Incorporation of Occupational Safety and Health into Unit Operations Laboratory Courses

NIOSH Instructional Module

SHAPE
Safety/Health Awareness for Preventive Engineering

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control
National Institute for Occupational Safety and Health

CDC
CENTERS FOR DISEASE CONTROL

INCORPORATION OF OCCUPATIONAL SAFETY AND HEALTH INTO UNIT OPERATIONS LABORATORY COURSES

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DISCLAIMER

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ABSTRACT

The primary objective of this instructional module is the development of an awareness in the faculty and students of the many facets of occupational safety and health (OS&H) as applied to laboratory work and pilot-plant operations. The students should become convinced, through exposure to OS&H principles in this course, that safety and health must be part of everything they do in the laboratory environment. The secondary objective of this instructional module is to ensure a safe laboratory environment for the conduct of routine chemical analyses and operation of bench- or pilot-scale unit operations equipment.

Unit I provides the background for the module in terms of industry needs for safety and health awareness on the part of all new engineering graduates. Unit II, an introduction to the module, describes the responsibility of the Unit Operations Laboratory Director to incorporate safety and health training throughout the course(s). Unit III presents the departmental safety and health program and its various functions: training, inspections, and development of supplemental safety and health regulations for the Unit Operations Laboratory.

Unit IV presents and explains general safety rules. The special safety precautions (preparation for workplace emergencies, use of personal protective equipment, and emergency shutdown procedures) required for the Unit Operations Laboratory are covered in Unit V. The sources and utilization of codified regulations and voluntary health and safety standards are discussed in Unit VI. Development of student awareness, rather than acquisition of detailed specific knowledge is the objective of this Unit. Special emphasis is given in this Unit to the Hazard Communication Standard and to the content and use of material safety data sheets. This Unit also serves to link safety and health instruction in Unit Operations Laboratory courses to the corresponding portions of Process/Plant Design courses.

Unit VII discusses the safety and health principles required for Unit Operations Laboratory courses in general. This Unit provides special emphasis on electrical safety, fire safety, handling and use of flammable and explosive liquids, machine safeguarding, and laboratory ventilation.

Unit VIII is a general introduction to industrial hygiene. Although the applications discussed will be directed toward Unit Operations Laboratory procedures and experiments, the knowledge gained by the students should be directly applicable to any industrial position after graduation. Again, this part of the module should form a link to the student's design course(s).

Unit IX is directed towards the students' responsibilities during the planning and execution phases of Unit Operations Laboratory experimentation. It is assumed that the supervising faculty will assign an experimental objective and will then teach the students how to plan and evaluate a proposed experiment using a hazard review approach. Although repeated checks with the instructor or teaching assistant are built into the planning/review and conduct phases of the experiment, it is not envisioned that this section will be used as a checklist for proper procedure under all circumstances.

Unit X is devoted to the methods by which chemical and physical hazards may be prevented or minimized in the Unit Operations Laboratory. Students will become familiar with hazard identification and the most common control options. The assumption has been made that the Laboratory is operated as a small, highly diverse, pilot plant. The recommendations presented in this section should have immediate impact not only on the students' design courses, but also on their behavior at their first job after graduation.

Unit I
BACKGROUND

PURPOSE:

To present an overview of the industrial concept of occupational safety and health and of the need for new graduates with bachelor of science in chemical engineering (B.S.Ch.E.) degrees to be able to function within such a system.

OBJECTIVE

To familiarize the laboratory director/instructor of required Unit Operations Laboratory course(s) with:

1. The industrial approach to safety and health
2. The level of training in and awareness of safety and health topics that the B.S.Ch.E. graduate should have
3. The specific safety and health topics the B.S.Ch.E. graduate should be aware of
4. The need for improving the communications skills of these students

INTRODUCTION

Necessity for including safety and health topics in engineering curricula

Including occupational safety and health topics as required components in all undergraduate engineering curricula results from the emphasis placed on this topic by various professional engineering societies including the American Academy of Environmental Engineers. These organizations have, in turn, been persuaded that safety and health is an essential design element by the efforts of the National Institute for Occupational Safety and Health (NIOSH), the National Safety Council (NSC), and various trade unions. The Academy's definition of environmental engineering includes both safety and health and environmental protection and is stated as " . . . the application of engineering principles to the management of the environment for the protection of human health, for the protection of . . . ecosystems, and for the environment-related enhancement of the quality of human life."[1]

INDUSTRIAL APPROACH TO SAFETY AND HEALTH

Several years ago, while teaching a process design course, one of my colleagues commented that, "A degree in chemical engineering is almost a license to kill." At that time, his perception of academia was uncomfortably near the truth, as safety and health topics received little attention in chemical engineering curricula except in process/plant design courses. Fortunately, his pessimistic view was not shared by industry for, at the same time, industrial leaders were setting good examples of safe performance for a healthy workforce.

Commitment to safety is the industrial norm

E.G. Jefferson, when he was chairman and chief executive officer (CEO) of E.I. duPont de Nemours & Co., expressed his company's philosophy as follows: "An operation that has demonstrated good, sustained safety performance usually [has] the added benefits of good housekeeping, good product quality, and high morale."[2] He continued, pointing out that " . . . the analysis and training that are essential to good safety bring also the benefits of superior operational control." He summed up the duPont commitment to safety in this way, " . . . no process is designed, no product manufactured, and no job performed without safety engineered into it. Safety is considered at the inception of everything we set out to do. And it is one of the chief factors in determining whether or not we continue doing it."

Safety is an integral part of design

In duPont's approach to safety and health, the implication is clear: safety is an integral part of design. A system approach is required to ensure that all designs include safety and health as integral components. It should be obvious that proper attention to safety and health is fundamental to the continued existence of any business. DuPont's experience in international operations has shown that the commitment to safety and health is a valuable corporate asset and one that is fully transferable across cultural boundaries.

Safety is an essential performance measurement criterion

The commitment of the Dow Chemical Company and its overseas subsidiaries fully parallels the duPont philosophy and experience. P.F. Oreffice, president and CEO,[3] stated Dow's basic policy: "Employees . . . must perform in such a manner as to prevent accidents which can cause personal injury [or] illness . . . and Dow facilities must be designed and operated to prevent property loss and interruption to our business. Safety performance and attitude shall be considered major and an essential employee performance measurement criteria. Every supervisor has the responsibility to provide a safe work environment with proper equipment and adequate training."

Safety and health applies to all employees

These statements by the CEOs of major chemical firms apply to all engineers and other employees, not just to chemists and chemical engineers. Occupational safety and health needs and the specific problem of worker protection must be addressed by all professions.

Extent of work-related injuries and illness in 1988

Many companies have now become fully committed to safety and industrial hygiene as integral parts of their operating philosophy. Some have made the decision to participate in the Occupational Safety and Health Administration's (OSHA) Voluntary Protection Program. One company reduced work-related injuries and illness 11% and workers' compensation costs 48%.[4] If every company, regardless of size, would do likewise, they would significantly decrease the 3270 job-related fatalities and 6.44 million injuries and illnesses that were reported in 1988.[5]

Genesis of Project SHAPE by NIOSH

As a typical professor, I have been exposed to industrial safety and occupational health programs: during summer industrial employment, through the safety program in the College of Engineering at Iowa State University, and while on a 2-yr assignment to National Aeronautics and Space Administration (NASA). Even with this exposure, no aspects of safety and health or of loss prevention trickled down into the classroom; engineering education in general was simply not safety oriented. To change that situation, Project SHAPE (Safety and Health Awareness through Preventive Engineering) was developed by the National Institute for Occupational Safety and Health (NIOSH).

Status of safety and health training in ChE departments in 1988

When undergraduate chemical engineering departments were surveyed in 1988 about the extent of safety and health topics in their programs, 74% indicated that safety and health had little or no part of the training in unit operations laboratories other than requiring that hard hats and safety goggles be worn. Fortunately, engineering departments can no longer take this attitude. The Accreditation Board for Engineering and Technology has decided that a significant safety and health content should be included in the design of all engineering curricula starting with accreditation visits beginning in September 1988.

WHAT INDUSTRY WANTS AND NEEDS

Industrial needs (1988) for safety and health awareness

To incorporate safety and health into the engineering curricula on our campus, over 70 engineering managers who hire new engineering graduates to work in the chemical, construction, electronics, aircraft, petroleum, and manufacturing industries were asked, "Regardless of curriculum, what safety and health background do you want each new engineering graduate to bring to his/her first job with your company?" The respondents wanted the new hirees to have an awareness of the personal responsibility of the engineer to ensure safe designs and of the consequences of failing to do so. In addition, these respondents uniformly wanted the new B.S. engineers to be aware of the different types of codes with which they will deal, such as the National Electric Code and American Society of Mechanical Engineers (ASME) pressure vessel codes. Note the emphasis: the students should be aware of the codes, *not* fully conversant with their contents. In addition, these experienced engineering managers wanted the new graduate to be knowledgeable of the general provisions of consumer product-safety standards, the principles of the Occupational Safety and Health Act (OSHAct), and the need to consider a wide range of environmental laws.

In addition, some engineering managers wanted the new graduate to be familiar with all EPA regulations. The extreme response could be paraphrased as follows, "The new hiree should be a Certified Safety Professional, a Registered Professional Engineer, a Certified Industrial Hygienist, and, oh yes, only 22 years old."

Person-oriented and system-oriented health and safety awareness

As a group, the respondents also said that it would be highly desirable if the new B.S. engineer had not only an awareness, but also some familiarity with person-oriented safety and health precautions common to that industry, such as:

- awareness of employer requirements
- economic impact of occupational safety and health
- community interdependence
- psychology of influencing human behavior
- human factors
- general safe work practices
- necessity for isolation

and safety topics related to physical facilities and design, such as:

- common sense approach
- need for continual systems reevaluation
- design of fail-safe systems
- process interlock logic and design
- hazards identification and evaluation
- fire protection systems
- electrical classification and codes
- pressure-vessel codes

- safety and health inspection techniques
- accident investigation methodology

Especially notable in the first list is the inclusion of community interdependence, Community Awareness and Emergency Response (CAER). The new graduate must realize that the systems he/she designs or works with do not exist in a vacuum—there is a responsibility to protect the surrounding community. It is thus reasonable to expect help from that community in times of catastrophe. The destruction of a large portion of the Hoechst-Celanese plant in Pampa, Texas, on November 14, 1987, probably caused by an unconfined vapor-cloud explosion, destroyed all on-site emergency vehicles. Fire trucks and ambulances were sent from nearby communities within minutes of the explosion. Implementation of the CAER program at the Pampa facility was a deliberate management decision and one that repaid the company's investment in time and money many times over.

Communications skills are essential

Some persons have the inate ability to influence human behavior. For others, it can be a skill unconsciously learned by those new graduates who have been involved in extracurricular college activities. Others will have to develop that capability. But all new graduates must learn the knack of listening discerningly to peers and especially to subordinates, technicians, operators, and assembly-line workers. The new graduate must also be an efficient and effective communicator in the medium of written reports and memoranda, operating procedures, etc. The ability to promote and improve safe conditions is severely compromised if these communications skills are poorly developed.

Students must learn to analyze problems

Many respondents from industry expressed the feeling that, "Universities are supposed to be teaching these young people to think. Well, teach them to think rationally, to apply common sense and safety and health principles in the design and conduct of all laboratory procedures and experiments. Teach them that they must always question their own work and that of others." Students must be taught to analyze all problems from many points of view including theory, application, economics, and safety and health in order to winnow out those relevant facts and criteria that will lead to a safe and productive experiment. Because these approaches must be followed in industry, the students must begin to learn these techniques in the laboratory.

Laboratory projects require continual evaluation for safety

Young engineers have almost invariably had scientific principles explained to them in terms of a "sanitized" universe where all processes operate at steady state and there are no unplanned outages. Transient conditions, whether due to scheduled turnaround, power outage, weather, fire, or even sabotage, are often the most dangerous of all. For this reason, all experiments must be continually evaluated for safety and health, and all laboratory practices and operating procedures must incorporate fail-safe principles. Junior and senior chemical engineering students cannot hope to have all the necessary skills to cope with these situations. They can, however, be taught to analyze all aspects of their experiments. They must learn to examine every experiment critically and to willingly and thankfully correct errors.

Desirable health topics: regulatory structure, health effects, monitoring and control

The engineering managers indicated that it would be desirable for all new engineering graduates to have some knowledge of such health topics as:

- overview of regulatory structure
- potential adverse health effects from chemicals
- exposure monitoring techniques
- evaluation of long-term health effects
- exposure reduction techniques
- safe work practices

The need for an overview of the regulatory structure was the most frequently identified topic. An overview is just that: an awareness that regulations exist, what they generally control, and where all the details can be found in an understandable form. The effects on human health from chemical exposure are common to all industry; only the chemicals and the populations potentially exposed change. Although exposure monitoring is normally done by the local industrial hygiene technician, plant nurse, consultant, or insurance company employee, the engineer should be aware of the need for these procedures in the workplace. Only monitoring can indicate whether the original system design will minimize long-term human-health effects and whether the equipment and all parts of the process are still functioning as intended. The newly hired engineer should have a general knowledge of the techniques for reducing worker exposure through engineering controls (design changes), administrative controls including evaluation and modification of work practices, and as a last resort, use of personal protective equipment.

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Unit II
INTRODUCTION TO THE MODULE

PURPOSE:

To introduce the module and to describe its purpose.

OBJECTIVE:

To define the responsibilities of the laboratory director, teaching assistants, and other laboratory personnel and associated faculty when teaching and implementing safety and health educational and protective programs in the Unit Operations Laboratory including:

1. Responsibility for safety and health education
2. Common safety problems
3. Safe work practices and chemical handling procedures for experiments
4. Purposes and functions of the Unit Operations Laboratory

SPECIAL TERMS:

1. Hazard recognition
2. Code of Federal Regulations (CFR)
3. Portals of entry
4. Exposure limits
5. Material safety data sheet (MSDS)

AIM OF THE MODULE

The aim of this module is to present a two-fold concept: teaching safety and health in the undergraduate curriculum and practicing safety and health in the laboratory. Practicing and teaching safety and health in the college/university chemical engineering department's Unit Operations Laboratory will instill in students the habits and practices that will eventually lead to safety and health in the workplace.

SCOPE OF UNIVERSITY COMMITMENT TO SAFETY AND HEALTH

Laboratory safety requires a total commitment by the central administration of the institution. This administration commitment must be evident in two ways: by financing and by encouraging and promoting the development of safety and health programs.

RESPONSIBILITY FOR SAFETY AND HEALTH EDUCATION

Faculty and staff: four responsibilities

Specific safety and health education for all engineering is carried out at three levels: professors and staff, teaching and research assistants, and students. This training should be coordinated with the college or university safety and health staffs. The faculty and departmental technicians have the primary responsibility

1. to identify and evaluate actual and potential hazards,
2. to estimate the relative severity of each hazard and the probability of its occurrence,
3. to upgrade the teaching and research facilities so the frequency and severity of accidents will be reduced, with the ultimate goal being accident prevention, and
4. to train all the students they supervise in the principles of hazard recognition and prevention.

The faculty and staff must also estimate the relative severity of each hazard and the probability of occurrence. In all laboratory activities, it is essential that "hazard communication" be interpreted not only as the "right to know" about any potential hazards and their consequences that may be encountered in laboratory or field work, but also as the right of students to report noncompliance with the established safety and health policies without fear that the student's grade might be compromised.

Teaching and research assistants: three responsibilities

Teaching and research assistants have the responsibility to assist with all safety and health training, as requested. It is also their responsibility to continually evaluate the conditions within the laboratory, the behavior of the students, and their approach to each experiment. Above all, teaching assistants should listen to the comments of the students in their charge, for students will talk with and comment to the teaching assistants more freely than to the supervising professors. In this way, the assistants will be able to monitor the experiments for needed improvements in theory, demonstration, and safety. The teaching assistants also have the responsibility of enforcing the departmental safety regulations in the laboratories they supervise. They must be given adequate, though closely monitored, authority to do so.

