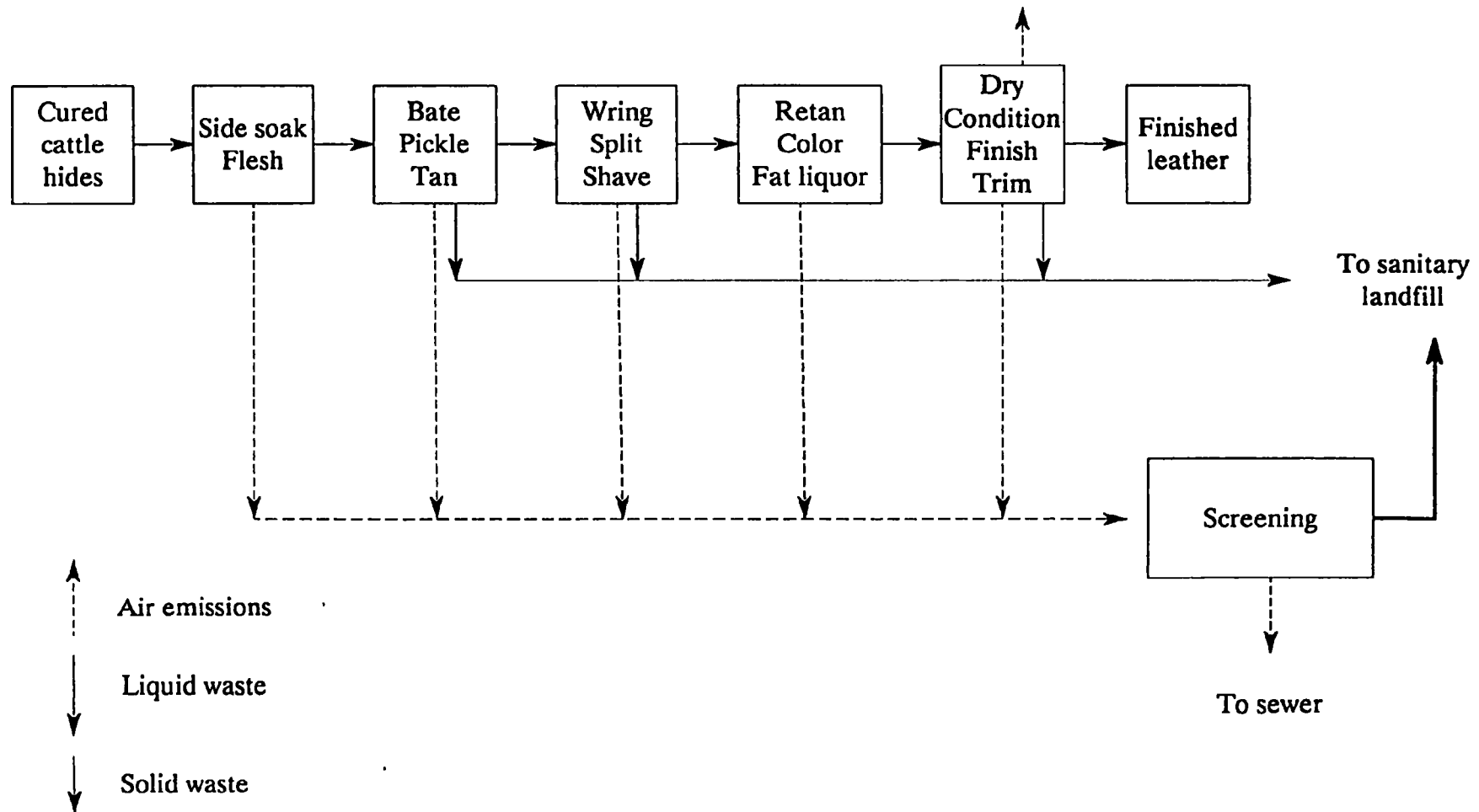
Hides and skins are received from meatpacking plants by truck or railroad car. Each cattlehide is tied in a bundle weighing approximately 25 kg. The bundles are cut open and the hides unfolded, inspected, and usually split along the backbone, producing two sides from each hide.

Next follows a sequence of wet operations. The sides are soaked in water to return some of the lost natural moisture. The remaining flesh or fatty substance adhering to the inside or flesh surface of the side is removed; these fleshings are usually either rendered in the tannery or sold. The cattlehides are then soaked in a lime and sulfide solution which either loosens or dissolves the attached hair. In some operations, the hair is only loosened through the caustic action of the lime, with the hair removed mechanically, followed by washing, drying, and sale as a by-product (for carpet pads and similar uses). However, the more common approach for hair removal is to completely dissolve the hair and discharge it to the wastewater stream.

Following hair removal, the hides are ready to be prepared for the actual tanning operation. The hides are placed in large rotating drums and treated in turn with an enzyme solution and then a salt-acid solution. These operations (respectively called bating and pickling) prepare the hide for the tanning process. While still in the drum after discharge of the pickling solution, the hides are tanned. A chromium sulfate solution is added to the drum and the hides and chrome solution are mixed for periods of up to 24 hours.

Following chrome tanning, all hides have a characteristic blue color caused by the chrome tanning solution. Upon removal from the tanning drums, excess moisture is removed from the hides through a wringing operation.

EXHIBIT 1: Process Flow Diagram of a Typical Chrome Tannery



Cattlehides are too thick for most purposes so the tanned hides are split using a machine similar to a horizontal band saw. The splitting operation produces a grain side of more or less uniform thickness. One surface of this grain side is the original outer surface of the cattlehide and retains the natural grain. The splitting operation also yields a thin, inner portion of the hide known as a "split" or "blue drop." Splits have no graining and are often used for suede garments. Both the grain side and the split may be further processed to form a piece of material of uniform thickness. This operation is called shaving and results in the removal of small pieces of leather with a consistency similar to very coarse sawdust.

Another series of wet operations gives the leather the color and other properties desired in the finished material. The tanned hides are placed into another drum for retanning, coloring, and fatliquoring. Retanning is a second, shorter tanning operation normally using a tanning agent other than chromium. After the retanning solution is discharged from the drum, a pigment is added in order to dye the leather to the desired color. The coloring solution is also discharged from the drum. Next a mixture of oils is added and the hides and oil are rotated in the drum. This operation, called fatliquoring, helps to produce the desired softness.

After removal from the retan, color, and fatliquor drum, the leather is dried and physically conditioned. The two most common approaches to this conditioning are staking and buffing. Staking is a form of massaging which makes the leather more pliable. Buffing is a light sanding operation applied to either the grain surface or the underside of a piece of leather. It is used to improve the nap of the underside or to smooth out surface imperfections on the grain surface.

One or more of several possible finishing steps give the leather the required pattern gloss or waterproof qualities. Usually all leather receives at least one coat of a liquid finish material. Finishes are either rolled or sprayed onto the leather. Often three or more coats of finish are applied to leather, each one followed by a drying cycle. Other finishing operations include embossing, in which patterns are pressed into the leather surface. Finally, the surface area of each piece of leather is measured electronically and the area stamped on the underside. The leather is then packaged and stored for shipment.

2. Vegetable Tanning

Vegetable tanning employs the use of extracts from the bark of various trees as the tanning agent. Since the introduction of chrome tanning, vegetable tanning has decreased in importance. Soles of shoes have been traditionally vegetable tanned; however, since the introduction of synthetic materials for shoe soles, vegetable tanning has further decreased in importance. Vegetable tanning is also used to produce leather used in crafts.

Many of the basic steps used in the chrome tanning process are also present in vegetable tanning. The sequence in which these steps are employed is somewhat different, and there are few finishing operations associated with vegetable tanning. The processing of hides prior to vegetable tanning begins with a soak in lime to loosen the hair. Hides are then removed from the lime solution and the hair is removed mechanically. The hides are then soaked and rinsed, and the fleshing operation is accomplished. Note that in the chrome tanning

process, fleshing preceded the hair removal operation. After fleshing, the hides are trimmed into a roughly rectangular shape and then passed through a bate and pickle operation similar to that used in the chrome tanning process. Coloring, the next operation, is often done utilizing a weak tanning solution. Normally vegetable tanned leather is not highly colored. After coloring, the hides are placed into vats containing the bark extract tanning solution and moved from a strong tanning solution to a slightly weaker one, then rinsed and partially dried.

True splitting is not usually a part of the vegetable tanning process; however, an operation called leveling is used to produce a uniformly thick piece of leather. Leveling removes only the thickest portions of the underside of the hide, and no "split" is produced. Next, the hide is oiled, which is a process similar to the fatliquoring in chrome tanning. Following oiling, the hide is dried and then mechanically conditioned.

Virtually no finishing is done at vegetable tanneries. Few, if any, spray finishes are applied and often the only finishing process employed is pressing to yield a smooth grain surface. Finally, the hides are measured, packaged, and stored prior to shipment.

B. SOURCES OF POLLUTION

Typical sources of emissions include (1) solvent receiving, (2) mixing vault, (3) supply drum, (4) spray chamber, (5) dryer, (6) receiving recycled solvents, (7) cleaning operation, (8) waste solvent storage (See Exhibit 2 for air emissions and solid waste generation points).

C. POLLUTANTS AND THEIR CONTROL

1. Air Emissions

Typical pollutants (either solid or gaseous) from a tannery include chlorine, formaldehyde, sulfuric acid, glycol ether EB, glycol ether PMA, methyl isobutyl ketone, toluene, xylol, phosphoric acid, methanol, manganese sulfate, chromium III, ethylene glycol, lead, copper, and zinc. See Exhibit 2 for a sample listing of toxic air pollutants and their amounts.

Air pollution control methods can include the use of a water fall (efficiency = 50% for particulates and 10% for VOC), a fume incinerator for spray booth exhausts, and process modifications (using more water-based processes and less solvent-based ones).

2. Process Liquid and Solid Wastes

Pieces of leather (containing 10 to 50% moisture) in various stages of processing, and wastewater treatment sludges constitute the bulk of the process solid waste from tanneries. In order to produce the quality products required by leather consuming industries, tanneries trim off inferior portions of hides at many steps in processing. Smaller pieces of leather wastes are produced in shaving and buffing operations. Approximately 35% of all tannery solid waste is trimmings and shavings of various types.