Student responsibilities

The students in the laboratories are responsible for their own personal safety and for that of others by observing all safety and health rules. If the departmental safety system works properly, students will not hesitate to report unsafe acts or conditions, as they know that failure to insist on safety may place their own well-being in jeopardy.

COMMON SAFETY PROBLEMS

Among the most common laboratory safety problems are housekeeping; storage of solvents (in excessive quantities [see 29 CFR* 1910.106], in improper containers, in unapproved storage facilities, or too close to oxiders); electrical hazards (underpowered electrical circuits, disintegrating electrical connections, and ungrounded apparatus); inadequate ventilation (inoperative fume hoods or those without face guards or inadequate face air velocity); and insufficient machine guards. Perhaps the two most common deficiencies in laboratories are the lack of safety equipment and insufficient emergency preparation on the part of the instructor.

Student awareness of chemical toxicity

Students should be informed of the toxicity and fire and explosion hazards of the various chemicals used in each experiment to implement safety and health awareness in introductory and organic chemistry laboratories. The toxicologic effects can be described in terms

*Code of Federal Regulations.

of portals of entry, organs affected, and standard exposure limits. Students should have access to and be required to read the material safety data sheet (MSDS) for every chemical they use. In addition, the students should be made aware of common references describing safe laboratory procedures.[1-3] The assistance of local university safety officers and the college of engineering safety and health committee should be sought by each laboratory director/instructor in developing specific safety procedures for each laboratory course and in designating primary and alternate evacuation routes.

Need for safe laboratory work practices, handling of spills

Safe work practices and chemical handling procedures including the need for any personal protective equipment (PPE) should be included in the description of each experiment. The disposal of chemicals should also be covered in terms of the need for neutralization of acids or bases, the separation of possibly reactive species, and the types of disposal containers for different materials.

UNIT OPERATIONS LABORATORY

Purposes:

1. Reinforce theory

The Unit Operations Laboratory courses in chemical engineering have many purposes. The first purpose is to reinforce theoretical coursework through the medium of experimentation with pilot-size or laboratory-size apparatus. To achieve this purpose, the students must learn to define problems; to plan and design experiments that will generate laboratory data on various aspects (fluid mechanics, heat and mass transfer operations, thermodynamics, kinetics, etc.) of chemical engineering theory; to collect, analyze, and interpret the data; and to report the results in professional form through written and oral reports. Pilot plant and laboratory experiments of all types, regardless of scale, can be hazardous if the requisite emphasis, care, and attention are not devoted to safety. It is of paramount importance that the students learn to work safely in the laboratory, whether as individuals or as part of a team.

2. Model validation

The second purpose of Unit Operations Laboratory courses is to provide students with examples of the agreement or lack thereof between mathematical models of chemical engineering operations and the results of the operations themselves. The students must also learn to use basic statistical techniques to facilitate data interpretation.

3. Learn to work safely and cooperatively in groups

Unit Operations Laboratory experiments are usually carried out by groups of two to four students. The third purpose of these courses is, therefore, to teach groups of students to work together safely and cooperatively. To accomplish this goal, students must learn to define and assign responsibility for various tasks associated with the group effort. The safety principles learned in the laboratory are applicable throughout the chemical and processing industries, in manufacturing environments, for the development of new materials, etc. The motivation for the students to learn these principles and techniques is survival: in industry, an error in safety can have catastrophic consequences, e.g., Texas City, Seveso, Flixborough, Bhopal, etc.[4,5]

Essential elements of hazard reduction and safe operation

Students must become indoctrinated with an understanding of the essential elements of hazard reduction and safe operations: accident anticipation, prevention, and control. The first of these elements involves developing safe procedures for equipment operation, knowing when personal protective equipment is required, and developing laboratory housekeeping procedures to meet industrial standards. The second element involves knowing emergency procedures including first aid, cardiopulmonary resuscitation (CPR), and the use of safety equipment. Medical treatment and damage control are the principal parts of the third element, but these are not responsibilities of the students.

Motivation for instruction in safety and loss prevention

Engineering faculty in general and chemical engineering faculty in particular must motivate their students to be concerned with the safety and health aspects of their professions. Safety and loss prevention are based on application of many of the same principles found in thermodynamics, fluid mechanics, heat transfer, etc. The faculty have the responsibility to aid the student in developing the "industrial attitude": worker and user safety, first; environmental protection, second; process control, even in unusual circumstances, third; and profit, last. The students must be taught to plan their experiments as if disaster is going to happen and to conduct the experiments safely for the benefit of all concerned.

The students must be knowledgeable about the potential safety and health hazards associated with their equipment and the chemicals they will use before starting experimentation.

USE OF MODULE

This module outlines the safety and health principles that should be included in Unit Operations Laboratory courses. The module is arranged in discrete sections so that faculty members may select those portions of the instruction they wish to add to their courses. Questions that may be used for quizzes on safety and health topics are included at the end of each subsequent unit.

Because some topics in this Module must necessarily be approached from several points of view, they will appear in different Units throughout the Module. The Index, the last Unit, should be relied on to seek additional and "see also" information.

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Unit III

SAFETY PROCEDURES AND PROGRAMS FOR THE UNIVERSITY/COLLEGE AND ITS UNIT OPERATIONS LABORATORIES

PURPOSE:

To describe the objectives of the university/college safety programs and the functions of the departmental safety committee.

OBJECTIVE:

To review the responsibilities and functions of appropriate campus or departmental safety programs that can provide assistance with safety instruction and training in the Unit Operations Laboratory:

1. Safety officer
2. Industrial hygiene staff
3. Fire marshal
4. Radiation safety officer
5. Departmental safety program
6. Functions of departmental safety committee
7. Audits and inspections
8. Responsibilities of faculty and staff for safety training

SPECIAL TERMS:

1. Hazardous waste chemicals
2. Respiratory protection
3. Hearing conservation
4. Hazard communication
5. Biological monitoring
6. Ionizing and nonionizing radiation
7. Audits and inspections
8. Material safety data sheet (MSDS)

INTRODUCTION

Objective of safety and health program

The objective of any college or university health and safety program must be to provide a safe and healthful atmosphere for all members of the college/university community. All administrators, faculty and staff, and students must take an active part in minimizing risks and in initiating (and completing, as appropriate) preventive measures to control any hazards associated with the activities under their direction or control. Safety must be an integral part of all aspects of each program at the college/university.

COLLEGE/UNIVERSITY SAFETY PROGRAM

Basis for campus safety and health program

The administration must ensure that the college/university complies with the intent of all applicable federal and state legislation and subsequent amendments including the following:

- Clean Air Act of 1963 and the Amendments of 1970;
- The Occupational Safety and Health Act of 1970 and any corresponding state statutes (e.g., the Texas Occupational Health Act of 1967 and the Texas Hazard Communication Act of 1985);
- The Water Pollution Control Act of 1970;
- The Energy Reorganization Act of 1974 and corresponding state statutes (e.g., Texas Radiation Control Act of 1961);
- The Resource Conservation and Recovery Act of 1976;
- The Toxic Substances Control Act of 1976;
- The workers compensation act for their state;
- National Fire Protection Association (NFPA) codes; and
- All future federal and state laws, acts, and regulations that relate to the college/university safety program.

The laws and regulations and such rules and procedures developed and promulgated by the campus safety committees or governmental agencies logically form the basis for the minimum requirements of a college/university safety program.

Components of typical campus safety and health program

The responsibilities of the campus safety and health program are logically divided into four segments: safety office, health office, fire marshal, and radiation safety office. The safety office staff is usually responsible for developing and maintaining the accident report system for the campus; pursuing accident investigations; and conducting general, special (chemical, types of heating, electrical, compressed gases, ventilation), and critical (explosive anesthetics, grounding, etc.) surveys. This group is responsible for ensuring that the university is in compliance with the Occupational Safety and Health Act and other laws specified by the college/university administration and for providing the necessary consultative services to the faculty. The safety office staff is also responsible for the collection and disposal of hazardous waste chemicals.

Safety and health staff

The industrial hygiene/health staff is usually responsible for monitoring and specifying the control measures for the hazards associated with exposure to noise, temperature extremes, and chemicals. This duty includes: assisting the several departments to develop and maintain written programs concerning such topics as respiratory protection, hearing conservation, hazard communication; monitoring the levels of noise and air contaminants; supervising biological monitoring; designing and inspecting control measures (e.g., ventilation systems, emergency-use respirators, etc.); and training for noise and chemical hazards. The health staff works with the safety staff to enforce applicable laws and regulations. They may also be involved in sanitarian functions, i.e., maintenance, quality control, and training staff for food service, waste disposal, housekeeping, vector control, and animal rooms.

Fire marshal

The fire marshal is responsible for developing and implementing programs for compliance with established fire prevention and protective standards. This staff is usually responsible for checking and servicing all portable fire extinguishers and other fire-fighting equipment as required by NFPA recommended standards and for inspecting and testing all fire alarm and sprinkler systems in accordance with established procedures. The staff investigates and maintains records of all fire and other emergency occurrences. The staff also evaluates and documents the effectiveness of the campus fire prevention program.

Fire safety training assistance

On request, the fire marshal and his/her staff also instruct university personnel and provide classes in fire prevention procedures; building evacuation; fire reporting; and use of fire-protection equipment such as fire extinghishers, fire-alarm systems, and fire hoses. The staff assists in interpreting NFPA, state, and local code requirements and assists in selecting all fire-protection equipment and systems.

Radiation/laser safety committee

The radiation/laser safety committee is organized according to requirements of the Nuclear Regulatory Commission (NRC) or the responsible state agency. The committee is responsible for establishing and reviewing policies and regulations governing the use of ionizing and nonionizing radiation. The committee provides administrative advice to the radiation/laser safety officer; receives, reviews, and acts on all applications for use of radioactive sources and lasers; receives and reviews reports of radiation monitoring, contamination, and personnel exposure; reviews all reports of radiation and laser safety incidents; and carries out other related duties as assigned by law or campus policy.

Radiation/laser safety officer

The radiation/laser safety officer provides surveillance of general health physics activities; serves as a consultant to the college/university, its faculty, staff, and students on all aspects of radiation and laser safety and production; inventories and tracks all radiation sources and lasers on campus; supervises/performs all sealed source leak tests; supervises all decontamination procedures; coordinates the radioactive waste disposal program; supervises, distributes, and processes personal monitoring devices; and keeps track of personnel exposure.

DEPARTMENTAL SAFETY AND HEALTH PROGRAM

The overall responsibility for safety and health (including housekeeping) rests with the department chairperson. Each member of a department, whether faculty, staff, or student, is responsible for knowing and observing the departmental safety regulations. (Typical regulations are presented in Unit IV.) Faculty members are responsible for safety and housekeeping in their research areas and teaching laboratories. Where two faculty members share a facility, the chairperson designates areas of responsibility. Each faculty member is responsible for developing, posting, and enforcing any special safety precautions or regulations particular to his/her area arising from the nature of the research or laboratory course. The faculty member and teaching/research assistant is responsible for explaining and enforcing the departmental safety regulations in his/her classes/laboratories and reporting all infractions to the chairperson or appropriate faculty member. Each student in a laboratory class is responsible for knowing and following all departmental safety regulations applicable to that class as they are explained to him/her. All affected persons have the added responsibility of being alert at all times for unsafe situations that could affect them, their co-workers, fellow students, or visitors.

Aspects of departmental safety programs

The safety program in any department has many aspects, including:

- recognizing actual and potential hazards in research and teaching laboratories and in the general academic environment;
- evaluating the magnitude of such hazards;
- controlling the hazards by elimination, modification of procedures, isolation of personnel, institution of effective engineering controls, or utilization of appropriate personal protective equipment;
- planning for accident/injury prevention;
- educating the faculty, staff, and students regarding proper safety techniques in the environment peculiar to the department; and
- establishing emergency action plans appropriate to any hazards present.

No departmental safety program can be effective without the support of and close cooperation with its counterparts at the college/university. Such interdependence is not secured without effective communication and deliberate effort on the part of the engineering faculty.

FUNCTIONS OF DEPARTMENTAL SAFETY COMMITTEE

The first of the departmental safety committee's many functions is developing and implementing all necessary procedures for maintaining a safe and healthful academic environment, whether related to undergraduate laboratory courses or graduate research laboratories. As part of this responsibility, the committee should prepare safety and health rules consistent with university policy and the degree of hazards potentially encountered. A departmental or even an individual laboratory safety manual should then be developed to outline safe work practices consistent with the rules. Other responsibilities are to conduct inspections/audits of all teaching, service, and research laboratory facilities, shops, storage areas, general facilities, computer rooms, offices, etc., and to assist the faculty to plan and conduct safety training.

Audits, resources, documentation

Other duties of the departmental safety committee involve arranging for an outside audit at least once a year and providing safety and health information in accordance with the Hazard Communication Standard (29 CFR 1910.1200) and its various state counterparts. An additional function of the departmental safety committee is to document all safety and health training and to maintain all required records.

Membership of departmental safety committee

To be effective, the committee must have diverse membership, most of whom should rotate. Committee membership could be composed of two faculty members (one designated as chairperson by the department chairperson), four graduate students, four to six undergraduates, and a departmental technician. Faculty members should serve on the committee in 2-year, overlapping intervals to ensure continuity of activities and uniformity of procedures. Student appointments should generally be limited to 1-year terms. The departmental technician will, almost of necessity, be a permanent member. This approach not only prevents an appointment from becoming onerous, but also exposes more of the faculty and students in the department to the functions of the safety committee.

Right of access; reporting

The committee must have right of access to any and all departmental areas and facilities at any time and specifically for annual, semi-annual, or quarterly inspections/audits. Such access should be coordinated with the faculty or staff member responsible for each facility or area. After each inspection/audit, the committee must discuss its findings with the responsible faculty or staff member and file a report with the department chairperson. It is the committee's responsibility to maintain a file of all inspection/audit reports, resulting correspondence, etc., in the departmental office.

AUDITS AND INSPECTIONS

Safety and health audit defined

A safety and health audit is the process whereby faculty, staff, and students evaluate the presence or absence of elements of the departmental safety and health program with regard to the requirements of applicable federal and state law and the campus-wide program.[1] An audit is not a program evaluation because it does not focus on the success of a departmental safety and health program; rather, the audit focuses on the existence of the necessary features of the program. Obviously, audits are conducted only when a program is supposedly in place and for the purpose of verifying the extent and completeness of the program.

Criteria for safety and health audit

The basic criteria for a safety and health audit are: a written description of the program; adequate communication between the departmental and college/university safety committees and with appropriate medical support staff within facilities; chemical, biological, and radiation/laser control procedures; environmental surveillance; faculty, staff, and student training; and preparations for emergencies.[2] The audit should be conducted by a qualified group composed primarily of persons not directly associated with the department. Audits of departmental safety and health programs should be performed every 3 to 5 years.

Safety and health inspection described

An inspection or survey involves evaluating all elements of the departmental safety and health program. The inspection logically begins with a physical evaluation of the laboratory facilities. Typical topics include facilities layout and escape routes, location of alarms, access to an emergency telephone, location and adequacy of safety equipment, provision for personal protective equipment, proper storage and segregation of chemicals by type, verification that limitations on chemicals and especially flammable solvents in laboratory storage are observed, transport and securing of compressed gas cylinders, type and number of portable fire extinguishers, etc. The presence of MSDSs for all chemicals used or produced in the laboratories should be verified. The degree of safety and health training of the faculty and staff associated with the laboratory must be determined, as must the extent of their training programs for the students taking laboratory courses.

Frequency of safety and health inspections and reports

A detailed inspection of all departmental areas and facilities should be made at least annually by the departmental safety committee with a written report to the chairperson and to the campus safety officer. The chairperson should bring those items requiring immediate corrective action to the attention of the responsible faculty or staff member with an allowed time for compliance. The chairperson should personally verify correction of these action items. If the appropriate corrective action has not been effected by the responsible party, the chairperson must implement all changes necessary to ensure a safe working or learning environment. Appendix A contains a set of example forms appropriate for developing a self-inspection program by the departmental safety committee. For maximum effectiveness, the self-inspection should be revised to accommodate the specific situations in each department. Quarterly safety reinspections should be made of all action items identified on the annual or prior quarterly inspections and of all departmental facilities added or modified since the previous inspection. The report of these inspections by the departmental safety committee should be forwarded to the chairperson for initiation of corrective action with a copy to the university safety officer.

TRAINING

The purpose of training in occupational safety and health is twofold: to develop the concept of safe behavior, hazard awareness, and emergency response in all members of the department, whether freshman, secretary, or professor, and to develop the concept of safety as an integral part of team work on the part of the students, staff, and faculty. To achieve these goals, each member of the department has specific responsibilities, many of which are carried out with the assistance of the departmental safety committee.

Faculty and staff: identify and evaluate actual and potential hazards

Each faculty and staff member has the responsibility to identify and evaluate, with the assistance of the university safety and health officers and/or fire marshal as needed, the actual and potential hazards in his/her research and teaching areas. He/she is also responsible for planning for accident prevention and for training his/her graduate students, the supervised employees, and the students in the proper use of all equipment and chemicals they are expected to use. Each faculty and staff member must identify the proper protective measures required for personal safety and must demonstrate the use of the available safety equipment to those employees or students using laboratory or research facilities or chemicals under his/her supervision.

Additional faculty responsibilities for safe laboratory operation

In addition to explaining the safety regulations applicable to his/her teaching or research areas, each faculty member should, with the assistance of the departmental safety committee, arrange for any necessary, additional, specialized (first aid, cardiopulmonary resuscitation, fire suppression) training. The faculty member is responsible for obtaining copies of the MSDS for every chemical in the laboratory, whether used by the students or not, and for maintaining those copies in each laboratory for ready access by the students. The Hazard Communication Standard (29 CFR 1910.1200) stipulates that the seller of any chemical or chemical mixture must provide a copy of the MSDS to the purchaser. The campus purchasing department or safety officer should be able to obtain any needed

MSDS. As the cost is minimal, the optimum approach is to include a copy of all the necessary MSDSs in the assignment/descriptive package for each laboratory experiment. In that way, each student will have a copy for personal use.

Sources of current safety and health reference materials

In addition to the laboratory MSDS file, the laboratory director should provide a current list of safety and health references. A typical list is included as Appendix B. References to safety and health articles from current professional journals and trade magazines should be included for each laboratory experiment. This way, the students should recognize that consideration of the safety and health aspects of each experiment is fundamental to their success in the course and in their future professional activities.

Summary of student responsibilities

Each teaching assistant and part-time instructor or research assistant is responsible for assisting his/her supervisor with the safety and health training program and with continually enforcing adherence to the departmental safety regulations and special area safety regulations as appropriate. Every student in the department must observe the departmental safety regulations, serve on the safety committee when so assigned, and assume the responsibility of bringing any unsafe acts to the attention of the supervising graduate assistant or faculty or staff member or to the attention of the chairperson, as necessary. In this way, students can assist in the training program while increasing their own safety, especially in laboratory and/or shop situations.

Documentation requirements

Documentation of all student/staff/faculty training should be maintained. A convenient record of instruction on the use of a MSDS is shown as Exhibit III.1. For the protection of the faculty responsible for the Unit Operations Laboratory, a typical release form is shown as Exhibit III.2. This form should not be used without modification for kinetics experiments as no mention is made of any reaction products. In any event, before its use, the college/university legal staff should approve that the release form conforms to the requirements of the Hazard Communication Standard and to any corresponding applicable state standards.

REFERENCES

1. Haas, B.H.: Industrial Hygiene Audits. Am. Ind. Hyg. Assoc. J. 43:867–873 (1982).
2. Corn, M., and P.S.J. Lees: The Industrial Hygiene Audit: Purposes and Implementation. Am. Ind. Hyg. Assoc. J. 44:135–141 (1983).

SAMPLE QUIZ QUESTIONS

1. How do students fit into the departmental safety program?
2. What is a safety and health audit?
3. What are the components of a safety and health audit?
4. What actions could occur as a result of a safety and health audit?
5. What is a safety and health inspection?

Exhibit III.1. MSDS Training Record

Department of Chemical Engineering

FROM: Safety Officer

TO: Departmental Safety Committee

SUBJECT: MATERIAL SAFETY DATA SHEET TRAINING IN THE DEPARTMENT OF CHEMICAL ENGINEERING

The following undergraduate students have been instructed on how to use Material Safety Data Sheets. The MSDS sheet on methanol was used.

Date	Presented by Instructor	Student Name Printed	Student Signature

Exhibit III.2. Typical Release Form

Unit Operations Laboratory

Department of Chemical Engineering

I, ______________________________ certify by my signature below that I have been given a copy of the Safety Regulations of the Department of Chemical Engineering, that I have had them explained to me in class, that I understand them, and that I will abide by them. I also certify as indicated by my signature below that I have received copies of the material safety data sheets (MSDS) for all of the chemicals that I will use in the Unit Operations Laboratory courses, that I have had their use explained to me in class, and that I am familiar with their use. Further, by my initials beside the name or abbreviation of each experiment below, I certify that I have had any specific safety hazards explained to me, that I understand the preventive and personal protective measures to be used in that experiment, that I have been instructed to read the specific chemical hazards associated with the experiment in the corresponding MSDS, and that my questions about the safety/industrial hygiene aspects of each experiment have been answered to my satisfaction.

____

Signature Date

_____	Absorption	_____	Cooling Tower
_____	Distillation	_____	Fluid Flow
_____	Extraction	_____	Membrane Separator
_____	Evaporation	_____	Heat Exchanger

Unit IV
GENERAL LABORATORY SAFETY RULES

PURPOSE:

To list general safety rules recommended for use in chemical engineering laboratories. Note that the list may not encompass all such laboratories because of the differing nature of the experiments conducted therein.

OBJECTIVE:

To define the need and authority for all laboratory safety rules and to provide a list of such rules for Unit Operations Laboratories and any supporting laboratory areas. The material in this unit covers:

1. The purpose and rationale for safety rules
2. Authority for safety rules and their enforcement
3. Student rights and responsibilities in the safety program
4. Recommended list of safety rules

INTRODUCTION

Purposes

Safety rules and standards are developed and instituted for two purposes: primarily, to protect the occupants of the laboratory and others nearby, and secondarily, to protect laboratory equipment and facilities. The following rules may not suffice for all chemical engineering departments because of the differing nature of the facilities available and of the experiments conducted.

Support

For a safety program to have a sound foundation, the faculty and staff must provide unwavering support. They must display their convictions that safety and health are important aspects of the student's education by consistently adhering to the safety rules of the department and the institution. These rules are meant to help the student realize that he/she is responsible not only for his/her own safety, but for that of other members in the group, and for that of neighboring groups, the teaching assistant, the professor, and the casual visitor. Each of those persons has a reciprocal responsibility for the safety of every other person in the laboratory.

Authority

The authority for development, promulgation, and enforcement of all safety rules is vested in departmental and campus safety committees. Authority for such actions ultimately rests in federal and state law. Even if these requirements were not in place, the faculty would have the responsibility under the Code of Ethics of the American Institute of Chemical Engineers for providing a safe and healthy educational environment. It is therefore incumbent upon the faculty to expose the students in chemical engineering laboratories to the basic principles of safety, health, and loss prevention. There is neither the intent nor the time in the Unit Operations Laboratory to make Certified Industrial Hygienists or Certified Safety Professionals of the students. It is even too much to expect that they become fully conversant with all the safety, health, and loss prevention topics they will need on the job after graduation. Although students cannot be expected to become fully familiar with even one such topic, all students can be exposed to many such topics in the course of their experimental work and be made to realize that the principles of safety, health, and loss prevention must become integral parts of every experiment and every design. Units V, VII, and IX of this module specifically address the inclusion of safety and health topics in Unit Operations Laboratory experiments.

Safety rules enhance laboratory safety

The easiest way to help students begin to understand the hazards associated with laboratory work, equipment, and chemicals is to provide them with a set of safety rules—rules designed to enhance laboratory safety by identifying and proscribing unsafe actions. The penalty for infractions should be severe, ranging from no credit for an experiment to dismissal from the laboratory with a failing grade in the case of repeated infractions of any type. Teaching associates, faculty directly involved in the laboratories, and the laboratory director should all assess safety penalties whenever warranted.

Student rights

The students' acceptance of safety and health as part of every project will be enhanced if an atmosphere is created wherein students feel free not only to correct each other but to point out faculty and staff deficiencies directly to them. It must be absolutely clear that each student has not only the right but also the responsibility to identify unsafe actions or procedures without jeopardizing his/her grade in the Unit Operations Laboratory or any other course.

Recommended safety rules

The following safety rules are recommended for Unit Operations Laboratories. Although these rules are recommended for general use, this list should be modified by the laboratory director for his/her own requirements.

Exhibit IV.1. Recommended Unit Operations Laboratory Safety Rules

1. "Horseplay" is hazardous and will not be tolerated.
2. Do not work alone in the laboratory at any time except to prepare flow diagrams and operating procedures for equipment.
3. Use required personal protective equipment (PPE) whenever specified by the laboratory director.
4. Do not wear contact lenses when vapors or fumes are present.
5. Wear safety glasses with sideshields and plastic lenses (must meet ANSI Standard Z87.1) at all times. Wear splash goggles or face shields as prescribed by the laboratory director.
6. Do not wear sandals, open-toed shoes, high-heeled shoes, shoes (or boots) with holes in the soles, or shoes with canvas uppers; do not wear shorts or skirts. Wear shirts or blouses.
7. Secure long hair and loose items of jewelry or clothing when working with rotating machinery.
8. Know the use and location of all first aid and emergency equipment in the laboratories, shops, and storage areas.
9. Know the emergency telephone numbers to summon the fire fighters, police, or emergency medical service. These numbers must be posted at every phone throughout the building.
10. Be familiar with all the elements of fire safety: alarm, evacuation and assembly, fire containment and suppression, rescue, and facilities evaluation.
11. Do not use ungrounded wiring and two-wire extension cords. Do not use worn or frayed extension cords or those with broken connections or exposed wiring. Check that electrical devices are grounded before they are turned on.
12. Be familiar with an approved emergency shutdown procedure before initiating any experiment.
13. Do not deviate from approved equipment operating procedures.
14. Keep all laboratory aisles and exits clear and unblocked.
15. Do not sniff, breathe, or inhale any gas or vapor unless directed to do so by the laboratory director.
16. Label all containers as to content and composition with an appropriate hazard warning. Label the container with the student's name and the date the container was filled.
17. Read and obey the instructions on all warning signs.
18. Segregate all liquid and solid wastes for disposal according to the instructions of the laboratory director. Neutralize all acidic and basic wastes before disposal. Place organic waste material in the designated waste disposal cans; do not pour into any sink or floor drain.
19. Practice good housekeeping in the laboratories, shops, and storage areas.
20. Do not eat, drink, use tobacco products, chew gum, or apply makeup in the laboratories, shops, and storage areas.
21. Place only chemicals in the "Chemicals Only" refrigerator; place only food items in a "Food Only" refrigerator. Do not use ice from the ice machine for human consumption or to cool any food or drink.
22. Report any glassware breakage or malfunctioning instruments or equipment to the teaching assistant.
23. Report all injuries, accidents, and "near misses" to the laboratory director. Complete the accident report as soon as possible.
24. Report spills of any chemicals to the teaching assistant. Follow his/her directions for containment and cleanup. Report all mercury spills to the laboratory director. Follow the prescribed instructions for cleanup and decontamination of all spill areas.
25. Wash hands before leaving the laboratories or shops—all students and supervising faculty and staff.
26. Do not toss tools, supplies, or any other items from one person to another.
27. Do not pipette or siphon any material, even water, by mouth.
28. Secure compressed gas cylinders at all times. Follow proper safety procedures when moving compressed gas cylinders.
29. Use only gauges that are marked "Use no oil" for oxygen cylinders. Do not use an oiled gauge for any oxidizing or reactive gas or any gas that has not been "water pumped."
30. Never play with compressed gas hoses or lines or point their discharges at any person.
31. Do not use open flames or heating elements when volatile chemicals are exposed to air.
32. Only expose toxic chemicals to the air under a hood. Only expose flammable chemicals to the air under a hood or in an adequately ventilated area.
33. Limit personal items brought into the laboratory to those things necessary for the experiment.
34. Discourage casual visitors to the laboratory; obtain permission from the teaching assistant or laboratory director for visitors to enter. All visitors and invited guests must adhere to all laboratory safety rules, with adherence being the responsibility of the person visited.

SAMPLE QUIZ QUESTIONS

1. Why are safety rules developed?
2. Trace the delegation of authority for the formulation of safety rules.
3. Why are radios, tape players, "Walk-man® ", etc. not allowed in the laboratory?
4. What are the options for eyewear in the Unit Operations Laboratory? Why are contact lenses not permitted when working with chemicals?
5. What types of footwear are permitted in the Unit Operations Laboratory? What types are specifically excluded and why?
6. Why are wastes to be segregated before disposal? Why should all acidic and basic wastes be neutralized before disposal?
7. Why is pipetting by mouth not allowed? How should exact, small quantities of liquids be dispensed?
8. What types of gauges may be used with compressed oxygen and air cylinders? Why does this also apply to cylinders containing NO_2, chlorine, SO_2, or anhydrous HCl?

Unit V
SAFETY PROCEDURES FOR UNIT OPERATIONS LABORATORIES

PURPOSE: To present the specialized safety procedures applicable to Unit Operations Laboratories

OBJECTIVE: To review the safety and health provisions for Unit Operations Laboratories in terms of:

1. Preparation for workplace emergencies
2. Special procedures including evacuation, fire safety, and electrical safety
3. Formal permission to start experimentation
4. Description and use of personal protective equipment
5. Emergency shutdown procedures

SPECIAL TERMS:

1. Warning properties
2. Personal protective equipment
3. Respirator
4. Hazard and operability analysis

PREPARATION FOR WORKPLACE EMERGENCIES

Students cannot be adequately prepared for workplace emergencies unless they have a clear understanding of what emergencies might occur. This topic considers the materials, equipment, and procedures to be used and any intrinsic hazards associated with those materials or others that may be generated as a result of chemical reactions. Students must also be aware of any physical hazards associated with the equipment they plan to use and any special hazards such as biohazards and radiation hazards. Their preparations must include adequate safety instruction and training, proper supervision, and both informing and warning all the persons involved of the potential hazards, required safeguards, waste handling methods, and emergency procedures.

Student awareness

To understand the hazards associated with equipment and chemicals before beginning experimentation, the students must be fully aware of any reactions involved and their corresponding energies, the proper use of fume hoods if required, the warning properties of the chemicals involved, the health hazards associated with those chemicals, required protective measures, etc. Similarly, the students must be aware of startup and shutdown procedures for all equipment, the location of emergency shutoff controls for all utilities serving their apparatus, the principles of machine guarding and electrical protection, how to evaluate the need for local exhaust ventilation, etc. These topics are covered in later units within this module.

Use of warning signs

Some warning signs used on campus are generally observed: **WET PAINT, SLIPPERY WHEN WET, WET FLOOR, COMBUSTIBLES ONLY** (on trash cans), etc. Other signs such as **NO PARKING** and **KEEP OFF THE GRASS** are often ignored. Warning signs used in the laboratory environment are usually obeyed: **HOT—DO NOT TOUCH, CAUTION—OPEN GRATE, DO NOT OPERATE** (on valves or switches), etc. Still others such as **DO NOT CHANGE SETTINGS** or **DO NOT TOUCH** (on the gas chromatograph) are widely regarded as an invitation to tinker. Students are inveterate "knob-twisters," and if not prevented, will turn a switch, valve, or rheostat knob just to see if anything will happen. In the case of the chromatograph, the calibration may be changed or the filaments may burn out, leaving the instrument useless.