Exhibit 2: Emissions of Toxic Air Pollutants From a Typical Tannery

| Emission Point | Pollutants | Emission Rate kg/hr | Control Methods | |
|-----------------------------|---|--|-----------------|--|
| Solvent Receiving | Methyl Ethyl Ketone Methyl Isobutyl Ketone Toluene Xylol | 22.58 1.67 10.04 1.17 | Incineration | |
| Mixing Vault | Methyl Ethyl Ketone | 0.52 | | |
| Supply Drum | Methyl Ethyl Ketone | 0.52 | | |
| Spray Chamber | Diacetone Alcohol Glycol Ether EB Glycol Ether PMA Methyl Ethyl Ketone Methyl Isobutyl Ketone Toluene Xylol | 1.89 11.85 7.6 75.72 59.05 95.78 33.38 | | |
| Dryer | Diacetone Alcohol Glycol Ether EB Glycol Ether PMA Methyl Ethyl Ketone Methyl Isobutyl Ketone Toluene Xylol | 1.89 11.85 7.6 75.72 59.05 95.78 33.38 | | Process Modification (e.g., water-based process instead of solvent-based process) |
| Receiving Recycled Solvents | Acetone Methyl Ethyl Ketone Toluene | 0.61 0.98 0.61 | | |
| Cleaning Operation | Less than 1 kg/hr of each pollutant | | | |
| Waste Solvent Storage | Less than 1 kg/hr of each pollutant | | | |

Another source of tannery wastes is the finishing department. Finishes are sprayed or rolled onto leather and the residue is considered to be a solid waste since it is land disposed. Finish residues are usually slurries containing 10 to 50% solids. Waste finishes account for about 2% of tannery solid waste.

Wastewater treatment is the single largest source of process solid waste. Almost all tanneries screen their wastewater. Direct dischargers and some discharging wastewater into municipal sewers have some form of primary or secondary treatment (only direct dischargers use secondary treatment). The screenings and sludges from these operations contain lime, chromium compounds, pieces of leather, hair, and other protein-like substances which are land disposed. Wastewater screenings and sludge account for about 60% of tannery solid waste.

Floor sweepings are the final source of process solid waste. These include twine used to tie bundles of hides, salt used to preserve the hides prior to handling, and general plant debris. Approximately 3% of tannery solid waste is floor sweepings.

Wastewater pretreatment is accomplished through sludge dewatering. Sludge dewatering is performed using gravity (sequential settling) or mechanical means. Three mechanical methods of sludge dewatering are used by tanneries - vacuum filters, centrifuges, and filter presses. All three are effective; however, there seems to be a preference for filter presses due to the slightly drier (40% solids) filter cake produced.

See Exhibit 3 for solid wastes, their amounts, and methods of disposal.

Exhibit 3: Hazardous Wastes From a Typical Tannery

| Waste Source | Pollutant | Concentration Range ^a (wet weight in mg/kg) | Disposal Method |
|---|------------------|---|---|
| Chrome trimmings & Shavings | Cr ⁺³ | 2,200 - 21,000 | Landfill |
| Chrome fleshings | Cr ⁺³ | 4,000 | |
| Unfinished chrome leather trim | Cr ⁺³ | 4,600 - 37,000 | |
| | Cu | 2.3 - 468 | |
| | Pb | 2.5 - 476 | |
| | Zn | 9.1 - 156 | |
| Buffing dust | Cr ⁺³ | 19 - 22,000 | |
| | Cu | 29 - 1,900 | |
| | Pb | 2 - 924 | |
| | Zn | 160 | |
| Finishing residues | Cr ⁺³ | 0.45 - 12,000 | Dewater sludge; all waste disposed in certified hazardous waste disposal facility |
| | Cu | 0.35 - 208 | |
| | Pb | 2.5 - 69,200 | |
| | Zn | 14 - 876 | |
| Finished leather trim | Cr ⁺³ | 1,600 - 41,000 | Landfill with leachate collection |
| | Pb | 100 - 3,300 | |
| Sewer screenings | Cr ⁺³ | 0.27 - 14,000 | |
| | Pb | 2 - 110 | |
| | Zn | 35 - 128 | |
| Wastewater treatment residues (sludges) | Cr ⁺³ | 0.33 - 19,400 | |
| | Cu | 0.12 - 8,400 | |
| | Pb | 0.75 - 240 | |
| | Zn | 1.2 - 147 | |

^a Range not shown when only one sample was analyzed for the constituent

D. REFERENCES

All information on air emissions for this report was taken from Assessment of Information Available Through State & Local Air Pollution Control Agencies to Support NESHAP Development presented by ViGYAN Inc. to the U.S. EPA on February 26, 1993.

All other information for this report was taken from Assessment of Industrial Hazardous Waste Practices in Leather Tanning and Finishing Industry presented by SCS Engineers to the U.S. EPA in November 1976.

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CEMENT INDUSTRIES

A. PROCESS DESCRIPTION

Cement industries typically produce portland cement, although they also produce masonry cement (which is also manufactured at portland cement plants). Portland cement is a fine, typically gray powder comprised of dicalcium silicate, tricalcium silicate, tricalcium aluminate, and tetracalcium aluminoferrite, with the addition of forms of calcium sulfate. Different types of portland cements are created based on the use and chemical and physical properties desired. Portland cement types I - V are the most common. Portland cement plants can operate continuously for long time periods (i.e. ≥ 6 months) with minimal shut down time for maintenance. The air pollution problems related to the production, handling, and transportation of portland cement are caused by the very fine particles in the product.

Exhibit 1 illustrates the stages of cement production at a portland cement plant:

1. Procurement of raw materials
2. Raw Milling - preparation of raw materials for the pyroprocessing system
3. Pyroprocessing - pyroprocessing raw materials to form portland cement clinker
4. Cooling of portland cement clinker
5. Storage of portland cement clinker
6. Finish Milling
7. Packing and loading

1. Raw Material Acquisition

Most of the raw materials used are extracted from the earth through mining and quarrying and can be divided into the following groups: lime (calcareous), silica (siliceous), alumina (argillaceous), and iron (ferriferous). Since a form of calcium carbonate, usually limestone, is the predominant raw material, most plants are situated near a limestone quarry or receive this material from a source via inexpensive transportation. The plant must minimize the transportation cost since one third of the limestone is converted to CO_2 during the pyroprocessing and is subsequently lost. Quarry operations consist of drilling, blasting, excavating, handling, loading, hauling, crushing, screening, stockpiling, and storing.

2. Raw Milling

Raw milling involves mixing the extracted raw materials to obtain the correct chemical configuration, and grinding them to achieve the proper particle-size to ensure optimal fuel efficiency in the cement kiln and strength in the final concrete product. Three types of processes may be used: the dry process, the wet process, or the semidry process. If the dry process is used, the raw materials are dried using impact dryers, drum dryers, paddle-equipped rapid dryers, air separators, or autogenous mills, before grinding, or in the grinding process itself. In the wet process, water is added during grinding. In the semidry process the materials are formed into pellets with the addition of water in a pelletizing device.

EXHIBIT 1:
Basic Flow Diagram of the Portland Cement Manufacturing Process (Part 1)

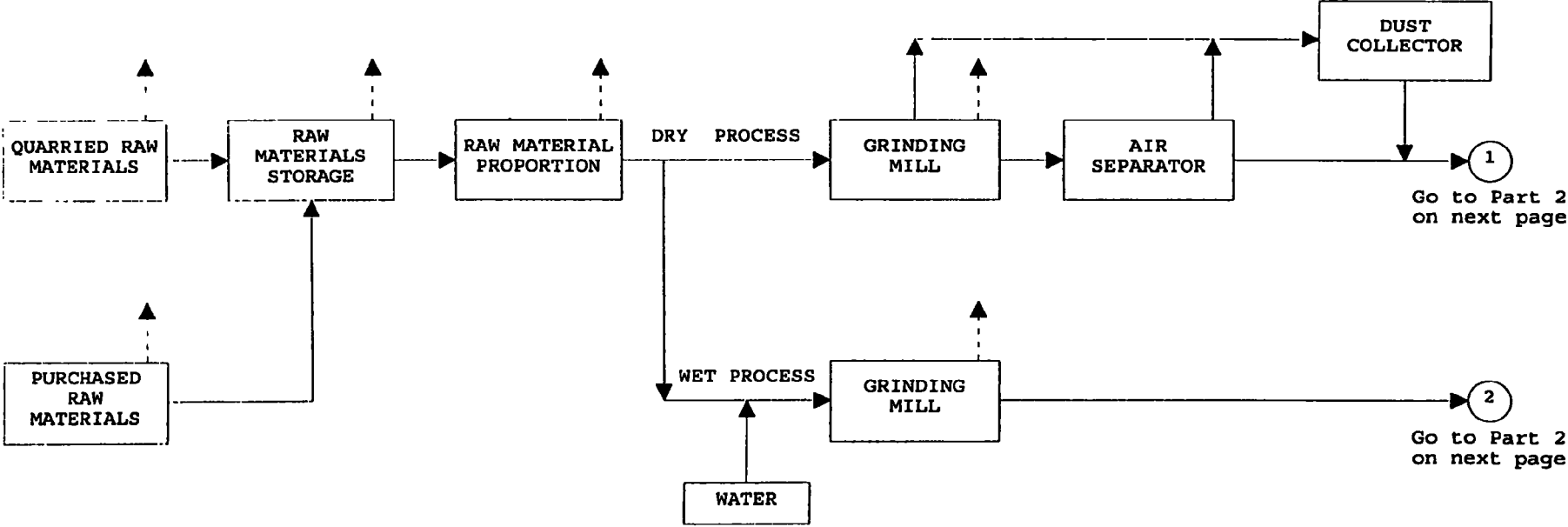


EXHIBIT 1:

Basic Flow Diagram of the Portland Cement Manufacturing Process (Part 2)