Warning signs must be obeyed

Everyone associated with the Unit Operations Laboratory must learn to believe in and obey safety notices, both informative and warning or directive. Informative notices may indicate the location of emergency telephone numbers or the material safety data sheet (MSDS) collection for the laboratory. Warning notices advise the reader of the (possible) existence of a hazard: **HEARING PROTECTION REQUIRED, NO SMOKING, DO NOT START, SEE JACK MORRIS (EXT. 2-1759) BEFORE OPERATING.** An effective way to teach students to obey notices is to show them what can happen if a warning is ignored. As an example, open a small bleed from the air line to the absorber. Attach a child's balloon at the outlet in a place the students cannot readily observe. Demonstrate flow control through a rotameter and then give up in disgust because you can't get the flowrate you want. Tag the supply valve as **DEFECTIVE—DO NOT OPERATE.** As soon as you leave, some enterprising, "helpful" student will try to get the desired flowrate. If he does, the pressure in the supply line will be high enough to inflate and burst the balloon. No one will be hurt, but everyone will get the message: signs carry vital information, and all warnings must be obeyed. (See Ref. 1, pp. 197–202 for a discussion of lockout procedures. See also OSHA standard, 29 CFR 1910.147, The Control of Hazardous Energy [Lockout/Tagout], for lockout and tagout procedures.)

Escape routes

If students are required to construct their experimental apparatus, they must be cautioned that the equipment must be located so that it will neither interfere with nor crowd adjacent experiments and that it must not block the aisles. Each student should be able to clearly identify two escape routes from the experimental area to the designated point outside the building where students and staff must assemble if the building is evacuated.

Escape routes from the laboratory must be clearly marked. If one route does not go directly to a hall but, instead, requires passage through another room, the laboratory director or the teaching assistant must, at the beginning of each laboratory period, ensure that the room is unlocked, that the route through the room is not blocked, and that the light in the room is on.

SAFETY AND EMERGENCY SHUT-DOWN PROCEDURES

A hazard and operability (HAZOP) analysis or a risk assessment must be conducted for each experiment. This procedure will allow the laboratory director, the teaching assistant, and the students to anticipate the types of emergencies that may occur in the laboratory or shop or storage area and to develop the corresponding response. Separate procedures should be developed for each experiment. Typical procedures have been developed by Pintar and adapted for use at Texas Tech University.[2,3] Before such procedures can be used effectively, each member of the group/team must know the location of all service line shutoff valves and the master power switch for the experiment. The general emergency shutdown procedure for any experiment is to: (1) shut off the power, (2) cut off the source of any heating fluid, (3) open drain valves or vents if that action will not create a hazard, and (4) evacuate the laboratory. The student or nearby supervisor will have to be the judge of the extent of the emergency shutdown procedure. If he/she thinks that evacuation is the only safe action to take, that judgment on the student's part must be accepted. The students must never be criticized for such an act nor should anyone be allowed to belittle or tease them. Few, if any, Unit Operations Laboratory experiments can be left unattended for up to 5 minutes while the laboratory director determines whether an emergency exists or not.

General emergency shutdown

The students must know the emergency shutdown procedure for their experiment. The emergency shutdown procedure is quite different from the normal shutdown routine and must be designed to function quickly and in a fail-safe manner. The emergency procedure must be committed to memory before startup. If an emergency occurs, the students will not have time to look up the procedure. Its execution must be automatic. The students should be quizzed over such procedures before being given permission to begin the experiment.

Location of utility shutoffs

The students must know the location of the shutoff valves or switches for all utilities (electricity, steam, water, air, other compressed gases) and reagent supply lines to their equipment. These controls must be clearly marked and readily accessible. In addition, the students should know the location of the master supply valves and switches supplying such services to the entire laboratory.

Contact with live electrical conductor

As part of their emergency training, students should be taught how to respond if a person makes contact with a live electrical conductor. Students must be aware that the ground around a person may also be energized, especially if it is wet. The first step is to try to de-energize the conductor, which is why students should know where the master shutoffs are located. Those switches must be clearly labeled. If the power cannot be shut off or if there is uncertainty as to whether it has been shut off, the students must proceed as if the line is still energized. Someone needs to summon help—both an ambulance and someone who can shut off the main power. If the rescuers can keep themselves insulated and remove the conductor using dry boards or sticks, that procedure should be attempted. Otherwise, the risk of a second electrocution is too great, and rescue must be delayed until the power has been shut off. Once the rescue has been made, someone must be prepared to give immediate first aid for electrical shock. The victim should be treated for shock even if he appears to be dead. Cardiopulmonary resuscitation should be administered as necessary until the ambulance arrives and emergency medical technicians have taken over.

Summoning emergency services

All persons in the laboratory (except visitors) must know how to summon emergency services by telephone to the laboratory or to any other location they may be using for any aspect of any experiment. Those services must be provided with clear directions. The person making the call must remain calm; give their name, location by building, room number, and floor; and tell what type of assistance is required (fire, ambulance, police) and where someone will meet the emergency vehicle.

Description of emergency

If anyone has been injured, the caller should give as complete a description as possible including whether the victim is unconscious, burned, or trapped; describe the nature of the emergency in as much detail as is available (e.g., explosion, runaway chemical reaction [tell what chemicals are involved], fire [tell whether chemical or electrical in origin]), and supply anything else that may help the emergency services dispatcher understand the problem. The caller should not hang up—additional information that has not been provided may be needed.

Moving injured persons

All others in the building should be notified about the emergency. No injured person should be moved unless he or she is in imminent danger. To do so might cause serious nerve damage, especially if the neck or spine are broken or twisted. Casualties should be treated for shock.

Fire alarm types

Alarms are of two general types, self-actuated and person-actuated. Fire alarms can be of either type; both are usually present in fairly new structures. Be sure that the students know that they should not wait for a self-actuated alarm to work in the event of a fire: the fusible link may not be in the correct temperature range or the battery may be "dead." In case of a fire, the students should evacuate the area and use the person-activated alarm on the way out.

As a result of building renovations, different types of alarms may be found in the same building. Even if the laboratories, shops, and storage areas have different types of fire detectors (thermal or heat sensitive, ionic or particle) and sprinklers, every student must know the location of at least two fire alarms and how to use them.

Faculty act as fire warden

In the event of a fire, the faculty member (and in his/her absence, the teaching assistant) should act as fire warden. Their first duty is to sound the alarm and to protect him/herself and the other people in the laboratory (or shop or storage area). The procedure is shown in Figure V-1. If the laboratory or the entire building needs to be evacuated, the supervising professor or teaching assistant should be prepared to direct this activity while sending someone else to call the fire department and give directions. If evacuation is required, the laboratory occupants should assemble in a previously designated location and assist in making a head count to be sure that no one has been left behind.

Evacuation in case of fire

After giving the alarm, if the fire is small and highly localized and if the correct type of portable extinguisher is available to use, laboratory and/or shop personnel may attempt to put the fire out. Later, the fact that a fire extinguisher has been used should be reported to the shop technician or supply clerk who will have the extinguisher recharged or replaced. If in doubt about being able to extinguish the fire, the laboratory occupants should leave the job to qualified personnel and exit promptly in an orderly fashion, taking any injured students or other persons with them. No one should hesitate to give the alarm and leave; the safety of the students and laboratory personnel is paramount.

Extinguishing a clothing fire

In the event of a clothing fire, the victim should immediately use the safety shower until the burning or smoldering items can be removed. Because use of a fire blanket may trap hot clothing next to the body and cause more severe burns, the quickest way a victim can extinguish or suppress a clothing fire, until he/she can get to a safety shower, is to **STOP, DROP** to the floor, and **ROLL. DO NOT RUN**—that action will only fan the flames higher.

SPECIAL SAFETY PRECAUTIONS

Because of the often complicated laboratory and analysis procedures involved, additional safety precautions are necessary for Unit Operations Laboratory courses. Whether the Unit Operations Laboratory is operated as a miniature pilot plant or as an advanced laboratory, the rationale behind many of these additional safety and health procedures should be apparent. The best way to evaluate the preparation for this part of the course is to use the teaching assistant as a test case. By this time, that graduate student should already know that safety and health considerations must be part of every laboratory experiment, and his/her willing assistance is to be expected.

Emergency evacuation procedures

The first special safety precaution involves developing emergency evacuation procedures from all facilities used in conjunction with the Unit Operations Laboratory experiments. A plot plan of all those facilities with the location of all major experimental, shop, and storage areas clearly noted on the drawing is needed together with evacuation routes (Figure V–2). This exercise will introduce the students to some of the requirements of the OSHA emergency action standard, 29 CFR 1910.38, Employee Emergency Action Plans and Fire Prevention Plans.

Exits and assembly point

Minimal emergency evacuation procedures consist of having clear and unobstructed aisles between, and at least two separate exits from, each experimental area; giving the alarm and providing directions to emergency services; designating an assembly point outside of the building so that a head count can be made after an evacuation to verify that no

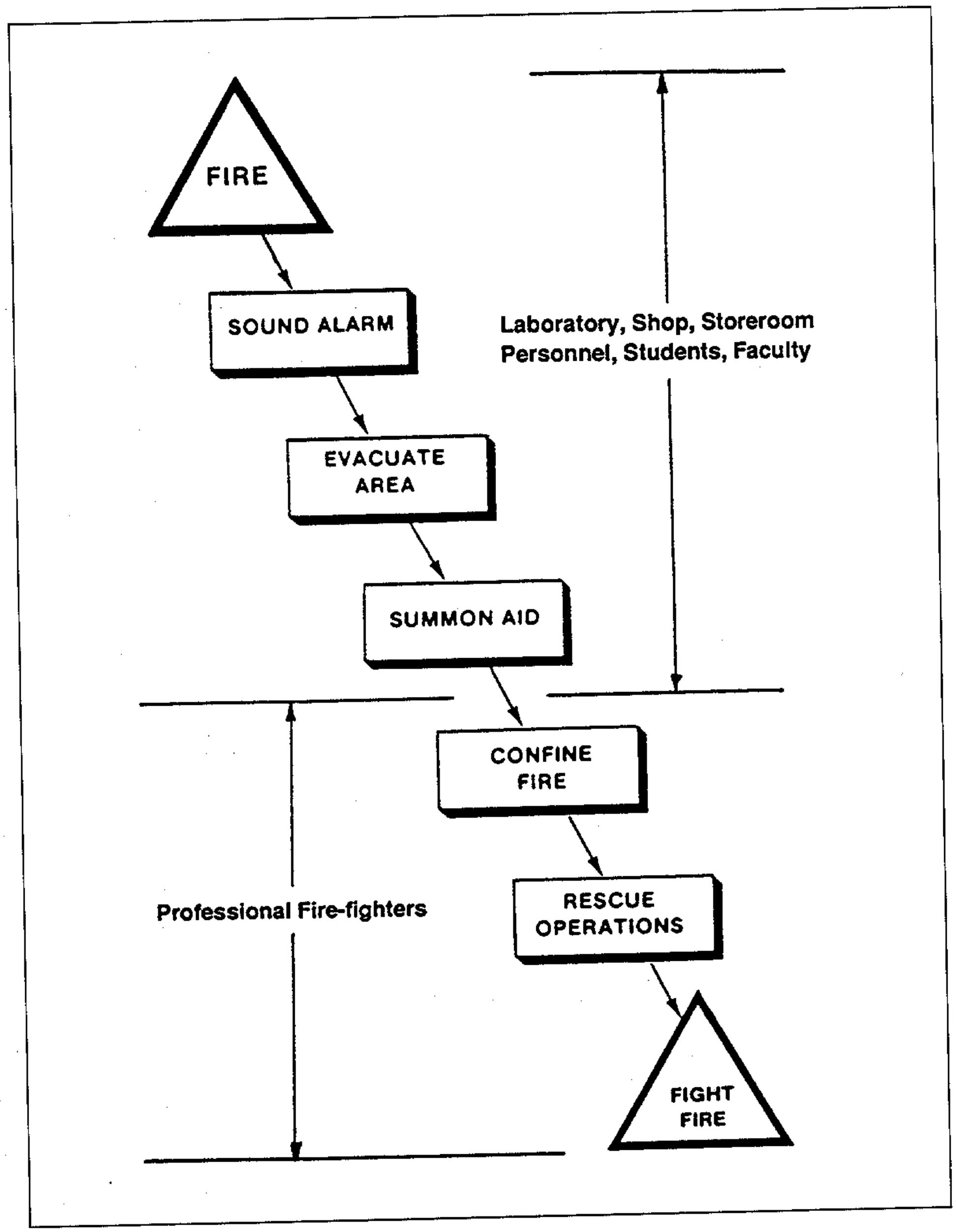

Figure V–1. Emergency procedure for fires.

From: Zabetakis, M.G.: "Fire Safety," Safety Manual No. 13, Mine Safety and Health Administration, Washington, DC (1976).

one was left behind; designating at least two people to sound the alarm during or immediately after departure; and following other steps as directed by the campus fire marshal.

Locating all safety equipment

The location of all safety equipment should be shown on a separate plot plan of the Unit Operations Laboratory and of all ancillary facilities used by the students. A typical laboratory diagram with a key to all experimental and safety equipment is illustrated

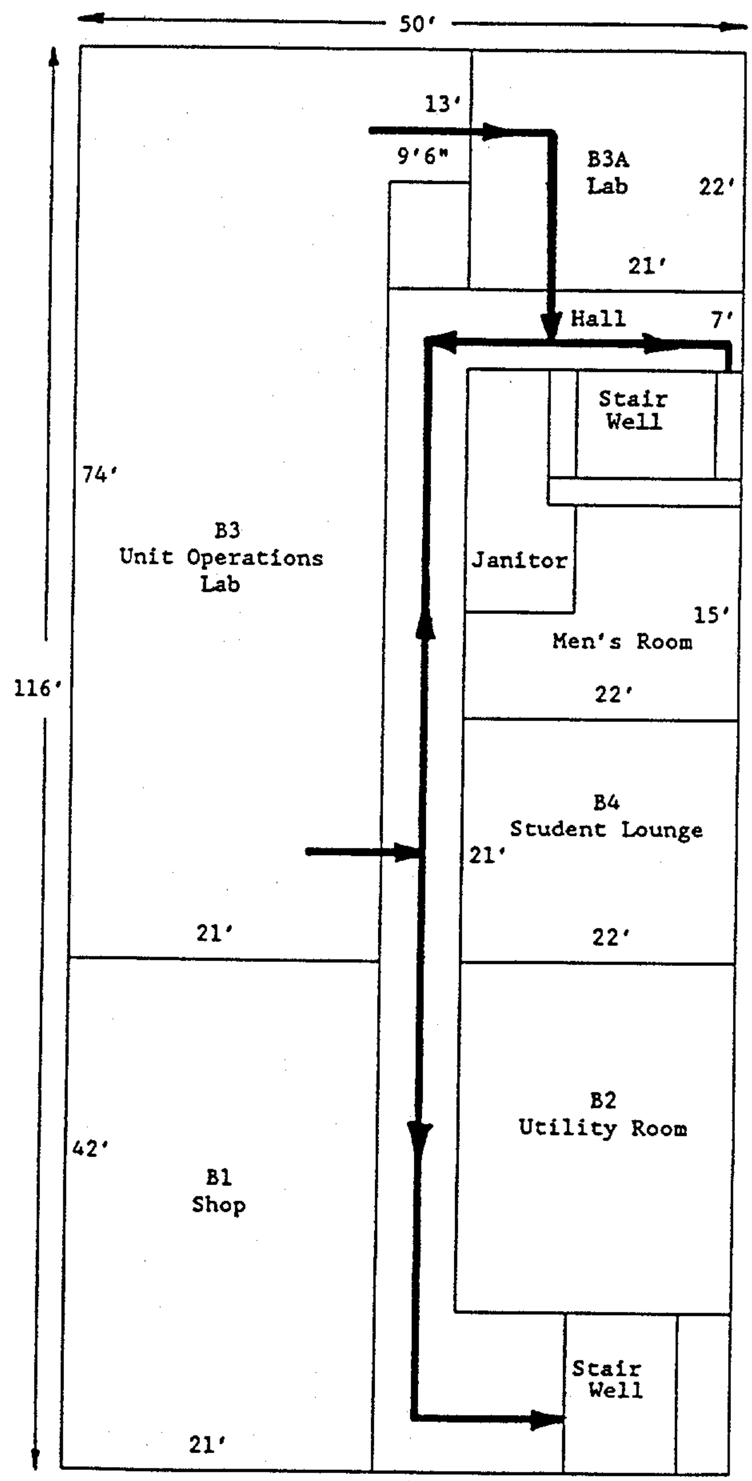

Figure V-2. Illustration of evacuation routes from a Unit Operations Laboratory.

in Figure V-3. One technique for ensuring that all students have reviewed this drawing is to remove some item of safety equipment or to partially block an escape route, crowd some experiment, etc. before a laboratory inspection or demonstration period. Students are then assigned the task of verifying the location of all equipment and the physical presence of all safety material. Those students who do not report either that a particular piece of apparatus is missing or that a floor-plan change is recommended have obviously not adequately reviewed the laboratory layout drawing, evacuation routes, etc.

Safety equipment demonstrations

The exercise described above will teach students the location of all safety equipment. They also must be shown how to use each item. Demonstrations can be arranged using the teaching assistants and shop personnel, through the safety office and the fire marshal. When demonstrating the safety shower, using a bucket to catch the shower discharge will avoid creating a slipping hazard on a wet laboratory floor. The students should be

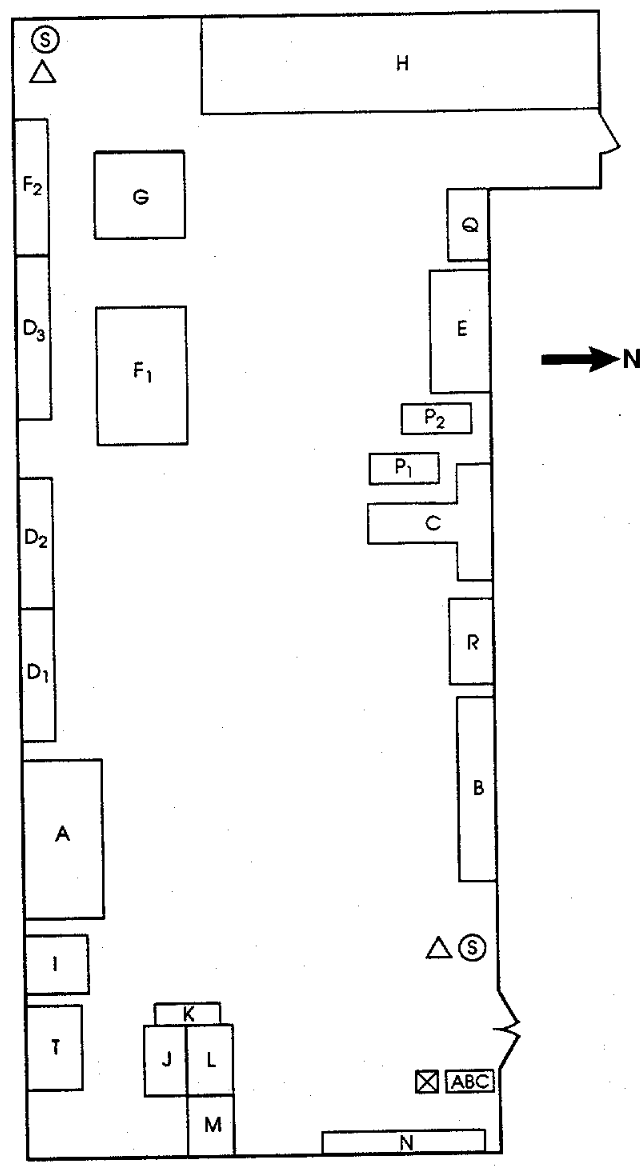

Figure V-3. Laboratory diagram and key illustrating the location of all safety equipment.

LABORATORY DIAGRAM KEY

1. EXPERIMENTS

A	GAS PERMEATION
B	FLUIDFLOW
C	LIQUID-LIQUID EXTRACTION
D_1	HEAT TRANSFER (SHELL-AND-TUBE)
D_2	HEAT TRANSFER (DOUBLE-PIPE)
D_3	HEAT EXCHANGER FOR HEAT-TRANSFER EXPERIMENTS
E	DISTILLATION COLUMN
F_1	COOLING TOWER
F_2	HEAT EXCHANGER FOR COOLING TOWER EXPERIMENT
G	GAS ABSORPTION
H	EVAPORATION

2. MISCELLANEOUS EQUIPMENT

I	ICE MACHINE
J	CHEMICAL STORAGE
K	TOOL BOX
L	MISCELLANEOUS SUPPLIES
M	SAFETY SUPPLIES (GOGGLES, GLOVES, APRONS)
N	HARD HATS
P_1	GAS CHROMATOGRAPH
P_2	PROCESS GAS CHROMATOGRAPH
Q	TRAY DRYER
R	SINK
T	TABLE (REFRACTOMETER)

3. SAFETY EQUIPMENT

⊠	FIRST AID BLANKET
Ⓢ	SAFETY SHOWER
△	EYE WASH FOUNTAIN
[ABC]	FIRE EXTINGUISHER

shown and required to practice in the instructor's presence how to force the eyelids open with one hand. The average person has no concept of how difficult it is to open the eye or to hold it open against a foaming stream of water. (The students will be grateful if towels are provided.)

Experiment change

Unauthorized changes in experiments can be dangerous. Along with being "knob twisters," some students attempt to make changes in their assigned experiments or even to carry out unauthorized experiments. Even small variations in quantities or types of reagents used in an experiment or excursions outside the operating range of a piece of equipment may be dangerous. Such departures from approved procedures and conditions should not be tolerated because of the potential hazards to the students at that and at nearby experiments.

Permission to start experimentation

Before any group is allowed to begin any experiment, they should have demonstrated that they have satisfactorily completed all steps in the initial planning of the experiment and in the hazard evaluation and that they are fully conversant with the written startup and shutdown procedures, whether prepared by themselves or provided for them. These procedures must include provisions for shutdown in case of emergency. Only after the students have demonstrated that they are competent to conduct the experiment should they be given permission to begin. A typical form that is useful for formalizing the permission to start is shown as Exhibit V.1.

Exhibit V.1. Permission to Start Experimentation

Experiment Subject/Title: ______________________________

Experimental design submitted ______________ approved ______________
date date

Apparatus constructed ______________ or not required ______________
date

Operating procedures approved by (initial if OK):

	TA	Lab Director
startup	____	________
data collection	____	________
shutdown	____	________
emergency shutdown	____	________

Preliminary report submitted ______________
date

Assignments:	Student Responsible:
data collection plan	________________
safety	________________
operating procedures	________________
data collection/recording	________________
calibration procedures/data	________________
theory	________________

Potential electrical hazards? ☐ **yes** ☐ **no** If **yes**, identify location:

____

____

Potential mechanical hazards? ☐ **yes** ☐ **no** If **yes**, identify location:

____

____

Required chemicals/physical state/purity/amounts:

____

____

____

____

MSDS reviewed ______________________________ ______________
signature of safety director for group/team date

Hazardous/toxic chemicals involved? ☐ **yes** ☐ **no** identities:

____

____

____

____

(Sheet 1 of 2)

Experiment Subject/Title (cont): ____________________

Incompatible chemicals involved? ☐ yes ☐ no If **yes**, identify and state why no alternatives used:

____

____

Process conditions—maximum expected values and locations:

temperature ____________ °F/°C at /in ____________

pressure ____________ psia/kPa in ____________

energy generated ________ Btu/min ________ watts ________ kJ

Personal protective equipment needed? ☐ **yes** ☐ **no**

eye protection: safety glasses ______ splash goggles ______ face shield ______

gloves ☐ **yes** ☐ **no** type: ____________

apron ☐ **yes** ☐ **no**

hard hat/bump cap ☐ **yes** ☐ **no**

boots ☐ **yes** ☐ **no**

Is all required personal protective equipment on hand? ☐ **yes** ☐ **no**

I certify that this experiment conforms to the Departmental and Unit Ops Lab safety rules/regulations.

____________________ ____________

signature of foreman/team leader date

I have reviewed the procedures and certify that they are in accordance with established Departmental and Unit Ops Lab requirements.

____________________ ____________

signature of teaching assistant date

I have reviewed the preliminary report and the safety section as provided by the students named above. I concur that all aspects of this experiment conform to procedures established by the Department and Unit Ops Lab with the following exceptions (if none, so state):

____

____

____

Permission to start is granted.

____________________ ____________

signature of laboratory director date

(Sheet 2 of 2)

Students not allowed to work alone in laboratory

Because of the hazards associated with some experiments, no student should be permitted to work alone in the laboratory at any time. Laboratory work at other than scheduled times should be prohibited unless specifically authorized by the laboratory director or his/her designee. The one exception to this rule would be when a student needs to enter the laboratory to prepare an instrument and piping diagram for the next experiment his/her group will be conducting. Even in that situation, the student should be required to notify the teaching assistant, the laboratory director, or one of the shop technicians that he/she will be in the laboratory preparing drawings or operating procedures for the experiment. The student should notify the same person of his/her departure.

Experiments should always be attended

No experiment should be left unattended at any time. At least two students should always be present when the experiment is in progress. The group leader is responsible for arranging rest and meal breaks for the group and for ensuring adherence to this practice. If the leader needs to be absent for any reason, he/she should appoint a deputy so that the experiment can proceed in an orderly fashion. The group leader should notify the teaching assistant or the laboratory director of the change. If any other group member needs to leave for any reason, he/she should notify the leader and estimate the time when he/she will return.

Student "check-in, check-out" procedure

Students are often careless about coming to and going from the laboratory. As the school term proceeds, a few students will begin to slip off if they are not required to follow the same type of "check-in, check-out" procedure used in the industrial environment. This procedure is the only way an accurate head count can be made in the event of an emergency evacuation.

Spills and cleanup

It is unrealistic to suppose that students will get through a laboratory without a spill. Fortunately, most of these spills are water that can be squeegeed into a floor drain. Cleanup may depend on the nature and amount of other spills; local procedures may require the student, the teaching assistant, or the safety office do the cleaning. Adequate quantities of materials (see Unit VII) should be maintained to neutralize small spills of acids and bases and to absorb spilled solvents. All spills, their nature, and the corrective action taken to clean up the spill and prevent future occurrences must be reported to the laboratory director (and to the safety office, if local campus procedures so require). The laboratory director may want to treat any spill of any chemical other than water in quantities greater than 25 cc as "reportable" to the appropriate authority, e.g., the State environmental protection agency, railroad commission, health department, air pollution control board, water pollution control board. If so, the necessary forms should be obtained ahead of time and the laboratory director should be prepared to guide the group in completing them. After such an exercise, the number of careless spills in the laboratory should decrease significantly.

Reaching overhead objects, valves

Unfortunately, students routinely stand on chairs, tables, etc., to reach overhead objects. This dangerous habit must be replaced by safe procedures. An adequate number of ladders, safety step-stools, and safety platforms of various sizes must be provided for use in reaching elevated valves, etc. To prevent damage to equipment, especially glass apparatus, students must not be allowed to climb on equipment frames.

Elevated work surfaces

Students on elevated catwalks or floor grating should be reminded that they are responsible for looking down and warning away students who may be beneath them. Students should not stand beneath equipment or beneath students on elevated levels. If necessary, warning signs (**Man Above**) should be displayed at appropriate locations. Observing these precautions should greatly decrease injuries from spills or dropped items.

PERSONAL PROTECTIVE EQUIPMENT

Personal protective equipment (PPE) includes all clothing and devices used to create a barrier between the wearer and workplace hazards.[4] For purposes of this module, the wearers may be students, staff, faculty, and/or visitors to the Unit Operations Laboratories, shop, or storage areas. The workplace hazards are normal and the unusual hazards associated with any part of any experiment.

Need for use

The need for PPE can only be determined by a complete hazard evaluation of all the chemicals, equipment, and procedures used in the Unit Operations Laboratory and its supporting analytical laboratories, shops, and storage areas. One fact is certain: the students will not use the required PPE unless all faculty members, teaching assistants, and shop personnel do so whenever they are in the laboratory. The impression that safety is unimportant can confuse the student whose summer or co-op experience has convinced him/her that industry considers safety and health to be essential components of all operations.

Enforcement of PPE use

Enforcement or reinforcement of the use of PPE is the responsibility of the laboratory director. Sanctions can range from a grade reduction to expulsion from the laboratory, depending on the frequency and nature of the infraction. It is imperative that all students be advised of the penalties for safety rule/procedure infraction at the beginning of the course. Frequent reminders are also necessary.

Safety glasses, other eye/face protection

Eye and face protective equipment (antisplash goggles and face shields) should be worn by all persons in an area where they may be subject to splashing chemicals or hot fluids (water, steam) or where they may be exposed to flying or falling blunt metal objects or the discharge of chips, turnings, or waste ejecta from any machinery. In all other cases, safety glasses must be worn. For those students requiring corrective lenses in their industrial safety glasses, the department may be able to arrange a reduced price with a local optical shop in exchange for recommending their services to the students. All eye and face protection must comply with American National Standards Institute (ANSI) Standard Z87.1-1979[5] and more recent versions. The minimum requirements for eye and face protection are detailed in readily available publications.[6,7]

Hearing protection

A variety of hearing protection should be available for student use.[8-10] Most people like the foam-type inserts. A few find them uncomfortable or have problems with irritation of the ear canal. For this reason, muff-type protectors should also be available. Most people find these less comfortable to wear for long periods of time because of the pressure on the head. Part of a muff's protection is lost when it is worn with safety glasses since the temple piece of the glasses causes a break in the seal around the ear. Because muffs are easy and quick to put on, they are ideal for frequent, short-term use. When hard hats are also required, the type of muff that mounts on a hard hat is excellent. It is also easier to check that students are using muffs than using earplugs when protection is needed. All students needing hearing protection must be trained in the proper use of the device(s) provided.

Noise damage to ear

Headsets for cassette players/radios are not suitable for hearing protection. They offer no protection; rather, they are a source of excess noise because the volume must be turned up to offset the background noise. This can result in levels well over 100 dBA going into the ear. Any sound over 90 dBA (and there is evidence as low as 80 dBA) will cause damage to the ear regardless of whether it is "music" or "noise." In addition, radios, etc., should not be allowed in the laboratory because they are distracting and may seriously impede communication.

PPE for extremities

Typical laboratory injuries can include burns, cuts, abrasions, chemical absorption, and electric shock. Other frequent injuries include those from falling objects, hot surfaces, and slipping on wet floors. Protection is provided by gloves, sleevelets, safety shoes or boots, and leggings, or aprons. Foot protection is classified according to its ability to resist minimum requirements for compression and impact as specified by ANSI Standard Z41-1983. The torso, which is subject to injury from splashes, impacts, and cuts, can be protected by aprons, coveralls, etc.