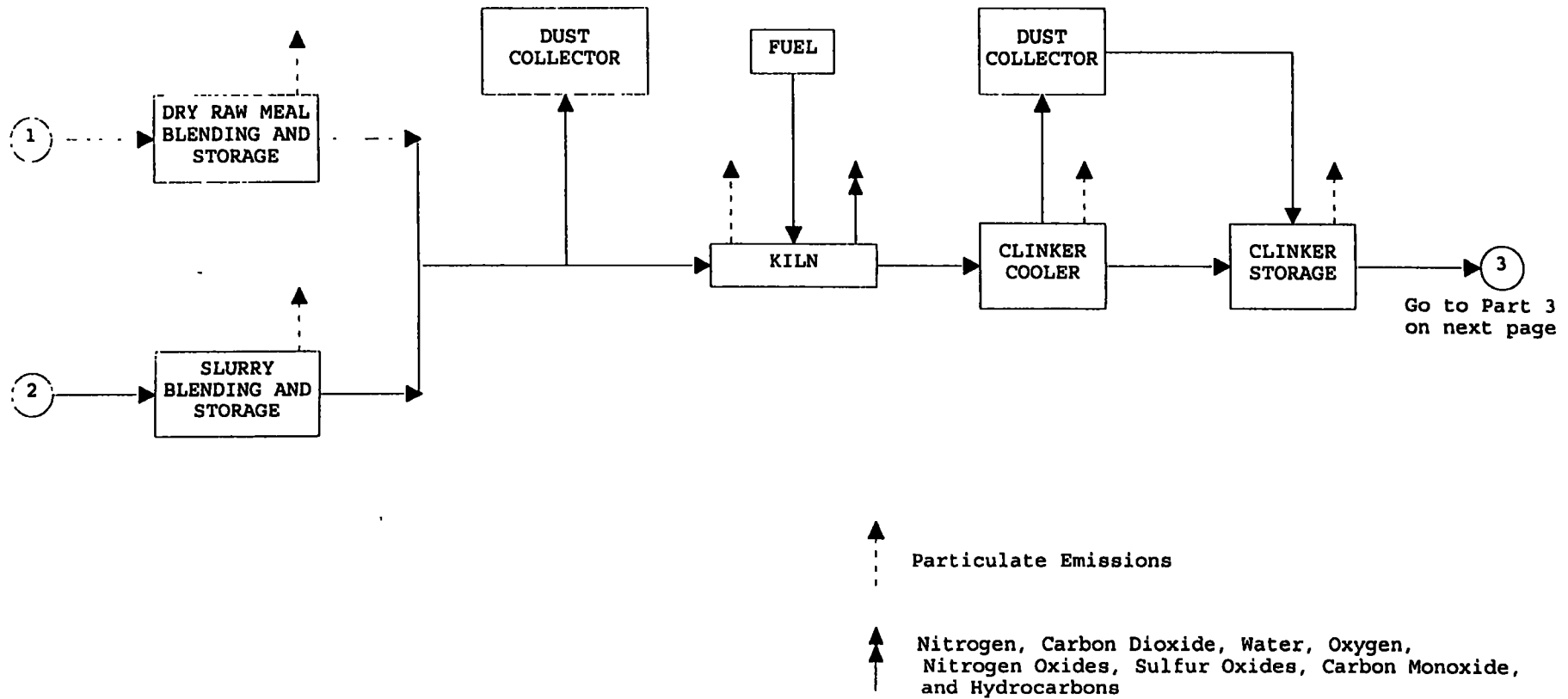
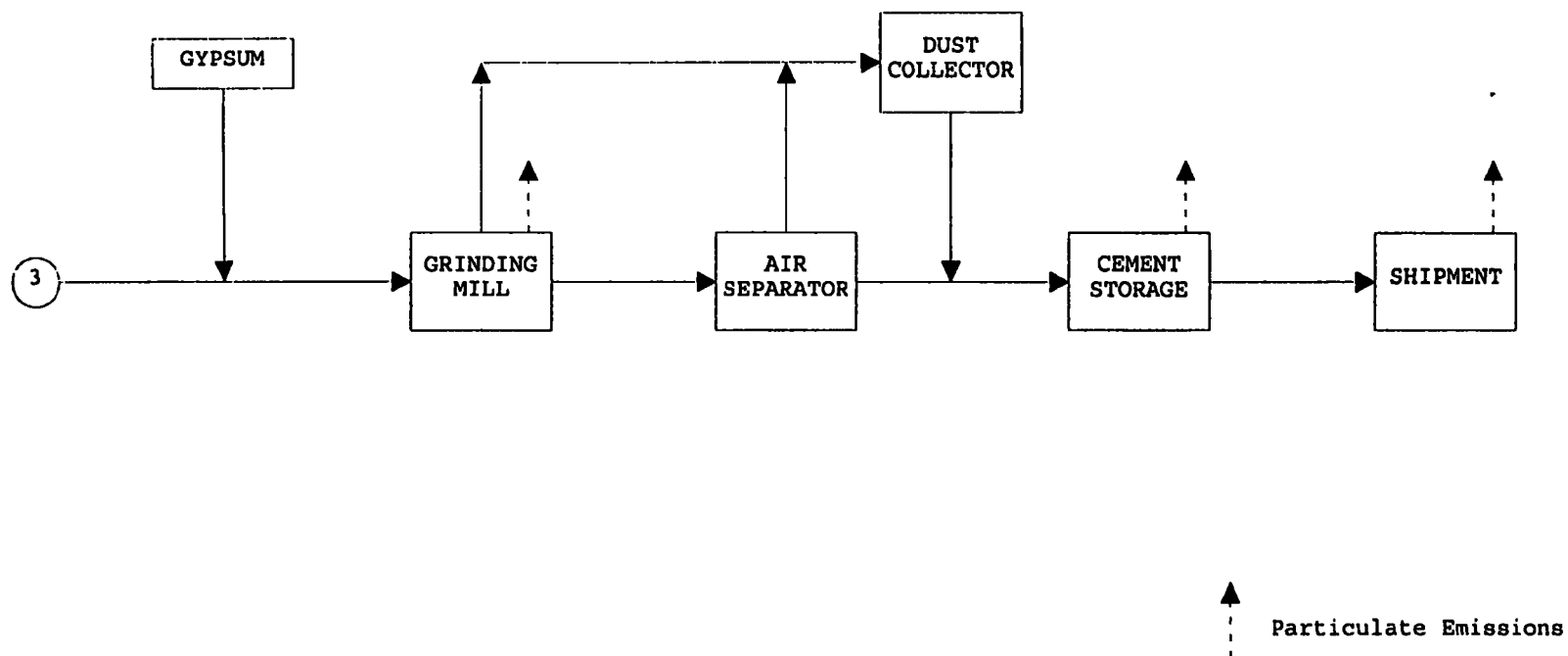


EXHIBIT 1:
Basic Flow Diagram of the Portland Cement Manufacturing Process (Part 3)



3. Pyroprocessing

In pyroprocessing, the raw mix is heated to produce portland cement clinkers. Clinkers are hard, gray, spherical nodules with diameters ranging from 0.32 - 5.0 cm (1/8 - 2") created from the chemical reactions between the raw materials. The pyroprocessing system involves three steps: drying or preheating, calcining (a heating process in which calcium oxide is formed), and burning (sintering). The pyroprocessing takes place in the burning/kiln department. The raw mix is supplied to the system as a slurry (wet process), a powder (dry process), or as moist pellets (semidry process). All systems use a rotary kiln and contain the burning stage and all or part of the calcining stage. For the wet and dry processes, all pyroprocessing operations take place in the rotary kiln, while drying and preheating and some of the calcination are performed outside the kiln on moving grates supplied with hot kiln gases.

4. Clinker Cooling

The clinker cooling operation recovers up to 30% of kiln system heat, preserves the ideal product qualities, and enables the cooled clinker to be maneuvered by conveyors. The most common types of clinker coolers are reciprocating grate, planetary, and rotary. Air sent through the clinker to cool it is directed to the rotary kiln where it nourishes fuel combustion. The fairly coarse dust collected from clinker coolers is comprised of cement minerals and is restored to the operation. Based on the cooling efficiency and desired cooled temperature, the amount of air used in this cooling process is approximately 1-2 kg/kg of clinker. The amount of gas to be cleaned following the cooling process is decreased when a portion of the gas is used for other processes such as coal drying.

5. Clinker Storage

Although clinker storage capacity is based on the state of the market, a plant can normally store 5 - 25% of its annual clinker production capacity. Equipment such as conveyors and bucket elevators is used to transfer the clinkers from coolers to storage areas and to the finish mill. Gravity drops and transfer points typically are vented to dust collectors.

6. Finish Milling

During the final stage of portland cement production known as finish milling, the clinker is ground with other materials (which impart special characteristics to the finished product) into a fine powder. Up to 5% gypsum and/or natural anhydrite is added to regulate the setting time of the cement. Other chemicals, such as those which regulate flowability or air entrainment, may also be added. Many plants use a roll crusher to achieve a preliminary size reduction of the clinker and gypsum. These materials are then sent through ball or tube mills (rotating, horizontal steel cylinders containing steel alloy balls) which perform the remaining grinding. The grinding process occurs in a closed system with an air separator that divides the cement particles according to size. Material that has not been completely ground is sent through the system again.

7. Packing and Loading

Once the production of portland cement is complete, the finished product is transferred using bucket elevators and conveyors to large, storage silos in the shipping department. Most of the portland cement is transported in bulk by railway, truck, or barge, or in 43 kg (94 pound) multiwalled paper bags. Bags are used primarily to package masonry cement. Once the cement leaves the plant, distribution terminals are sometimes used as an intermediary holding location prior to customer distribution. The same types of conveyor systems used at the plant are used to load cement at distribution terminals.

B. SOURCES OF POLLUTION

Although portland cement plants generate the same final product using similar processes, plant layouts vary according to fuels and raw materials used, location, climate, site topography, and the manufacturer of the equipment. The flow diagram in Exhibit 1 depicts the manufacturing process at a portland cement plant and indicates emission points throughout the process.

C. POLLUTANTS AND THEIR CONTROL

This section briefly discusses the nature of the pollutants generated from, and controls used at, several sources in the cement manufacturing process. Air pollutants are typically of greater concern than solid or liquid wastes.

1. Air Pollutants

Air pollutants generated during the cement manufacturing process consist primarily of particulates from the raw and finished materials, and fuel combustion by-products. Exhibit 2 indicates sources of air pollution, and differentiates between particulates and other air pollutants.

Controlling particulate emissions from sources other than the kiln usually entails capturing the dust using a hood or other partial enclosure and transporting it through a series of ducts to the collectors. The type of dust collector used is based on factors such as particle size, dust loading, flow rate, moisture content, and gas temperature. The best disposal method for collected dust is to send it through the kiln creating the clinker. However, if the alkali content of the raw materials is too high, the dust must be discarded, or must be pretreated before introduction into the kiln. The highest allowable alkali content is 0.6 percent (as sodium oxide). Exhibit 3 summarizes the general applicability of a number of collection systems for use by the cement industry.

Additional air pollutants emitted include such materials as sulfur oxides and nitrogen oxides generated from the kiln and drying processes. Sulfur dioxide is generated from the sulfur compounds in the ores and the combusted fuel and varies in amount produced from plant to plant. The efficiency of particulate control devices is inconclusive as the result of variables such as feed sulfur content, temperature, moisture, and feed chemical composition, in addition to alkali and sulfur content of the raw materials and fuel. The combustion of fuel in rotary

Exhibit 2: Air Pollution and Control at Cement Production Facilities

| Emission Point | Pollutants | Emission Rate (gr/acf ¹) | Control Device | Percent Efficiency |
|---|--------------|---|---|-----------------------|
| Quarries | Particulates | 5-40 | Fabric Filter: • Pulse Jet • Reverse Air/Shaker | ≥ 99.6 |
| Raw Mill Systems | Particulates | 5-20 | Fabric Filter: • Pulse Jet • Reverse Air/Shaker • Cartridge | ≥ 99.6 |
| Kiln System | Particulates | 4-18 | Dust Collectors: • Reverse Air • Precipitator | ≥ 99.5 |
| Clinker Coolers | Particulates | 5-10 | Fabric Filters: • Pulsed Plenum/Pulse Jet • Reverse Air • Precipitator | ≥ 99.6 |
| Finish Mill Systems | Particulates | 5-20 | Fabric Filter: • Reverse Air/Shaker | ≥ 99.6 |
| Finish Mill Systems | Particulates | 5-100 | Fabric Filters: • Pulse Jet • Pulsed Plenum | ≥ 99.6 |
| For use with High- Efficiency Separators | Particulates | 150-300 | Fabric Filters: • Pulse Jet • Pulsed Plenum | ≥ 99.9 |
| Packing and Loading Departments | Particulates | 5-40 | Fabric Filters: • Pulse Jet • Reverse/Air Shaker • Cartridge | ≥ 99.6 |

¹ gr/acf = grains/actual cubic foot

Exhibit 3: Applicability of Emission Control Methods

| Operation | Mechanical Collector | Wet Scrubber | Fabric Collector | Electrostatic | Gravel Bed Filter |
|----------------------------|---------------------------|----------------|--------------------------|---------------------|--------------------------|
| Primary grinding | Unsatisfactory efficiency | Not applicable | Successful | Not applicable | None in use |
| Air separators | Not applicable | Not applicable | Successful | A few installations | Questionable application |
| Mills | Not applicable | Not applicable | Successful | A few installations | Questionable application |
| Storage silos | Not applicable | Not applicable | Successful | Not applicable | Impractical |
| Feeders and belt conveyors | Not applicable | Not applicable | Successful | Not applicable | Impractical |
| Packing and loading | Not applicable | Not applicable | Successful | Not applicable | Impractical |
| Coal dryer | Preliminary cleaning only | Practicable | Successful | Not common | Practicable |
| Kiln gases | Preliminary cleaning only | Impractical | 12 x 30 Glass Successful | Successful | Practicable |
| Clinker cooler | Preliminary cleaning only | Not applicable | Successful | Not common | Successful |

cement kilns generates nitrogen oxides from the nitrogen in the fuel and incoming combustion air. The amount emitted depends on several factors including fuel type, nitrogen content, and combustion temperature. Both sulfur dioxide and some of the nitrogen oxide react with the alkaline cement and are removed from the gas stream.

a. Raw Material Acquisition

During raw material acquisition the primary air pollutant emitted is particulate matter. Particulate matter is also emitted from the handling, loading, unloading, and transport of raw materials purchased from another source, such as coal. In certain areas exhaust from portable equipment may also be a consideration.

The following methods are used to control particulate emissions generated from the quarry and handling of purchased raw materials:

- fabric filters (pulse-jet or reverse-air/shaker)
- water sprays (with and without surfactants)
- silos (with and without exhaust venting to fabric filters)
- mechanical collectors
- chemical dust suppressants
- material storage buildings
- equipment enclosures
- enclosures
- wind screens
- foams
- bins
- paving

Dust that is collected by these means is restored to the process. For quarry operations, newer plants typically use the pulse-jet fabric filters while older plants employ the reverse-air or shaker-type fabric filters.

b. Raw Milling

Fugitive dust is emitted from raw material feeders, stackers, blenders, reclaimers, conveyor belt transfer points, and bucket elevators used for transferring materials to the mill department from storage. Particulate emissions from the dry raw mills and subsequent equipment occur during temporary failure or from improperly designed or maintained seals.

The following devices are used to collect particulate matter in the raw mill and raw mix storage areas:

- mechanical cyclones (usually used in series with another control)
- fabric filters (pulse jet or reverse air/shaker)
- electrostatic precipitators (rarely used)

Newer plants typically use the pulse-jet fabric filters while older plants employ the reverse-air or shaker type fabric filters.

c. Pyroprocessing

The main pyroprocessing system emissions are nitrogen, carbon dioxide, water, oxygen, nitrogen oxides, sulfur oxides, carbon monoxide, and hydrocarbons. Cement kiln dust (CKD) is also produced.

The cement kiln itself has been designated as best available control technology (BACT) for the control of SO₂. The highly alkaline conditions of the kiln system enable it to capture up to 95% of the possible SO₂ emissions. However, if sulfide sulfur (pyrites) is present in the kiln feed, this absorption rate can decline to as low as 50%. Therefore, sulfur emissions can be decreased through careful selection of raw materials.

No device to control cement kiln NO_x emissions has been developed, but there are several prospects:

- stable kiln operation (reduces long term NO_x emissions);
- burner configurations for the rotary kiln (efficiency varies);
- staged combustion for precalciner kilns;
- recirculation of the flue gas (oxygen deficient air in the rotary kiln); and
- alternative/low-nitrogen fuels.

Cement kiln dust (CKD) is the powder retrieved from the exiting gases and is either all or partly returned to the operation or removed entirely. The type of system, the chemical makeup of the raw materials and fuel, and the condition of the system operations all affect the chemical configuration of the CKD. Portland cement specifications usually limit the amounts of sodium and potassium. Because bypass CKD contains a large quantity of these minerals, CKD is usually removed from the process. The CKD from a preheater tower is composed of the same general elements as the kiln feed and therefore is returned to the process. The handling, storage, and deposition of CKD can generate fugitive dust emissions.

The following methods are used to control particulate emissions from the kiln system:

- reverse-air fabric filters
- electrostatic precipitators (ESPs)
- acoustic horns (sometimes used in conjunction with the two devices above)

d. Clinker Cooling

Reciprocating grate clinker coolers most often employ fabric filters, but ESPs and gravel bed filters are also used with a mechanical cyclone or multiclone dust collector sometimes placed in front. Newer plants typically use pulse-jet or pulsed-plenum fabric filters and older plants use reverse-air type fabric filters which may simply be a smaller form of a kiln fabric filter. Gravel bed filters, which are also used by the cement industry, contain quartz granules; contaminated gas passes through this filter and the dust settles to the bottom of the bed.

e. Clinker Storage

The devices used to control dust emissions from clinker storage areas are similar to those used in the raw milling process. The particulate emissions generated by dropping clinkers onto storage piles can be reduced by using a rock ladder or variable-height, automatic, stacker belt conveyor systems. Fugitive dust generated from open storage piles is tempered by rain and snow, wind breaks, and pile covers. Clinker in open piles is moved using front-end loaders; in storage halls overhead bucket cranes are used. Fugitive clinker dust emitted from open storage piles is common and very difficult to control.

f. Finish Milling

Particulate matter is emitted from mill vents, air separator vents, and material-handling system vents. Newer plants usually use pulse-jet or pulsed-plenum fabric filters with high-efficiency separators, while older plants use reverse-air/shaker fabric filters. The cement dust collected by the fabric filter is restored to the system. In cold weather, a plume may develop at the baghouse vent; this may be mistaken for particulate matter, but actually is condensed water vapor from the cooling system.

g. Packing and Loading

In the shipping department particulate matter is emitted from the silos and the handling and loading operations. Active and passive fabric filters are used to collect this dust. During loading of the product, particulate emissions are controlled by a fabric filter connected to the transport vessel; collected dust is restored to the shipment. To ensure dust-free loading onto the transport vessel, a flexible loading spout consisting of concentric tubes is used. The outermost tube seals the delivery spout to the transport vehicle. The product is then delivered through the inner tube and displaced air drawn up the outer tube to a filter. At distribution terminals, fabric filters are again used and the collected dust is returned to the product. New plants typically use pulse-jet fabric filters while older plants use reverse-air or shaker-type fabric filters.

2. Liquid and Solid Wastes

The overflow from slurry concentrating equipment (i.e. thickeners) constitutes the main water pollution problem. For new plants that process slurry, closed-cycle water systems are used to return the overflow water to the process. Another source of waste is the stripped overburden, which is used as a raw material or disposed of in a local landfill. An estimate of overburden deposited in a landfill varies from 0 - 3 metric tons per metric ton of cement produced.

The combustion processes of cement kilns and rotary kilns have been used to dispose of hazardous waste material. For the cement kiln, waste material is burned with a primary fuel. For a wet process kiln, the raw materials are introduced into the top of the kiln and exit at the bottom as cement clinker. The burner is located at the lower end of the kiln where the fuel and waste are ignited. The hot gases move up the kiln and heat the raw materials, exit the kiln, and are then cleaned in a baghouse prior to exiting through a stack. When waste is fired, any ash generated becomes a part of the cement product.