Resistance of gloves, clothing

The material selected for body protection must be suitable for the possible hazard/intended use, e.g., rubber for electrical hazards, neoprene for acetic acid or methyl isobutyl ketone, etc. The manufacturers of such items should be consulted for recommendations for protective materials. A typical list of glove materials and their applications is shown in Table V-1. (A more complete list is available from the U.S. Environmental Protection Agency).[11]

Table V-1

Permeation Data for Common Glove Materials*

CHEMICAL	VITON (10 mil)		BUTYL (17 mil)		SILVER SHIELD (3 mil)		NITRILE (22 mil)	
	Breakthrough Time (Hrs.)	Permeation mg/m²/sec	Breakthrough Time (Hrs.)	Permeation mg/m²/sec	Breakthrough Time (Hrs.)	Permeation mg/m²/sec	Breakthrough Time (Hrs.)	Permeation mg/m²/sec
Acetaldehyde	NR	—	9.6 hrs.	0.066	>6 hrs.	ND	NT	—
Acetic Acid (Glacial)	NT	—	NT	—	NT	—	1.9 hrs.	221
Acetic Acid (50%)	NT	—	NT	—	NT	—	>8 hrs.	ND
Acetone	NR	—	>17 hrs.	ND	>6 hrs.	ND	NT	—
Acetonitrile	NT	—	>8 hrs.	ND	>8 hrs.	ND	NT	—
Ammonium Hydroxide (29%)	NT	—	NT	—	NT	—	>8 hrs.	ND
Aniline	NR	—	>8 hrs.	ND	>8 hrs.	ND	1.2 hrs	3
Benzene	6 hrs.	.012	NR	—	>8 hrs.	ND	27 min.	97
Butyl Acetate	NR	—	1.9 hrs.	7.61	>6 hrs.	ND	1.7 hrs.	24
p-t Butyltoluene	>8 hrs.	ND	1.7 hrs.	8	>8 hrs.	ND	NT	—
Carbon Disulfide	>16 hrs.	ND	NR	—	RD	—	20 min.	86
Carbon Tetrachloride	>13 hrs.	ND	NR	—	>6 hrs.	ND	5.7 hrs.	8
Chloroform	9.5 hrs.	0.46	NR	—	NR	—	NT	—
Chloronaphthalene	>16 hrs.	ND	NR	—	>8 hrs.	ND	NT	—
Cyclohexane	>7 hrs.	ND	1.1 hrs.	20.3	>6 hrs.	ND	>8 hrs.	ND
Cyclohexanol	>8 hrs.	ND	>11 hrs.	ND	>6 hrs.	ND	NT	—
Cyclohexanone	NR	—	>16 hrs.	ND	>6 hrs.	ND	NT	—
Dibutyl Phthalate	>8 hrs.	ND	>16 hrs.	ND	>6 hrs.	ND	NT	—
1,2 Dichloroethane	6.9 hrs.	.81	2.9 hrs.	53	>6 hrs.	ND	16 min.	292
Diisobutyl Ketone (80%)	1.2 hrs.	90.6	3.3 hrs.	41.2	>6 hrs.	ND	NT	—
Dimethyl Formamide	NR	—	>8 hrs.	ND	>8 hrs.	ND	35 min.	41
Dioxane	NR	—	>20 hrs.	ND	>8 hrs.	ND	NT	—
Divinyl Benzene	>17 hrs.	ND	2.2 hrs.	238	>8 hrs.	ND	NT	—
Ethyl Acetate	NR	—	7.6 hrs.	3.4	>6 hrs.	ND	NT	—
Ethylamine (70% in water)	NR	—	>12 hrs.	ND	NR	—	NT	—
Ethyl Alcohol	NT	—	NT	—	NT	—	>8 hrs.	ND
Ethyl Ether	NR	—	NR	—	>6 hrs.	ND	NT	—
Formaldehyde (37% in water)	>16 hrs.	ND	>16 hrs.	ND	>6 hrs.	ND	>8 hrs.	ND
Furfural	3.6 hrs.	14.8	>16 hrs.	ND	>8 hrs.	ND	NT	—
n-hexane	>11 hrs.	ND	NR	—	> 6 hrs.	ND	>8 hrs.	ND
Hydrazine (70% in water)	NR	—	>8 hrs.	ND	2.1 hrs.	1.0	>8 hrs.	ND
Hydrochloric Acid (37%)	RD	—	RD	—	>6 hrs.	ND	>8 hrs.	ND
Methylamine (40% in water)	>16 hrs.	ND	>15 hrs.	ND	1.9 hrs.	2.0	NT	—
Methylene Chloride	1 hr.	7.32	NR	—	1.9 hrs.	0.002	NT	—
Morpholine	1.9 hrs.	97	>16 hrs.	ND	>8 hrs.	ND	NT	—
Nitrobenzene	>8 hrs.	ND	>23 hrs.	ND	>8 hrs.	ND	1 hr.	15
Nitropropane	NR	—	>8 hrs.	ND	>8 hrs.	ND	NT	—
Pentachlorophenol (1% in kerosene)	>13 hrs.	ND	NR	—	>8 hrs.	ND	NT	—
n-Pentane	>8 hrs.	ND	NR	—	>6 hrs.	ND	NT	—
Phenol (85% in water)	>15 hrs.	ND	>20 hrs.	ND	NT	—	>8 hrs.	ND
Propyl Acetate	NR	—	2.7 hrs.	2.86	>6 hrs.	ND	NT	—
Sodium Hydroxide (50%)	RD	—	RD	—	>6 hrs.	ND	>8 hrs.	ND
Sulfuric Acid (3 molar)	RD	—	RD	—	>6 hrs.	ND	>8 hrs.	ND
Tetrachloroethylene	>17 hrs.	ND	NR	—	>6 hrs.	ND	NT	—
Toluene	>16 hrs.	ND	NR	—	>6 hrs.	ND	28 min.	25
Toluene Diisocyanate	>16 hrs.	ND	>8 hrs.	ND	>8 hrs.	ND	>8 hrs.	ND
1,1,1-Trichloroethane	>15 hrs.	ND	NR	—	>6 hrs.	ND	2.2 hrs.	44
Trichloroethylene	7.4 hrs.	0.24	NR	—	>6 hrs.	ND	9 min.	62
Vinyl Chloride	4.4 hrs.	0.098	NR	—	>8 hrs.	ND	NT	—

NR = Not Recommended
NT = Not Tested
RD = Resists Degradation; not tested for permeation

ND = None Detected
> = Greater Than
< = Less Than
— = Data not available

*Information courtesy of Lab Safety Supply Co., Janesville, WI, 1989.

(Sheet 1 of 2)

Table V-1 (cont'd)

Permeation Data for Common Glove Materials*

CHEMICAL	PVA		NEOPRENE UNSUPPORTED		NEOPRENE SUPPORTED	
	Breakthrough Time (Hrs.)	Permeation mg/m²/sec	Breakthrough Time (Hrs.)	Permeation mg/m²/sec	Breakthrough Time (Hrs.)	Permeation mg/m²/sec
Acetaldehyde	—	—	10 min.	<9000	17 min.	<9000
Acetic Acid (Glacial)	—	—	7 hrs.	—	>6 hrs.	—
Acetic Acid (50%)	—	—	—	—	—	—
Acetone	—	—	5 min.	<900	10 min.	<900
Acetonitrile	1 hr.	<0.9	30 min.	<9	1½ hrs.	<0.9
Ammonium Hydroxide (29%)	—	—	>6 hrs.	—	>6 hrs.	—
Aniline	1½ hrs.	<9	35 min.	<9	3 hrs.	<9
Benzene	7 min.	<0.9	—	—	—	—
Butyl Acetate	ND	<0.9	—	—	—	—
p-t Butyltoluene	—	—	—	—	—	—
Carbon Disulfide	ND	<0.9	—	—	—	—
Carbon Tetrachloride	ND	<0.9	—	—	—	—
Chloroform	ND	<0.9	—	—	—	—
Chloronaphthalene	ND	<0.9	—	—	—	—
Cyclohexane	—	—	—	—	—	—
Cyclohexanol	6 hrs.	<0.9	2½ hrs.	<9	3 hrs.	< 0.9
Cyclohexanone	—	—	—	—	—	—
Dibutyl Phthalate	ND	<0.9	2 hrs.	<0.9	5 hrs.	<9
1,2 Dichloroethane	—	—	—	—	—	—
Diisobutyl Ketone (80%)	ND	<0.9	—	—	—	—
Dimethyl Formamide	—	—	10 min.	<90	1 hr.	<90
Dioxane	—	—	—	—	—	—
Divinyl Benzene	—	—	—	—	—	—
Ethyl Acetate	ND	<0.9	15 min.	<90	20 min.	<90
Ethylamine (70% in water)	—	—	—	—	—	—
Ethyl Alcohol	—	—	1½hrs.	<9	3 hrs.	<9
Ethyl Ether	>6 hrs.	<0.9	10 min.	<90	10 min.	<90
Formaldehyde (37% in water)	—	—	2 hrs.	<0.9	2 hrs.	<9
Furfural	ND	<0.9	20 min.	<90	2 hrs.	<90
n-Hexane	ND	<0.9	45 min.	<900	1½ hrs.	<90
Hydrazine (70% in water)	—	—	ND	—	ND	—
Hydrochloric Acid (37%)	—	—	ND	—	ND	—
Methylamine (40% in water)	—	—	4½ hrs.	<90	6 hrs.	<0.9
Methylene Chloride	17 min.	<0.9	—	—	—	—
Morpholine	3 hrs.	<0.9	—	—	—	—
Nitrobenzene	>6 hrs.	<0.9	—	—	—	—
Nitropropane	>6 hrs.	<0.9	5 min.	<900	1 hr.	<90
Pentachlorophenol (1% in kerosene)	7 min.	<900	6 min.	<0.9	6 min.	<0.9
n-Pentane	ND	<0.9	30 min.	<900	45 min.	<9
Phenol (85% in water)	30 min.	<90	3 hrs.	<90	>6½ hrs.	<0.9
Propyl Acetate	2 hrs.	<9	—	—	—	—
Sodium Hydroxide (50%)	—	—	ND	—	ND	—
Sulfuric Acid (3 molar)	—	—	3 hrs.	—	>6 hrs.	—
Tetrachloroethylene	—	—	—	—	—	—
Toluene	15 min.	<9	—	—	—	—
Toluene Diisocyanate	ND	<0.9	—	—	—	—
1,1,1-Trichloroethane	1 hr.	<0.9	—	—	—	—
Trichloroethylene	30 min.	<0.9	—	—	—	—
Vinyl Chloride	—	—	—	—	—	—

NR = Not Recommended
NT = Not Tested
RD = Resists Degradation; not tested for permeation
ND = None Detected
> = Greater Than
< = Less Than
— = Data not available

*Information courtesy of Lab Safety Supply Co., Janesville, WI, 1989.

(Sheet 2 of 2)

Head protection

Head protection should be required whenever students are in an experimental area. In the laboratory environment, head injuries are often caused by bumping the head against a sharp or other fixed object, by falling, or by being hit by an object dropped from above. Head protection must resist penetration and must absorb the shock of an impact. The shell of the hard hat is usually aluminum or impact-resistant plastic to provide protection against penetration. The shock-absorbing liner keeps the shell away from the wearer's skull when properly adjusted. The applicable standards are ANSI Z89.1-1969 and later editions. Head protection can usually be omitted in analytical laboratories, calculation areas, and shops. If the students are only exposed to bumping their heads while working around the equipment, a bump cap can be used.

Because most chemical engineers will have to wear hard hats, safety glasses, and safety shoes as the minimum PPE, using these items in the Unit Operations Laboratory is good "conditioning." Hard hats can usually be obtained by industrial donation. For those students who do not already have safety glasses, the department may provide visitor-type safety glasses at nominal cost. A list of recommended PPE is given in Appendix C.

Respirators

Respirators prevent harmful substances from entering the lungs. Some respirators also supply air to the wearer from an external source. Hazards that necessitate the use of respirators include an oxygen-deficient atmosphere (below 19.5% oxygen) and/or the presence of hazardous dust, fumes, vapors, or gases. Each Unit Operations Laboratory experiment should be designed and provided with sufficient engineering controls (not a part of the students' assignments) so that respirators will not be required except in an emergency and possibly during the subsequent cleanup. Even in such situations, the persons who will wear the respirators (faculty and technicians) must be advised that respirators do not eliminate exposure to hazard(s). Furthermore, because respirators are not always properly maintained, they will not prevent over-exposure in the event of equipment failure. Laboratory directors are responsible for maintaining the respirators, and they can obtain additional information and the legal requirements associated with respirators from 29 CFR 1910.134, Respiratory Protection.

Respirator selection

Selecting the proper respirator is governed by the chemical and physical properties of the contaminant, the hazard (toxicity, concentration), its extent (contaminated area), and amount of oxygen present. Other selection factors include the required mobility of the wearer, estimates of the maximum exposure time, energy expenditure (level and difficulty of work) required by the wearer, and the limitations (chiefly demand rate or peak airflow rate and capacity) of the available respirators.

Respirator types: air-purifying

Basically, respirators are air-purifying or atmosphere-supplying. Air-purifying respirators utilize filters (for dusts, mists, and fumes) or adsorbents (for gases, vapors, and some mists and fumes) to remove contaminants from the air. The first category may range from the single-use, two-strap respirator for mists and dusts (NIOSH approval no. TC-21C series) to cartridge or canister types with half or full face-mask. Respirator fit-tests are necessary for all but the simplest "dust" masks. The sorbent used is specific for the class of material being removed from the air: acid gases, hydrocarbons, ammonia, etc. Air-purifying respirators may not be used in oxygen-deficient environments or in those that are immediately dangerous to life and health (IDLH) because of the nature and potential exposure of the contaminant. No cartridge-type respirator may be used unless the chemical for which it is intended has adequate warning properties such that breakthrough can be detected by the user. The warning properties of industrial chemicals are listed in Appendix D. A partial list of gaseous materials for which cartridge respirators are not allowed, regardless of concentration or exposure time, is given below.*

Warning properties of chemicals

Acrolein	Fluorine	Nitro compounds
Aniline	Formaldehyde	a. —Nitrobenzene
Arsine	Hydrogen cyanide	b. —Nitrogen oxide
Boron hydrides	Hydrogen fluoride	c. —Nitroglycerine
Bromine	Hydrogen selenide	d. —Nitromethane

Carbon dioxide	Hydrogen sulfide	Ozone
Carbon disulfide	Mercury vapor	Perchloroethane
Carbon monoxide	Methanol	Phosgene
Carbonyls	Methyl ethyl ketone peroxide	Phosphine
Carcinogens	Methyl isocyanate	Phosphorus trichloride
Cyanogen	Methyl bromide	Stibine
Dimethylaniline	Methyl chloride	Sulfur chloride
Dimethylsulfate	Methyl iodide	Toluene diisocyanate
Ethyl cyanide	Nickel carbonyl	Vinyl chloride

*Source: Class materials, Course no. 222, Respiratory Protection, OSHA Training Institute, Des Plaines, IL (1983).

All sorbent-type respirators are intended for use in an escape situation or when the laboratory director *knows* that the concentration of the contaminant and the required work duration do not exceed the rating or capacity of the unit. If the main cylinder valve on an ammonia tank were to fail, the only recourse would be immediate evacuation, tripping the fire alarm as the laboratory is evacuated. That action should cause evacuation of the entire building. The fire department or other emergency operator (such as dialing 911 in areas with that service) should be phoned from another building. The laboratory director should not even consider putting on a full-face, canister-type gas mask and reentering the building for two reasons: complete venting of a no. 2 cylinder would put about 175 lb of ammonia (about 3700 ft^3 at 70°F) into the laboratory. Not only would the atmospheric concentration be in the explosive range, the air would be oxygen-deficient. In a 70 ft. × 24 ft. × 12 ft. laboratory area, that much ammonia would give an average concentration of 18.4% oxygen. In the area around the ruptured valve, the local concentration could temporarily be less than 10% oxygen. The fire department should be told to bring their SCBA's and "smoke eaters" to clear the building.

Respirator types: atmosphere-supplying and SCBA

The atmosphere-supplying category of respirator may consist of a mask and an air hose to a piped-in breathing-grade air supply or a complete self-contained breathing apparatus (SCBA). In all events, the respirator must be approved for its intended use and must provide adequate protection and useful life for the anticipated exposure during an emergency—without an unacceptable penalty such as excessive weight or severely limited mobility.