D. REFERENCES

1. Air and Waste Management Association. Air Pollution Engineering Manual. New York: Van Nostrand Reinhold, 1992.
2. Hall, F.D. Evaluation of the Feasibility of Incinerating Hazardous Waste in High-Temperature Industrial Process, 1984.
3. Reding, J. T., P.E. Muehlberg, and B.P. Shepherd (Dow Chemical). Industrial Process Profiles for Environmental Use: Chapter 21. The Cement Industry, February 1977.

PRINTED CIRCUIT BOARD MANUFACTURING

A. PROCESS DESCRIPTION

Printed circuit boards are electronic circuits created by mounting electronic components on a non-conductive board, and creating conductive connections between them. The creation of circuit patterns is accomplished using both additive and subtractive methods. The conductive circuit is generally copper, although aluminum, nickel, chrome, and other metals are sometimes used. There are three basic varieties of printed circuit boards: single-sided, double-sided, and multi-layered. The spatial and density requirement, and the circuitry complexity determine the type of board produced. Printed circuit boards are employed in the manufacturing of business machines and computers, as well as communication, control, and home entertainment equipment.

Production of printed circuit boards involves the plating and selective etching of flat circuits of copper supported on a nonconductive sheet of plastic. Production begins with a sheet of plastic laminated with a thin layer of copper foil. Holes are drilled through the board using an automated drilling machine. The holes are used to mount electronic components on the board and to provide a conductive circuit from one layer of the board to another.

Following drilling, the board is scrubbed to remove fine copper particles left by the drill. The rinsewater from a scrubber unit can be a significant source of copper waste. In the scrubber, the copper is in a particulate form and can be removed by filtration or centrifuge. Equipment is available to remove this copper particulate, allowing recycle of the rinsewater to the scrubber. However, once mixed with other waste streams, the copper can dissolve and contribute to the dissolved copper load on the treatment plant.

After being scrubbed, the board is cleaned and etched to promote good adhesion and then is plated with an additional layer of copper. Since the holes are not conductive, electroless copper plating is employed to provide a thin continuous conductive layer over the surface of the board and through the holes. Electroless copper plating involves using chelating agents to keep the copper in solution at an alkaline pH. Plating depletes the metal and alkalinity of the electroless bath. Copper sulfate and caustic are added (usually automatically) as solutions, resulting in a "growth" in volume of the plating solution. This growth is a significant source of copper-bearing wastewater in the circuit board industry.

Treatment of this stream (and the rinsewater from electroless plating) is complicated by the presence of chelating agents, making simple hydroxide precipitation ineffective. Iron salts can be added to break the chelate, but only at the cost of producing a significant volume of sludge. Ion exchange is used to strip the copper from the chelating agent, typically by using a chelating ion exchange resin. Regeneration of the ion exchange resin with sulfuric acid produces a concentrated copper sulfate solution without the chelate. This regenerant can then be either treated by hydroxide precipitation, producing a hazardous waste sludge, or else concentrated to produce a useful product.

Growth from electroless copper plating is typically too concentrated in copper to treat directly by ion exchange. Different methods have been employed to reduce the concentration of copper sufficiently either to discharge the effluent directly to the sewer or to treat it with ion exchange. One method, reported by Hewlett-Packard, replenishes growth with formaldehyde and caustic soda to enhance its autocatalytic plating tendency, and then mixes it with carbon granules on which the copper plates out in a form suitable for reclaiming.

Following electroless plating, copper is electroplated on the board to its final thickness, and a layer of tin-lead solder is plated over the copper. A photoresist material is then applied to the board and exposed by photoimaging a circuit design. Following developing and stripping a selected portion of the photoresist, that portion of the tin-lead plate is etched to reveal the copper in areas other than the final desired circuit pattern.

The exposed copper is then removed by etching to reveal the circuit pattern is the remaining copper. Ammonia-based etching solutions are most widely used. Use of ammonia complicates waste treatment and makes recovery of copper difficult. An alternative to ammonia etching is sulfuric acid/hydrogen peroxide etching solutions. This latter etchant is continuously replenished by adding concentrated peroxide and acid as the copper concentration increases to about 80 g/L. At this concentration, the solution is cooled to precipitate out copper sulfate. After replenishing with peroxide and acid, the etchant is reused. Disadvantages of the sulfuric acid-peroxide etching solution are that it is relatively slow when compared with ammonia, and controlling temperature can be difficult.

Exhibit 1 shows the general processes in printed circuit board manufacturing.

B. SOURCES OF POLLUTION

Wastes are generated from the following five processes that are common to the manufacture of all types of circuit boards:

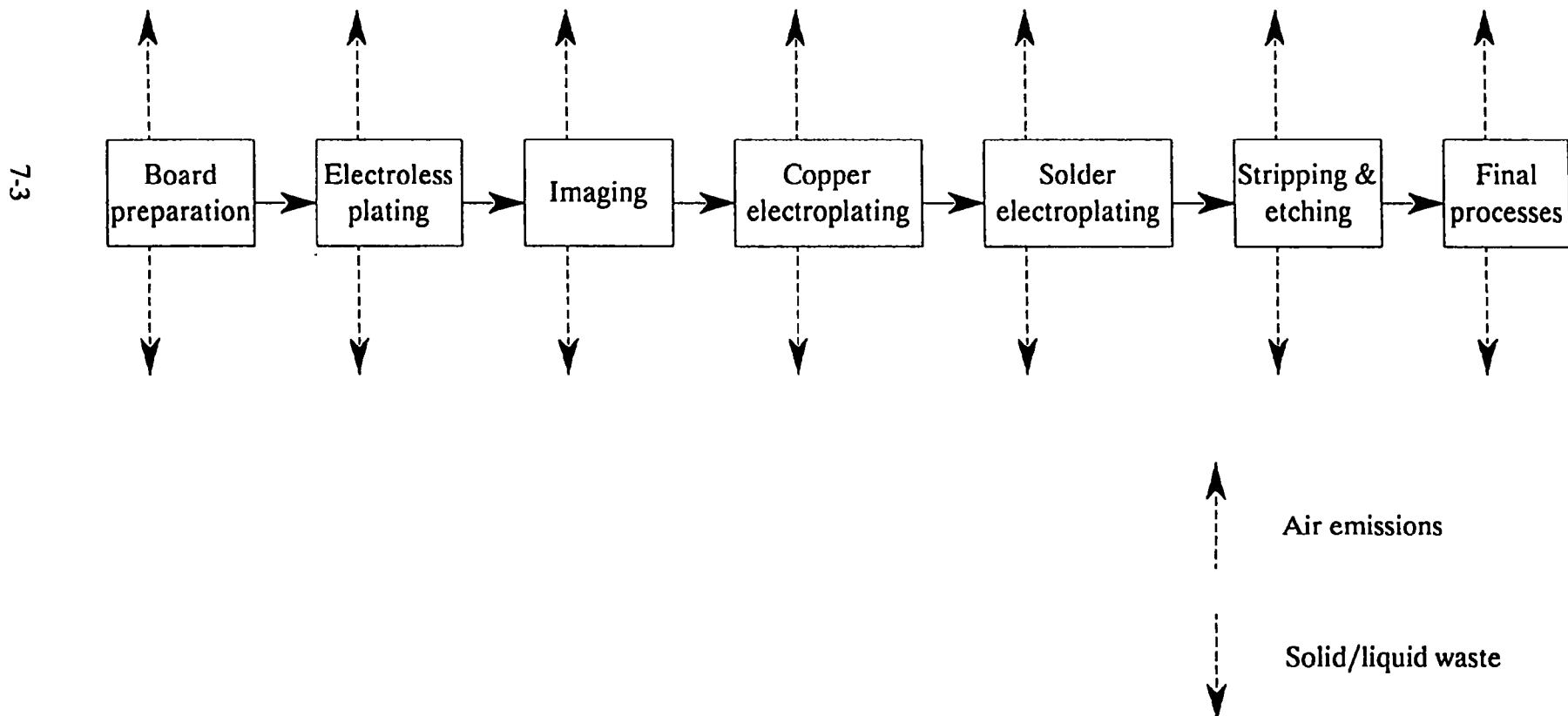
- cleaning and surface preparation
- catalyst application and electroless copper plating
- pattern printing and masking
- electroplating
- etching

The wastes generated include airborne particulates, spent plating baths, and waste rinsewater among others. Exhibit 1 indicates the sources of pollution.

C. POLLUTANTS AND THEIR CONTROL

Emissions of air pollutants from the manufacture of printed circuit boards stem primarily from the board cleaning and preparation process; other emissions are generally of much less significance. The majority of the emissions are acid fumes and organic vapors from the

EXHIBIT 1: Process Flow Diagram of a Typical Printed Circuit Board Manufacturing Plant



cleaning processes. Some particulates are also emitted in the drilling and finishing of the boards. Proper ventilation and exhaust of all process baths, rinse operations, and mechanical operations is essential to managing the air emissions of a printed circuit board manufacturing operation and can also contribute to reduction in liquid and metal waste generation. Exhibit 2 lists air pollutants and methods of control.

Each manufacturing process may generate multiple waste streams. Rinse water and other rinse solutions are usually the largest streams by volume, but are generally lower in concentration of hazardous chemicals than spent process baths. Contamination of rinse streams can be minimized by strategies that reduce drag-out of process solutions. Treatment and reuse of rinse streams is also effective in reducing overall waste generation.

Airborne particulates emitted from cutting, sanding, routing, drilling, beveling, and slotting operations during board preparations are usually controlled by baghouse and cyclone separators. The collected pollutants are then disposed of, along with other solid wastes at landfills.

Acid fumes from acid cleaning and organic vapors from vapor degreasing are usually not contaminated with other materials, and therefore are often kept separate for subsequent treatment. The acid fume air stream is collected via chemical fume hoods and sent to a scrubber where the acid is removed with water. The scrubbed air then passes on to the atmosphere, and the absorbing solution is neutralized along with other acidic waste streams. Similarly, organic fumes are often collected and passed through a bed of activated carbon. The carbon bed is then regenerated with steam. In many cases, the regenerative vapor is cooled and the condensate containing water and solvent drummed and set aside for off-site treatment. In a few cases, the regenerative vapor is combusted in a closed fumes burner.

The spent acid and alkaline solutions from the cleaning steps are either sent off site for disposal or neutralized and discharged to the sewer. Spent chlorinated organic solvents are often gravity separated and recovered in-house, or hauled away for reclaiming.

Most of the remaining wastes are liquid waste streams containing suspended solids, metals, fluoride, phosphorus, cyanide, and chelating agents. Low pH values often characterize the wastes due to acid cleaning operations. Liquid wastes may be controlled using end-of-pipe treatment systems, or a combination of in-line treatment and separate treatment of segregated waste streams. A traditional treatment system for the wastes generated is often based on pH adjustment and the addition of chemicals that will react with the soluble pollutants to precipitate out the dissolved contaminants in a form such as metal hydroxide or sulfate. The solid particles are removed as a wet sludge by filtration or flotation, and the water is discharged to the sewer. The diluted sludge is usually thickened before disposal in landfills. Recent improvements in in-line treatment technologies, such as reverse osmosis, ion exchange, membrane filtration, and advanced rinsing techniques, increase the possibility for the recovery and reuse of water and metallic resources.

Exhibit 3 delineates the waste streams from printed circuit board manufacturing.

Exhibit 2: Air Emissions from Printed Circuit Board Manufacturing

| Emission Point | Pollutants | Control Device |
|---------------------|--------------|------------------------------|
| Surface Preparation | Particulates | Baghouses/Cyclone separators |
| | VOC | Carbon adsorber |
| Surface Cleaning | Acid fumes | Wet scrubbers |
| | VOC | Carbon adsorber |

| Exhibit 3: Waste Streams From the Manufacture of Printed Circuit Boards | | |
|--|-------------------------------|---|
| WASTE SOURCE | WASTE STREAM DESCRIPTION | WASTE STREAM COMPOSITION |
| Cleaning/Surface Preparation | Spent acid/alkaline solution | metals, fluoride, acids, halogenated solvents, alkali, board materials, sanding materials |
| | Spent halogenated solvents | |
| | Waste rinse water | |
| Electroless Plating | Spent electroless copper bath | acids, stannic oxide, palladium, complexed metals, chelating agents, copper |
| | Spent catalyst solution | |
| | Spent acid solution | |
| | Waste rinse water | |
| Pattern Printing and Masking | Spent developing solution | vinyl polymers, chlorinated hydrocarbons, organic solvents, alkali |
| | Spent resist removal solution | |
| | Spent acid solution | |
| | Waste rinse water | |
| Electroplating | Spent plating bath | copper, nickel, tin, tin/lead, gold, fluoride, cyanide, sulfate |
| | Waste rinse water | |
| Etching | Spent etchant | ammonia, chromium, copper, iron, acids |
| | Waste rinse water | |

D. REFERENCES

This report contains excerpts of information taken directly from the following sources:

1. Higgins, Thomas. Hazardous Waste Minimization Handbook. Chelsea, Michigan: Lewis Publishers, Inc., 1991.
2. Jacobs Engineering Group, Guides to Pollution Prevention: The Printed Circuit Board Manufacturing Industry. Pasadena, California, June 1990.
3. Kirsch, F. W., and Looby, G. P. Waste Minimization Assessment for a Manufacturer of Printed Circuit Boards, July 1991. EPA/600/M-91/022

ELECTROPLATING

Electroplating is the process of depositing a coating having desirable characteristics by means of electrolysis. The purpose of electroplating is to alter the characteristics of a base metal's or other material's surface to provide improved appearance, ability to withstand corrosive agents, resistance to abrasion, or other desired properties, or a combination of them. The electroplating industry utilizes chemical and electrochemical operations to effect these improvements. Because metal electroplating is the most prevalent type, it will be used for process descriptions and pollutant identification.

A. PROCESS DESCRIPTION

1. Material Preparation

Base materials are generally prepared for plating by mechanical, chemical, or electrochemical means. Metal imperfections, scales, oils, and grease must be removed from the surface if electroplating is to be successful. Mechanical operations performed in electroplating facilities include abrasive blast cleaning, barrel finishing, grinding, polishing, and buffing. Chemical operations include degreasing, alkaline cleaning, acid treatments, chromating, phosphating, passivating, bright dipping, chemical polishing, and electroless nickel plating.

2. Plating

Electroplating operations include nickel, chromium, cadmium, zinc, copper, tin, iron, gold, and silver plating as the most important processes. Alloys may be deposited from solutions with compatible anions. Anodizing is used most often for aluminum plating. Each electroplating metal is chosen for its particular characteristics. Some common electroplating metals and their specific characteristics are:

- nickel: corrosion and wear resistance, and to rebuild worn parts.
- chrome: corrosion resistance, bright metallic appearance, impart improved mechanical properties (hardness, lubricity) to base.
- cadmium: corrosion protection
- zinc: corrosion protection
- copper: electrical conductivity properties
- gold: high conductivity, inertness, aesthetic appeal.
- silver: high conductivity, inertness, aesthetic appeal.

The plating cycle following the pretreatment steps can be very simple, such as a sequence of cleaning-rinsing-plating-rinsing-drying, or very complex, requiring a number of cleaning steps with additional steps of acid dipping, striking, activation, multiple rinses and the deposition of more than one metal. All processing steps within a given cycle must be arranged so that the solutions will not be contaminated. Cleaners, acid dips and strikes vary in composition and concentration and are formulated for a particular base material. Cleaners are generally alkaline and are used to remove the last traces of oil and grease.

Acid dips are not intended to remove scales or oxides but are used to neutralize traces of alkaline cleaners left on the base material after rinsing and to activate the surface to receive the electrodeposit. Some materials require more intense activation steps than others. Each base material must be treated differently and each metal deposited requires a specific cycle.

Thus, each electroplating operation is comprised of a number of steps of different duration, where the products are moved in a sequence from one chemical solution to another. Two operations used most frequently are barrel operations and rack plating.

- In **barrel operations** small parts are electroplated while tumbling freely in rotating barrels.
- In **rack plating**, components held in a rack are dipped into an electroplating solution. Rack plating is required for a large percentage of materials electroplated. Racks are used for reasons including maintenance of shape or surface conditions, achievement of the desired distribution of coating, or size or shape of workpiece.

3. **Alternative processes**

Recent developments such as new regulations on the discharge of toxic materials, the small number of certified landfill sites, and the rising costs of plating metals and chemicals have given rise to alternative electroplating methods. Some of the more prevalent methods include aluminum electroplating and ion vapor depositing.

a. Aluminum electroplating

Aluminum electroplating imparts corrosion resistance to the base material. This method is being used as a substitute for the costly and highly toxic cadmium electroplating. Aluminum is less costly than cadmium, and can be used at higher temperatures.

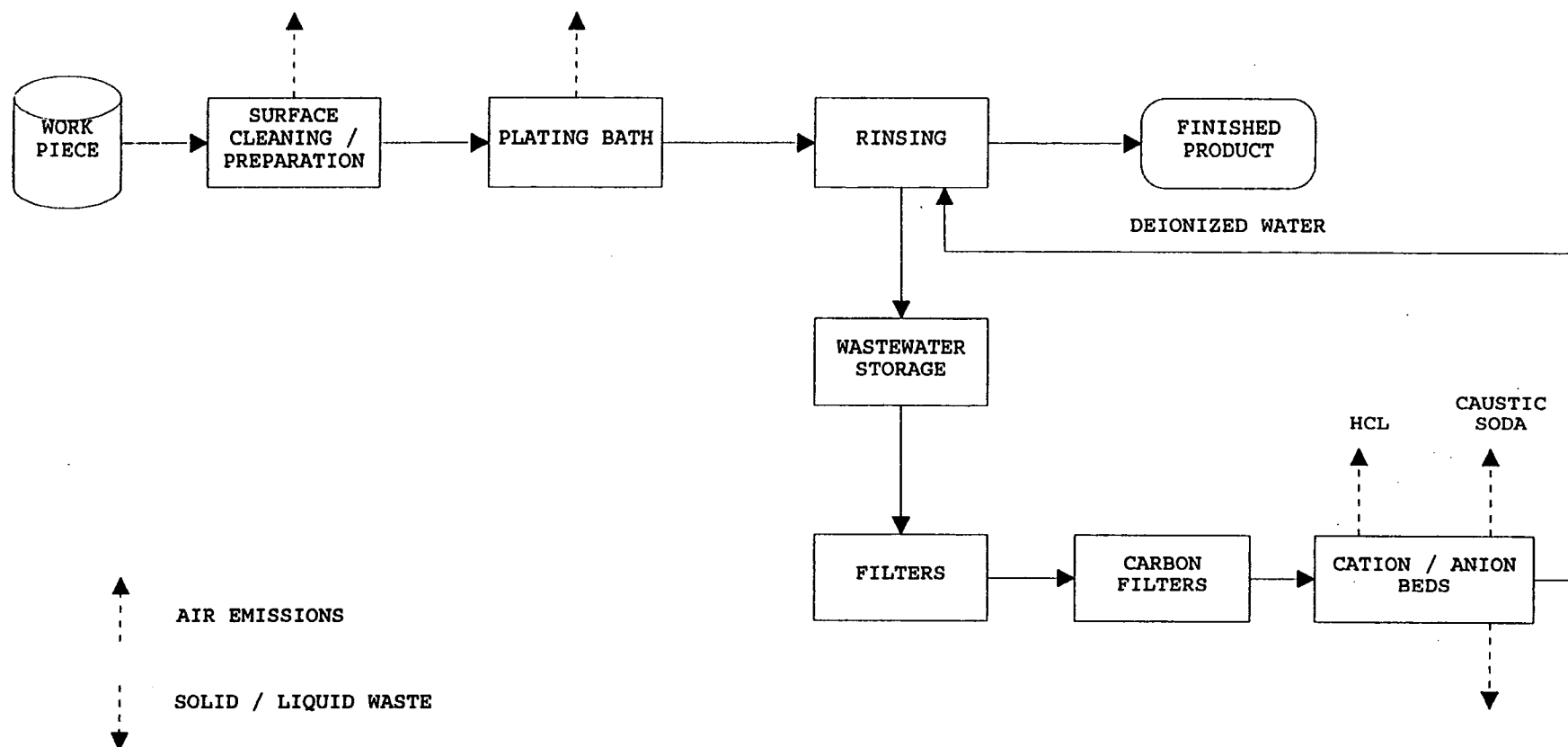
b. Ion vapor deposition

Old electroplating methods applied coating by dipping or by a metal spray. These are inefficient since they do not impart a thin and uniform coating. Ion vapor deposition utilizes a high-voltage system inside a vacuum to ionize the coating substance and impart a negative charge to the parts. This charge causes the coating substance ions to electrodeposit in the air. The air in the chamber is replaced by a low-pressure ionized gas. The substance's vapor must interact with the ionized inert gas to attract oppositely charged parts and coat them uniformly. Ion vapor deposition is most often used when aluminum is the coating substance.