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SAMPLE QUIZ QUESTIONS

1. What should you do immediately if your clothing catches fire or any burning material is spilled on you? After that immediate action, what should you do next?
2. What is your first duty in case of a fire in the laboratory?
3. Why is an assembly point designated for emergency building evacuations? Where is it for your laboratory? What do you do when you get there?
4. Where are the main shutoff valves or switches for the utilities (water, air, steam, electricity) for the Unit Operations Laboratory?
5. What information should be given when requesting emergency services (fire, ambulance) by telephone?
6. What are the only two conditions under which an attempt can be made to rescue someone in contact with a "live" electrical conductor?
7. What are the two most important factors affecting the selection of gloves or other protective clothing? For the experiment you are doing next, what glove material should be used?
8. What safety problems are associated with working on an elevated platform?
9. What is the general emergency shutdown procedure applicable to all Unit Operations Laboratory experiments?
10. Describe the emergency shutdown procedure for your present (or next) experiment.
11. What factors govern the selection of respirators?
12. What emergency safety equipment is in the Unit Operations Laboratory? Prepare a freehand sketch of the laboratory floor plan showing your experimental area, the escape routes, and the location of the nearest fire extinguisher, safety shower, eye-wash fountain, and the emergency shutoff valves and/or switches governing the utilities for your area?
13. Describe how to use an eye-wash fountain.
14. What personal protective equipment is available to you for your experiment? Where is the PPE located? Why is it necessary?

Unit VI
SAFETY AND HEALTH STANDARDS AND REGULATIONS

PURPOSE:

To familiarize the laboratory director/instructor with the sources and uses of typical codified regulations and voluntary standards the students will later encounter in industry. Voluntary and mandated codes and standards are constantly being upgraded. The laboratory director/instructor should always use the most recent version so that the students can be made aware of and adhere to only the most up-to-date requirements.

OBJECTIVE:

To explain the sources and uses of safety and health laws and regulations and voluntary industrial standards in terms of:

1. OSHA regulations
2. EPA responsibilities
3. Hazard communication standard
4. Voluntary standards

SPECIAL TERMS:

1. Standards
2. Codes
3. Hazard Communication Standard
4. Hazard communication program
5. Recommended practices
6. Material safety data sheet (MSDS)
7. Hazardous chemical

REGULATIONS

All Unit Operations Laboratory directors/instructors should already be familiar with some design standards, either through exposure in design courses, or, more likely, through use in an industrial setting. In any event, the purpose of such standards is the development of measuring methods to characterize the composition, properties, or performance of materials. Similarly, safety and health standards set out the minimum criteria needed to develop and maintain a safe and healthful occupational environment. On entering the work force, students will be exposed to these standards and others enforced by government regulations. The students must, therefore, become aware of the existence of safety and health standards and the absolute need to include them as essential design criteria.

OSHA, NIOSH, state agency functions

The Occupational Safety and Health Act, passed by Congress in 1970, created the Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH). OSHA has issued regulations that contain standards to provide workplace protection to employees in the private sector. (Federal, state, and local governmental employees are not covered.) States have the option of enforcing comparable (including more restrictive) standards themselves or allowing the standards to be enforced by federal inspectors. In some states that elect to provide coverage, the enabling state legislation includes state employees. Other states cover public employees under separate regulations. The safety and health office of each institution needs to determine what regulations apply to all laboratory directors and to their teaching assistants. Since students are not employees, they may not be covered except through measures put in place to protect college/university employees. Some states, e.g., Texas, have laws making the instructor personally responsible for the safety of the students.

Evolution of OSHA standards

OSHA regulations were originally based on voluntary industry standards in existence at the time the Act was passed, i.e., chemical exposure limits developed by the American Conference of Governmental Industrial Hygienists (ACGIH), safety standards developed by the American National Standards Institute (ANSI), etc. There is an ongoing process of developing new standards as new information is developed about hazards and abatement techniques. Many recommended standards developed by other organizations are reviewed and updated more frequently than are the OSHA standards. Two examples are the threshold limit values (TLVs) recommended by ACGIH and the recommended exposure limits (RELs) developed by NIOSH for specific air contaminants. Although at some point these and other updated standards may provide a higher level of worker protection than do the OSHA standards, the students must realize that for regulatory purposes, the OSHA standards are those with which industry must comply.

OSHA area and regional offices as resources

OSHA area offices can serve as a resource center. They have available free copies of standards and information pamphlets on a wide variety of safety and health topics. Some offices have films or videotapes on safety and health subjects available on a loan basis. The safety and health supervisors can answer specific questions. The area offices can often provide speakers to address specific safety or health topics. Laboratory directors should make it a point to visit the nearest OSHA office to become acquainted with the area director, safety supervisor, and industrial hygiene supervisor and learn about the resources they can provide. A list of OSHA regional and area offices is shown in Appendix E.

NIOSH research, technical assistance and training

The National Institute for Occupational Safety and Health (NIOSH) was established by the Occupational Safety and Health Act that was enacted in 1970. The Act made NIOSH responsible for conducting research, training, and technical assistance to make the Nation's workplaces healthier and safer. To identify hazards, NIOSH conducts surveys, laboratory and epidemiologic research, publishes its findings, and makes recommendations for improved working conditions to OSHA and the Mine Safety and Health Administration in the U.S. Department of Labor. The organization and administration of NIOSH and the functions of its laboratories are also shown in Appendix F.

State consultation programs

Since enforcement personnel cannot make on-site consultation visits, state consultation programs have been developed. Laboratory directors may be able to arrange for staff of the state consultation program to assist with an initial self-inspection of the Unit Operations Laboratory and to recommend control measures for all identified hazards. Further information can be obtained from OSHA.

EPA interaction with safety and health

The U.S. Environmental Protection Agency (EPA) is responsible for controlling air and water pollution and for managing solid waste. The Clean Air Act and its amendments and the Clean Water Act are the sources of many EPA regulations. Others are derived from the Resource Conservation and Recovery Act; the Toxic Substances Control Act; and the Comprehensive Environmental Response, Compensation, and Liability Act (Superfund Law); and the Superfund Amendments and Reauthorization Act (SARA). Faculty teaching specific courses in pollution control should be able to provide details of these acts and the resulting regulations. A list of EPA regional offices, addresses, and telephone numbers is in Appendix E.

Solve the problem, don't relocate it

The unwary or unthinking engineer may use one or more of the control strategies described elsewhere in this module to convert a workplace (laboratory) hazard into an external environmental pollution problem. In that case, the problem will not have been solved, only relocated. All students must be advised to seek the advice of their future employer's environmental control group before implementing any chemical, biological, or radiation hazard control measures.

HAZARD COMMUNICATION STANDARD

The federal OSHA Hazard Communication (HAZCOM) Standard (29 CFR 1910.1200) or comparable state law now covers every private sector employee. Although state and local government employees are not covered by federal OSHA, they may be covered by state laws. Some state laws make the laboratory director/instructor personally responsible for the health and safety of the students in his/her class. This responsibility makes enforcement of the standard doubly important. The federal OSHA standard will be used when discussing the HAZCOM standard. The laboratory director/instructor can obtain information from the nearest OSHA area office on applicable coverage for his/her institution.

Purpose of HAZCOM standard

Although students in the Unit Operations Laboratory should not be exposed to chemicals that may cause serious health effects, they may be exposed to such chemicals in the workplace. Other chemicals may be safety hazards because of their potential to ignite and burn and/or to react violently with other substances encountered on the job. The purpose of the HAZCOM standard is to reduce the incidence of occupational illnesses and injuries resulting from exposure to chemicals. The objective of this standard is approached in two ways: establishing uniform requirements to evaluate hazards associated with all chemicals manufactured, imported, or used in the workplace, and ensuring this information is transmitted to affected employers and potentially exposed employees.

HAZCOM standard requirements

The HAZCOM standard requires chemical manufacturers and importers to conduct a hazard determination and to prepare material safety data sheets (MSDS) for chemicals with physical and/or health hazards. These MSDS must be sent with the initial shipment of any hazardous chemical to every employer for use in its hazard communication program. If the manufacturer/importer obtains new information on hazards, the MSDS must be updated and revised copies must be sent with new orders. This requirement means that the receiver must verify whether or not an MSDS that has been received must be used to update the MSDS collection. If the revision date has been recorded on the list of hazardous chemicals required by the written hazard communication program (see below), this comparison can be readily made and the "new" MSDS retained or discarded as appropriate. A revised MSDS must replace the previous MSDS. New safety and health training may be required if a new hazard(s) has been identified. Chemical manufacturers or importers must also ensure that containers of hazardous chemicals are labeled with the identity of the contents (in a name that matches that on the MSDS), appropriate hazard warnings, and the manufacturer's (or other responsible party's) name and address.

a. Written hazard communication program

A written communication program must be developed, normally at the college/university level, describing how the requirements of the HAZCOM standard will be met.[1,2,3] The program addresses labeling requirements, collection, and maintenance of MSDS's and provision for immediate access to information by and training of individuals who are, or may be, exposed to the chemicals. The written program must also contain a list of the hazardous chemicals present in the work area. It is more practical to have a separate list for each laboratory rather than a single list for the institution. This list makes it easier to periodically review and update the list thereby limiting the chemicals that have to be addressed during training sessions. Although it is not required by the standard, listing the date of revision for each MSDS on this list is also beneficial, as already noted. The written program must also address any hazards associated with nonroutine tasks and the hazards associated with chemicals contained in unlabeled pipes in the work area. (In this module, the work area encompasses all areas involved in the Unit Operations Laboratory course(s).)

b. Labeling

When received, all containers of hazardous chemicals are supposed to be appropriately labeled as to the identity and hazards associated with the chemical. These labels must not be removed or defaced. If the chemical is transferred to another container, it must also be properly labeled unless it is a portable container into which the hazardous chemical is transferred from a labeled container for immediate use by the individual performing the transfer. Stationary containers may be labeled by signs, placards, operating procedures, or other such written materials as long as the alternative method identifies the containers to which it applies and conveys the required information.

c. Material Safety Data Sheet (MSDS)

A copy of each MSDS must be kept in the work area and be readily accessible to the students, teaching assistant, staff, and faculty. This practice enables them to review the hazards in more detail after noting a warning label or to take a copy to the emergency room if someone has been accidentally overexposed. An example of the form used to prepare an MSDS is shown in Appendix F. An explanation of the required sections and a glossary of terms commonly used in preparing an MSDS are also included in Appendix F.

Each MSDS must contain the following information:

1. the identity used on the label and, unless it is protected as a trade secret:
   a. its chemical and common name(s) if the hazardous chemical is a single substance; or
   b. the chemical and common name(s) of the ingredients that contribute to those known hazards, and the common name(s) of the mixture itself if the hazardous chemical is a mixture that has been tested as a whole to determine its hazard; or,
   c. the following must be listed if the hazardous chemical is a mixture that has not been tested as a whole:
      i) the chemical and common name(s) of all ingredients that have been determined to be health hazards and that comprise 1% or greater of the composition, except that chemicals identified as carcinogens shall be listed if the concentrations are 0.1% or greater; and,
      ii) the chemical and common name(s) of all ingredients that have been determined to be health hazards and that comprise less than 1% (0.1% for carcinogens) if there is evidence that the ingredient(s) could be released from the mixture in concentrations that would exceed an established OSHA permissible exposure limit (PEL) or an ACGIH TLV, or that could present a health hazard; and
      iii) the chemical and common name(s) of all ingredients that have been determined to present a physical hazard when present in the mixture;
2. physical and chemical characteristics of the hazardous chemical (such as vapor pressure, flash point);
3. the physical hazards of the hazardous chemical including the potential for fire, explosion, and reactivity;

4. the health hazards of the hazardous chemical, including signs and symptoms of exposure, and any medical conditions that are generally recognized as being aggravated by exposure to the chemical;

5. the primary route(s) of entry;

6. if available, the OSHA PEL, the NIOSH REL, the ACGIH TLV, and any other exposure limit used or recommended by the chemical manufacturer or importer preparing the MSDS, where available;

7. whether or not the hazardous chemical is listed in the National Toxicology Program Annual Report of Carcinogens,* or has been found to be a potential carcinogen in the International Agency for Research on Cancer (IARC) Monographs,† or by OSHA;

8. any generally applicable precautions for safe handling and use that are known to the chemical manufacturer or importer preparing the MSDS, including appropriate hygienic practices, protective measures during repair and maintenance of contaminated equipment, and procedures for clean-up of spills and leaks;

9. any generally applicable control measures that are known to the chemical manufacturer, importer, or employer preparing the MSDS, such as appropriate engineering controls, work practices, or personal protective equipment;

10. emergency and first aid procedures;

11. the date of preparation of the material safety data sheet or date of the last revision; and

12. the name, address, and telephone number of the chemical manufacturer, importer, employer, or other responsible party preparing or distributing the MSDS who can provide additional information on the hazardous chemical and appropriate emergency procedures, if necessary.

d. Training

Before an individual works with hazardous chemicals, he/she must be provided information on the institution's HAZCOM program and with training on the hazards associated with those chemicals. The information provided must cover the requirements of the HAZCOM standard, the operations in the individual's work area (Unit Operations Laboratories, shops, storage areas) where hazardous chemicals are present, the location and availability of the written HAZCOM program, including the list of hazardous chemicals, and the MSDS. Training can be done on a chemical by chemical basis or on classes of hazards. Although not required by the standard, it is suggested that the instructor keep records of the training that was conducted including the material covered, names of the presentor and students, and dates. The training must include at least:

1. methods and observations that may be used to detect the presence or release of a hazardous chemical in the work area (such as monitoring conducted by an individual, continuous monitoring devices, visual appearance or odor of hazardous chemicals when being released, etc.);

2. the physical and health hazards of the chemicals in the work area;

3. the measures that individuals can take to protect themselves from these hazards, including specific procedures that have been implemented to provide protection from exposure to hazardous chemicals such as appropriate work practices, emergency procedures, and PPE to be used; and

*Fifth Annual Report on Carcinogens—Summary 1989, Technical Resources, Inc. NTP 89-239, NIEHS, Research Triangle Park, NC. (Always see latest edition.)

†IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans, World Health Organization, Geneva, Switzerland.

4. the details of the HAZCOM program that has been developed, including an explanation of the labeling system and the MSDSs and how individuals can obtain and use the appropriate information.

Right to complain

Since hazardous conditions can arise very quickly in a teaching laboratory, it is important that each student be encouraged to question and report any potential or actual unsafe actions by any individual in the lab. The students must believe that they can make such reports without fear of reprisal.

VOLUNTARY STANDARDS

NFPA standards

The National Fire Protection Association (NFPA), a nonprofit voluntary association, is the primary fire safety organization in the United States. NFPA serves as a central clearinghouse of fire safety information. Many NFPA recommended codes and standards have become the basis for local and state regulations and laws. All NFPA codes, standards, and recommended practices are phrased in terms of required performance. In this regard, they are similar to the way in which American Society for Testing and Materials (ASTM) standards are prepared.

ANSI/UL standards

American National Standards Institute (ANSI) is the coordinating body of a voluntary federation of standards-writing entities representing commerce, industry, and public/consumer interest groups. All ANSI standards meet national needs without significant overlap or conflict. Some NFPA standards have been adopted by ANSI, the Underwriters' Laboratories (UL), the Factory Mutual (FM) Research Corporation, and/or their Canadian counterparts. OSHA has adopted many NFPA standards. NFPA provides publications, films, and training aids for use in teaching fire safety, life safety, electrical safety, etc. A sample of the NFPA/ANSI/UL standards applicable to Unit Operations Laboratory courses and as reinforcements to capstone process/plant design courses is listed in Appendix G.

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SAMPLE QUIZ QUESTIONS

1. What are the purposes of the Hazard Communication Standard? How are those objectives accomplished?
2. What is the minimum information required on a label?
3. What are the differences in standards, codes, regulations, and specifications? What legal standing does each have?
4. How are voluntary standards developed and used?
5. What are exposure limits? How are they determined; What is a ceiling limit?
6. What are the differences in the TWA, REL, PEL, STEL, and IDLH values for a chemical? Which of these exposure limits are enforceable by OSHA?
7. What are the seven basic groups or types of information found in the MSDS for any chemical?