B. SOURCES OF POLLUTION

There are several possible process paths for electroplating, each dependent on such factors as electroplating metal type, reason(s) for electroplating, and dip tank chemical makeup. The process diagram shown in Exhibit 1 is for a general electroplating process with acid recovery. All sources in the electroplating process emit air pollutants, and many generate hazardous waste. These are indicated in the exhibit.

EXHIBIT 1: Sources of Pollution in the Electroplating Process



C. POLLUTANTS AND THEIR CONTROL

Exhibit 2 identifies air emissions from electroplating operations, and Exhibit 3 identifies potentially hazardous waste generation.

Exhibit 2: Air Emissions From Different Chrome Electroplating Operations

| Emission Source | Pollutants | Emission Rate | Control Device | Control Eff. (%) |
|---|--|---|--|---|
| Surface Cleaning/ Preparation • Acid/alkali cleaning • Cold cleaners • Vapor degreasers | Cu, Ni, Zn, Pb Fe VOC VOC | 3 mg/l each 36 mg/l 190-560 kg/yr 9500 kg/yr | Covers Increased freeboard Refrigerated chiller Carbon adsorber | |
| Surface Modification • Hard chromium plating • Decorative chromium plating • Chromic acid anodizing | Cr ⁺⁶ | 15-90 g/hr 4-66 g/hr 1.2-2.8 g/hr | Demister Wet scrubber Chemical fume suppressants | 87.9-99.7 95.4-99.4 99.5-99.8 |

Exhibit 3: Potentially Hazardous Wastes Generated From Electroplating Operations

| Waste Source | Pollutant | Amount | Disposal Method |
|---------------------------|---|--------|-----------------|
| Chemical operations | Heavy metals | | Landfilling |
| Electroplating operations | Heavy metals Oil and grease Asbestos Cyanides Solvent | N/A | Landfilling |
| Degreasing | Chlorinated & fluorinated hydrocarbons ¹ | | N/A |

¹Hydrocarbons include trichloroethylene, perchloroethylene, methyl chloroform, trichlorotrifluoroethylene, methylene chloride.

Potentially hazardous wastes are found in one of three forms: (1) low-solids slurry, (2) high solids sludge, and (3) solid waste. Treatment of the low-solids slurry is performed by densification or densification and dewatering to produce a waste more easily disposed of to the land. Concentrated solutions of heavy metals may alternatively be treated by reclamation or chemical fixation and solidification. High-solids sludge and solid wastes are sometimes treated by volume reduction processes, such as incineration, to reduce the transportation and final disposal costs.

The increasing costs and liability of hazardous waste disposal are leading many electroplating facilities to incorporate process modifications to reduce hazardous waste generation. Some of these modifications include:

- Reduction of drag-out. Drag-out is the liquid which clings to a part as it is removed from a process bath.
- Modification of rinsing operations that are used to remove residual drag-out.
- Recovery of materials from rinsewaters.
- Reducing or eliminating tank dumping.
- Substituting less hazardous materials into the process (noncyanide baths, vacuum disposition, ion vapor deposition).

D. REFERENCES

1. Assessment of Industrial Hazardous Waste Practices: Electroplating and Metal Finishing Industries - Job Shops, EPA Hazardous Waste Management Division, 1976.
2. Hazardous Waste Minimization Handbook, 1991, pp. 75-212.

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LEAD SMELTING

Lead is usually found naturally as a sulfide ore containing small amounts of copper, iron, zinc, and other trace elements. There are two major lead smelting processes: primary lead smelting and secondary lead smelting. Primary lead smelting involves any process engaged in the production of lead from sulfide ore concentrates through the use of pyrometallurgical techniques. Secondary lead smelting involves the reclaiming and refining of lead from leadbearing scrap materials in which the predominant component is lead.

A. PROCESS DESCRIPTION

1. Primary lead smelting

The processing of lead from sulfide ores involves three major phases -- **sintering**, **reduction**, and **refining**.

a. *Sintering*

The sulfide ore is first reduced to sinter. Sinter is a coherent mass of lead formed by heating, but not melting, the ore. The sinter machine is a continuous steel pallet conveyor belt moved by gears and sprockets, with each pallet consisting of perforated or slotted grates. Fans beneath the pallets create a draft, either up or down, to create the conditions necessary for autogenous primary reactions.

The updraft sinter machine design is superior to the down-draft design for many reasons. The sinter bed is more permeable, which permits a higher production rate. Second, the small amounts of lead that form will solidify at their point of formation, instead of flowing down and collecting on the grates or at the bottom of the sinter charge and causing reduced blower capacity, as they do in a down-draft sinter machine. Also, the updraft design can produce sinter of higher lead content. Finally, the updraft design can produce a single strong sulfur dioxide effluent stream by the use of weak gas recirculation. This is extremely helpful in air emissions control. To maintain a desired sulfur content of 5 to 7 wt % in the sinter charge, limestone, silica, sinter recycle, and flue dust are often added to the sinter mix.

b. *Reduction*

After sintering, lead reduction occurs in a blast furnace. The blast furnace, which is a water-jacketed shaft furnace supported by a refractory base, is charged with a mixture of sinter, metallurgical coke, and various recycled and cleanup materials.

Solid products from the blast furnace generally separate into four layers: speiss (the lightest material, basically arsenic and antimony), matte (copper sulfide and other metal sulfides), slag (primarily silicates), and lead bullion. The first three layers are collectively called slag,

and contain most of the impurities. The slag is continuously collected and is either processed at the smelter for its metal content or shipped to treatment facilities.

After the lead bullion leaves the blast furnace, it usually requires preliminary treatment, or drossing, in kettles before undergoing refining operations. As the bullion is cooled, copper, sulfur, and other metals and impurities collect on the surface as dross. The dross is removed from the solution and may undergo some recovery methods.

c. *Refining*

The final smelting phase is refining, which is done in cast iron kettles. There are five refining steps:

1. Removal of antimony, tin, and arsenic.
2. Removal of metals by Parke's process.
3. Vacuum removal of zinc.
4. Removal of bismuth by the Betterson process.
5. Removal of remaining traces of metal impurities by the addition of NaOH and NaNO_3 .

The final refined lead is then cast into pigs for shipment.

2. *Secondary lead smelting*

Three types of furnaces are employed in the recovery of lead from scrap material, each with different processes and emissions: reverberatory, blast, and pot furnaces. Each furnace type also produces a different lead grade: soft, semisoft, and hard.

a. *Reverberatory Furnaces*

Reverberatory furnaces are used in sweating operations. Sweating heats the mix charge, melting the metal which is tapped off at intervals as semisoft lead. This is a continuous process, with more charge being added in such a manner as to keep a small mound of unmelted material on top of the bath. Reverberatory furnaces are also used to reclaim lead from oxides and drosses.

The reverberatory furnace produces semisoft lead which usually contains trace amounts of antimony and copper.

b. *Blast Furnaces*

Blast furnaces, or cupolas, are similar to those used in the ferrous industry. Rerun slag, scrap cast iron, limestone, coke, drosses, oxides, and reverberatory slags form the usual charge in a blast furnace. Hard lead is charged into the cupola at the start of the process

to provide molten metal to fill the crucible. The charges are added as the material metal melts down. The limestone and iron form a flux that floats on the top of the molten lead and retards oxidation.

Slag is tapped at intervals while the molten lead flows from the furnace at a more or less continuous rate. Approximately 70% of the molten material is tapped off as lead and the remaining 30% as slag. About 5% of the slag is retained for later use. The blast furnace produces hard lead, which typically contains 5-12% antimony and trace amounts of arsenic, tin, copper, and nickel.

c. *Pot Furnaces*

Pot-type furnaces are used for remelting, alloying, and refining processes. Remelting is usually done in small furnaces using alloys in ingot form as charge. Alloying usually begins with a metal lower in the percentage of alloying materials than desired. The required amount is then added to the molten material. Antimony, tin, arsenic, copper, and nickel are the most commonly used alloying elements.

The refining processes most commonly used are those for the removal of copper and antimony to produce soft lead, and those for the removal of arsenic, copper, and nickel to produce hard lead. Aluminum is often added to the molten lead. The aluminum reacts with copper, antimony, and nickel to form complex compounds that can be skimmed off the surface. A procedure known as "dry drossing", where sawdust is introduced into the agitated mass of molten metal, is also used. During dry drossing, carbon, which aids in separating globules of lead suspended in the dross, is formed.

Pot furnaces generally produce soft lead, a high-purity grade formed after considerable refining has been performed. Soft lead may be designated as corroding, chemical, acid copper, or common desilverized lead.

B. SOURCES OF POLLUTANTS

Exhibit 1 is a flow diagram of the primary lead smelting process. Both air emission points and hazardous waste generation points are identified. Exhibit 2 identifies the air emission points and hazardous waste generation points for the general secondary lead smelting process.

C. POLLUTANTS AND THEIR CONTROL

Exhibits 3 and 4 identify the pollutants by source that are emitted or generated by the various smelting processes. Exhibit 3 presents air pollutants, and identifies control devices, if any, for primary and secondary lead smelters. Exhibit 4 presents hazardous waste pollutants, and identifies the disposal methods, if any.

EXHIBIT 1: Diagram of a Typical Primary Lead Smelting Process

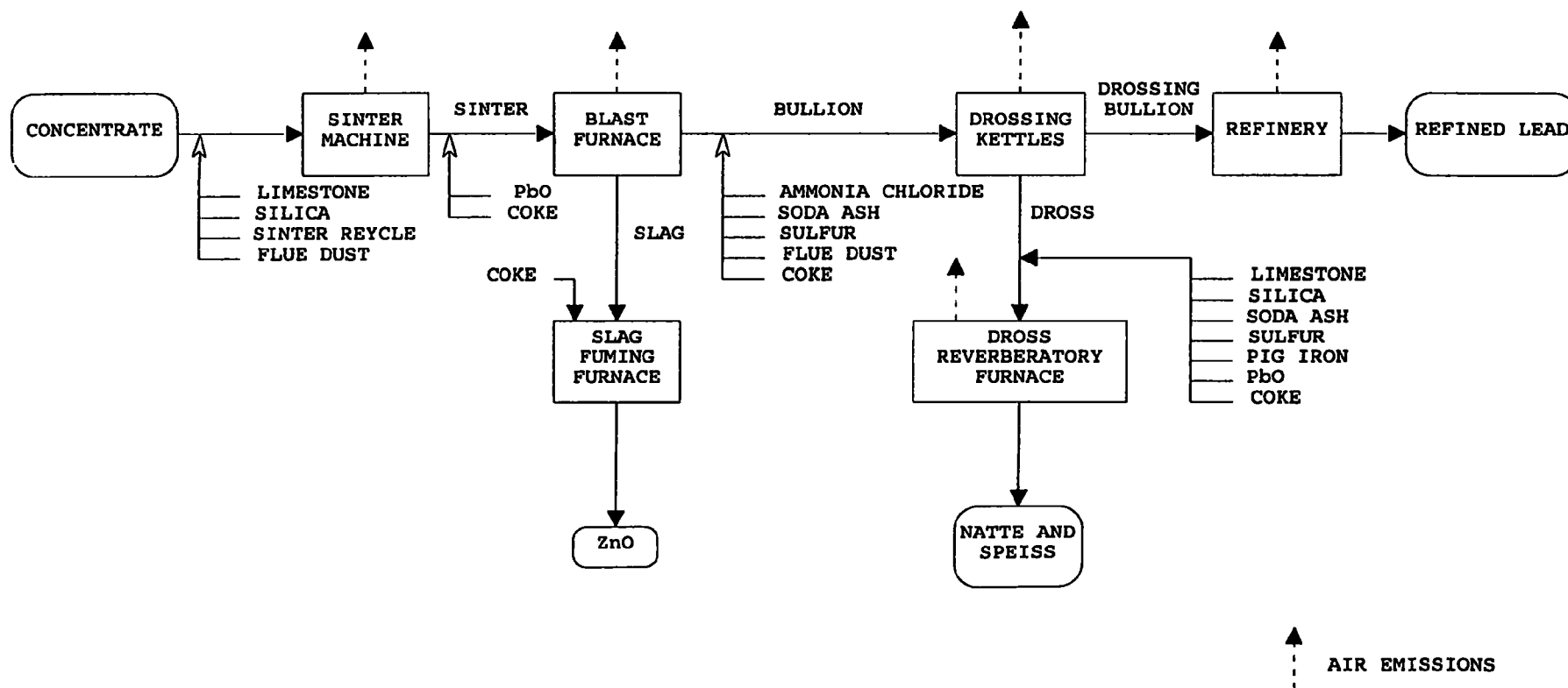


EXHIBIT 2: Diagram of a Typical Secondary Lead Smelting Process

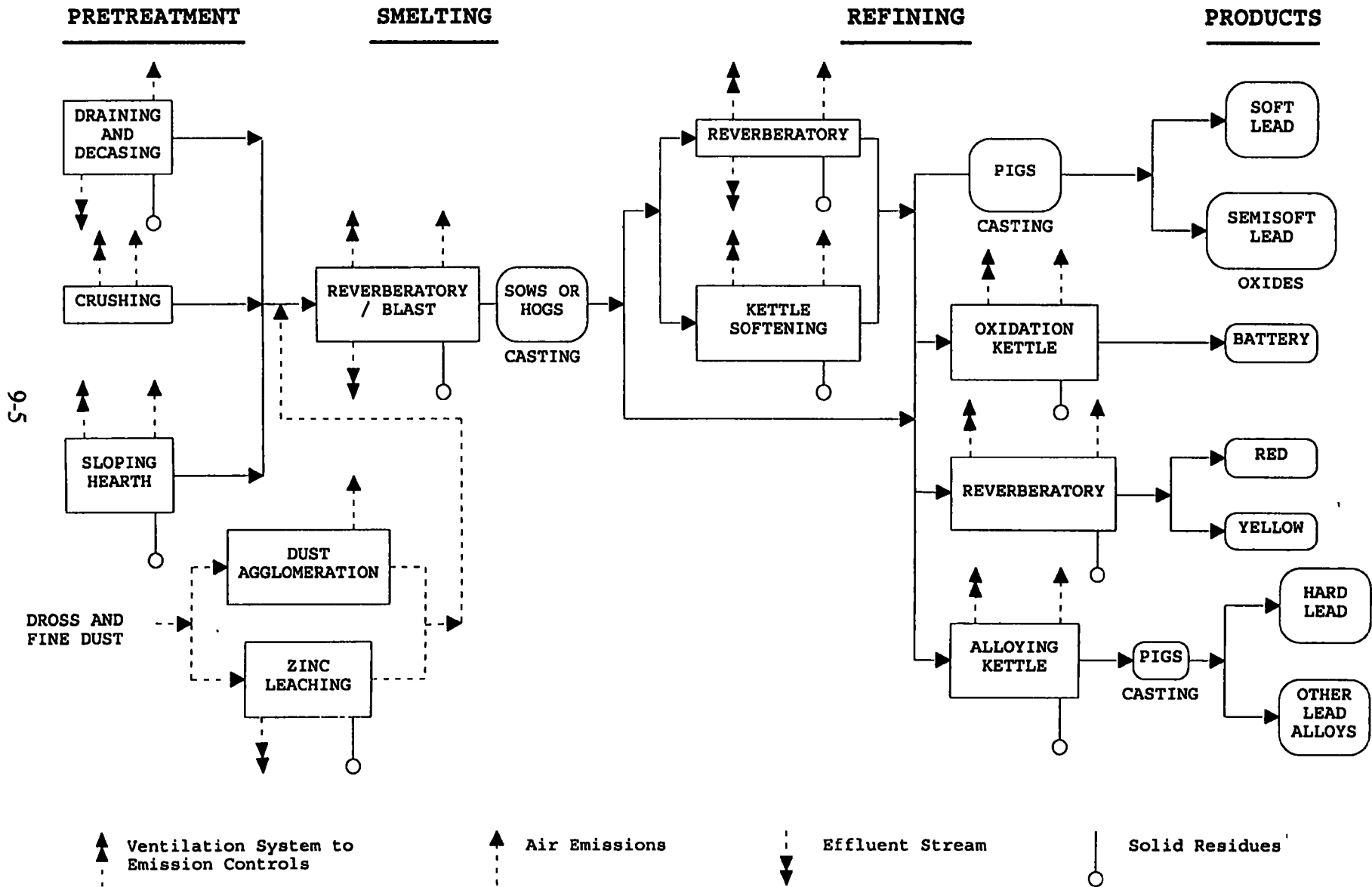


Exhibit 3: Air Emissions From Primary and Secondary Lead Smelters

| Emission Point | Pollutants | Emission Rate | Control Device | Control Eff.(%) |
|--------------------------|--|----------------------------|--|-----------------|
| PRIMARY LEAD SMELTING | | | | |
| Öre Crushing | Particulates | 1.0 kg/mt | Baghouse | 95-99 |
| | SO ₂ | No data | | |
| Sinter Machine | Particulates | 106.5 kg/mt | Baghouse ESP | 95-99 95-99 |
| | SO ₂ | 275.0 kg/mt | Sulfuric acid plants | > 96 |
| | POM, As, fluorides, Sb, Pb, Hg, Se | Trace amounts | | |
| Blast Furnace | Particulates | 180.5 kg/mt | Baghouse | 95-99 |
| | SO ₂ | 22.5 kg/mt | | |
| | POM, As, fluorides, Sb, Cd, Pb, Hg, Se | Trace amounts | | |
| Dross Reverb. Furnace | Particulates | 10.0 kg/mt | | |
| Refining | Particulates SO ₂ | | | |
| Materials Handling | Particulates | 2.5 kg/mt | Enclosures Water spraying | |
| | SO ₂ | No data | | |
| SECONDARY LEAD SMELTING | | | | |
| Reverb. Furnace | Particulates SO ₂ ; SO ₃ ; oxides, sulfides/sulfates of Pb, Sn, As, Cu, | 1.4-4.5 gr/ft ³ | Baghouse with gas-cooling devices & settling chambers | |
| Lead Blast Furnace | Particulates CO | Up to 4 gr/ft ³ | Hoods; Baghouse; Afterburner | |
| Pot-type Furnace | Lead oxide Particulates | | Baghouse | |

Exhibit 4: Sources of Hazardous Waste in Lead Smelting Operations

| Waste Source | Pollutant | Amount (mt/y) ^a | Disposal Method |
|--|---|---|--|
| Primary | Heavy metals (As, Cd, Cr, Cu, Hg, Pb, Sb, Zn) | 4400 | Land storage before recycle. Immediate recycle. Land storage or open dumping of dredged sludge in unlined lagoons. |
| Secondary | Heavy metals (Cu, Cr, Pb, Sb, Sn, Zn) | 160 | Dumping in lined or unlined lagoon. |
| Blast furnace slag | Cr Cu Mn Ni Pb Sb Sn Zn | 2 18 2 2 162 10 2 10 | Open dumping of discarded slag. |
| Scrubber slag | Cd Cr Cu Mn Pb Sb Zn | 0.02 0.001 0.001 0.005 24 0.5 0.001 | |
| Cupola furnace slag & matte | Cu Mn Ni Pb Sb Sn Zn | 41 0.4 0.4 158 4 0.4 2 | |
| Reverb. furnace slag | Cr Cu Mn Pb Sb Sn Zn | 0.8 0.2 1.2 8 0.1 30 0.8 | |
| | | | |
| | | | |

^a metric tons per year

D. REFERENCES

1. Air Pollution Engineering Manual, Air & Waste Management Association.
2. 40 CFR 60, Part R