Unit VII

SAFETY PRINCIPLES FOR UNIT OPERATIONS LABORATORY PROJECTS — FIRE, MECHANICAL, AND ELECTRICAL HAZARDS —

PURPOSE:

To describe the safety principles associated with good laboratory practice in the Unit Operations Laboratory and its supporting shops and other facilities.

OBJECTIVE:

To review and describe the following elements:

1. Location and use of safety equipment
2. Spill cleanup
3. Fire and explosion protection
4. Fire hazards
5. Flammable liquids
6. Pressure relief systems
7. Bonding and grounding
8. Machinery and machine guarding
9. Use of hand and powered tools
10. Electrical hazards

SPECIAL TERMS:

1. Fire triangle and fire tetrahedron
2. Flammability and explosion limits
3. Permissible exposure level
4. Threshold limit value
5. Recommended exposure limit
6. Flash point
7. Auto-ignition temperature
8. Pressure relief valve
9. Process interlock
10. Grounding
11. Bonding
12. Machine guarding
13. Electric shock
14. Ventricular fibrillation
15. Cardiac arrest
16. Ground-fault circuit interrupter

LOCATION AND USE OF SAFETY EQUIPMENT

The fabrication stage of laboratory experiment instruction projects will usually be done in the department or in other shops. The students and technicians working in those areas need immediate access to a first aid kit; a shock blanket; respirators for use when sawing, drilling, machining, and grinding; fire extinguishers (all types); and personal protective equipment such as face shields or goggles, hearing protection, and the appropriate types of gloves for welding and electrical work. The only respirators likely to be needed are those specifically for oil mist, wood dust, painting, and fumes. All such respirators must have the appropriate NIOSH approval number. Because of the many respirator models available, the laboratory director should talk to the manufacturers' technical service group (not the local sales representative) for information on specific applications. The 800 number for the technical service group should be available from the salesman, the Thomas Register, or the annual business/product indices volumes printed by various trade associations involved in safety, health, and air pollution control.

Spill kits

Spill kits should consist primarily of oil sorbents. Materials such as sodium bicarbonate to neutralize spills of acid cleaning solutions used in welding should also be included.

Students must know location and use of all safety equipment

The erection stage of experiment construction will be carried out in the laboratory. Even if the students are working on the first experiment of the school year, they must know the location and use of all safety equipment in the laboratory. Those details are covered in Section V of this module.

FIRES AND PROTECTION*

Fires are of two general types: surface and flame. (Explosions are special cases of the sudden and violent onset of flame fires in vapors.) Surface fires, represented by the "fire triangle" (Figure VII-1 [a]), occur on the exposed surfaces of the fuel. They do not involve the formation of free radicals. In a flame fire, however, the successive stages of combustion proceed through the rapid formation and combustion of free radicals. Flame fires involve the direct combustion of a gaseous fuel, whether premixed or as a diffuse cloud, and the components, represented by the "fire tetrahedron" (Figure VII-1[b]), are fuel, air, energy, and chain reactions.

No fire can start unless all elements of the fire triangle or fire tetrahedron shown in Figure VII-1 are present: fuel, oxygen (or an oxidant), heat (or energy, as a spark), and free radicals, depending on the type of fire. The most common source of laboratory and store-

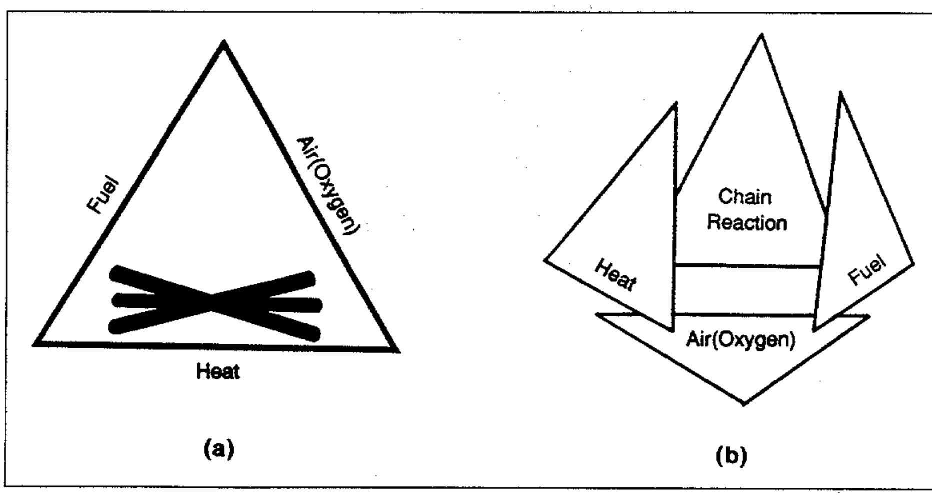

Figure VII-1. The fire triangle (a) and the fire tetrahedron (b).

From (a): Zabetakis, M.G.: "Fire Safety," Safety Manual No. 13, Mine Safety and Health Administration, U.S. Dept. of Labor, Washington, DC (1976).

(b) McElroy, F.E.: Accident Prevention Manual for Industrial Operations, 8th ed., pp. 624-626. National Safety Council, Chicago, IL (1980).

*Taken in part from Zabetakis, M.G.: Fire Safety, Safety Manual No. 13, Mine Safety and Health Administration, U.S. Dept. of Labor, Washington, DC (1976).

room fires is flammable vapors. In shops, the most likely sources are oily rags, oil-based paints and enamels or lacquers, and wood dust or shavings.

Ignition sources

The source of ignition (the heat or energy) can be sparks, including static electricity, open flames, open heaters and other hot surfaces, friction, exothermic reactions, and smoking. Many causes, including carelessness, can be eliminated by rigorous enforcement of safety rules. The only way to minimize carelessness is by being on the alert for it and constantly correcting the offender.

Classes of fires

Fires are classified into four groups:

Class A—those fires that involve ordinary combustible materials such as wood, coal, plastics, paper, and cloth. They are best extinguished by cooling with water or by blanketing with certain dry chemicals.

Class B—those fires that involve vapors above flammable or combustible liquids such as gasoline, diesel fuel, kerosene, and grease. They are best extinguished by excluding air or by special chemicals that interrupt or quench the combustion chain reactions.

Class C—those fires that involve combustible materials in electrical equipment. They are extinguished by nonconducting extinguishing agents such as carbon dioxide and certain dry chemicals.

Class D—those fires that involve combustible metals such as magnesium, titanium, zirconium, sodium, and potassium. They are extinguished by special extinguishing agents designed for such applications.

Color codes for fire extinguisher classes

Extinguishers are labeled with special color-coded symbols to indicate the class or classes of fires on which they can be used. The letter corresponding to each class is often placed in a field of a specified color and shape as shown in Figure VII–2:

Class A—green triangle,
Class B—red square
Class C—blue circle, and
Class D—green star.

Multipurpose extinguishers carry the label of each class of fire on which they can be used (e.g., AB, ABC). Further, extinguishers are often labeled to indicate their extinguishing capacity (e.g., 1A, 2A) based on standardized tests developed by Underwriters' Laboratories, Inc. The applications and general requirements of portable fire extinguishers are described in 29 CFR 1910.157, Portable Fire Suppression Equipment.

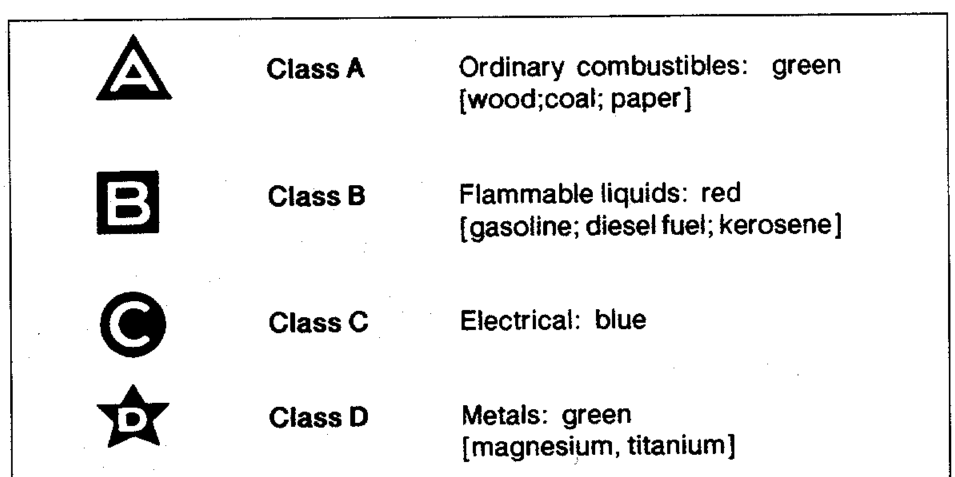

Figure VII–2. Labels for classes of fire extinguisher.

From: Zabetakis, M.G.: "Fire Safety," Safety Manual No. 13, Mine Safety and Health Administration, Washington, DC (1976).

If one of the elements of the fire triangle or fire tetrahedron is missing, a fire cannot occur. If one element can be removed, the fire will go out. Flame fires can be extinguished if the chain of formation and combustion of free radicals in the vapor state can be interrupted. This quenching can be accelerated by capturing the free radicals with large inorganic ions (such as K^+) in dry powder extinguishers. Another way to suppress a flame fire is by the decomposition of halogenated agents into free radicals that preferentially react with the free radicals produced by the combustion of the fuel.

Removal is the principle behind all fire extinguishers. Just as water can, in many cases, be used to extinguish a fire by eliminating the heat, portable extinguishers act by diluting or partially displacing the oxygen supply (carbon dioxide and Halon types), or by forming a barrier (dry powder types) between the combustible material and the other elements of the fire, or by breaking the free radical chain in flame fires (Halon types).

The extinguishing agents are expelled from hand-held portable extinguishers by a hand pump (for water); a compressed gas stored in the extinguisher (water, dry chemical, and on occasion, Halon 1211 and 1301); a small auxiliary pressurized cartridge of carbon dioxide or nitrogen (dry chemical, dry powder); or the vapor of the liquid extinguishing agent itself (carbon dioxide, Halon 1211 and 1301). The characteristics of portable fire extinguishers are shown in Table VII–1.

Table VII–1

Portable Fire Extinguisher Characteristics*

Fire class	Extinguishing agent	Available sizes	Horizontal range, ft.	Discharge time, sec.
A	Water	1.5–5 gal	30–40	45–180
A, B	Foam	1.25–2.5 gal	35	35–60
A, B, C	Ammonium phosphate	2–3 lb	5–20	8–25
B, C	Carbon dioxide	2.5–20 lb	2–4	15–30
B, C	Potassium bicarbonate	2–30 lb	5–20	8–25
B, C	Potassium chloride	2–30 lb	5–20	8–25
B, C	Potassium bicarbonate/urea	17–19	15–30	26–30
B, C	Halon 1211	2.5 lb	4–6	8–10
B, C	Halon 1301	2–4 lb	8–12	8–12

*From: Zabetakis, M.G.: "Fire Safety," Safety Manual No. 13, Mine Safety and Health Administration, U.S. Dept. of Labor, Washington, DC (1976).

Water as an extinguishing agent

Water is the most important extinguishing agent available. It can be used as a solid stream, spray, or foam, depending on the nature and location of the fire. Water usually works by cooling the surface (removing the heat component) of the burning material. In some cases, it also tends to block the flow of air (removing the oxygen component) to the fire zone if used as a foam or spray that is converted to steam by the fire. Foams can be used to carry water to normally inaccessible places.

When not to use water

As a general rule, water is not used to fight fires of low-flash-point liquids such as gasoline, electrical fires, or fires involving water-reactive materials such as carbides and metallic sodium. An exception to this rule is the use of foams to fight fires above flammable and combustible liquids and to blanket fuel spills so as to confine the fuel vapors and prevent a fire.

Carbon dioxide as an extinguishing agent

Carbon dioxide is widely used to extinguish electrical fires and fires above flammable liquids. Because carbon dioxide is a nonconductor of electricity, it can be used to fight fires in energized electrical equipment. It is a heavier-than-air gas and thus tends to spread throughout the fire area.

Carbon dioxide works primarily as a diluent of the air brought into the fire zone; as such, it effectively blocks the flow of oxygen. To a lesser extent, it also acts as a cooling agent. Carbon dioxide "snow" and gas released from an extinguisher are quite cold (about −110°F). Carbon dioxide, however, is not effective against fires in materials such as ammonium nitrate that do not need air to burn or in certain metals such as sodium and magnesium that may react with the carbon dioxide. Because of its role in respiration, carbon dioxide cannot be tolerated by the body in even moderate amounts.

Dry chemicals as extinguishing agents

Commercial dry chemicals are ordinarily made up of one or more of five basic powders: sodium and potassium bicarbonate, urea/potassium bicarbonate, potassium chloride, and monoammonium phosphate. These chemicals are fairly stable and nontoxic. Silicones and other additives are usually added to these chemicals to improve their storage and flow characteristics. Dry chemicals are used primarily in fighting Class B and C fires. Certain mixtures are, however, also used against Class A fires. Dry chemicals act quickly to extinguish a fire by coating and smothering it and by interfering with the chemical reactions in the fire zone.

Halons and their problems

The Halons have been used as fire extinguishing agents for a number of years. Unfortunately, many of them are toxic and also produce toxic decomposition products at the elevated temperatures encountered in fires. For this reason, carbon tetrachloride (Halon 104), chlorobromomethane (Halon 1011), and methyl bromide (Halon 1001) are no longer used in fire extinguishers. However, bromochlorodifluoromethane (Halon 1211) and bromotrifluoromethane (Halon 1301) are now used against both Class B and C fires, particularly in fixed installations.

Phosgene is a decomposition product

Both Halon 1211 and Halon 1301 are gases at room temperature. Easily liquefied and stored as liquids at elevated pressures, they are extremely effective fire extinguishing agents, because they interfere with the chemical reactions in the fire zone. They do, however, decompose in a fire to produce carbonyl chloride (phosgene) and other toxic gases, and must therefore be used under carefully controlled conditions.

Metal fire extinguishing agents

Many materials, available for use against metal fires, are designed for specific applications and are commercially available, proprietary mixtures. Often, materials such as talc, graphite powder, sodium chloride, sand, and dolomite have been used to isolate and cool metal fires. These materials and the commercial dry powders should be handled only by experienced personnel.

FIRE HAZARDS

Categories of fire hazards

Fire hazards are usually grouped into four categories: those associated with flames, heat, fire gases, and smoke. A fifth hazard may arise in enclosed areas: the depletion of oxygen. Fires in enclosed areas are especially hazardous not only because they produce heat and toxic products but also because they consume the oxygen in the surrounding air.

Flame action

Most burning materials produce flames, although many flames are almost invisible to the naked eye. The most common colors of flames are violet, blue, green, yellow, orange, red, and mixtures of these colors. The colors and temperatures of flames depend on the nature of the burning materials and on any contaminants, such as dust, in the air. All flames are potentially dangerous; they can produce burns and can act as ignition sources either on contact or by convection and radiation, at a distance. They can propagate freely through gas mixtures or remain relatively fixed above burning liquid or solid fuels.

Dangers of heat

The heat produced in a fire causes adjacent layers of combustible material to ignite and thus spreads the fire. Further, fire heats the surrounding air. Exposure to such hot air may lead to heat exhaustion, respiratory problems, and death. Air temperatures as high as 300°F can be tolerated, but only for short periods.

Fire gases, smoke

Gases formed as a result of a fire include carbon dioxide and carbon monoxide, both of which are extremely dangerous: carbon dioxide because of its role in respiration and carbon monoxide because of its toxicity. Most fire deaths are caused by these gases (and by other fire gases such as acrolein, hydrogen sulfide, and the oxides of nitrogen) and not directly by flames or heat. Because the effects of such gases are often delayed, any person who escapes from a fire zone should be hospitalized. Fire gases formed from combustibles such as wood, fabrics, plastics, coal, oil, and grease are usually accompanied by liquid droplets, tarry particles and carbon, known as "smoke." These aerosol particles tend to impair vision and create a health hazard. Further, they may absorb the fire gases and become more toxic.

FIRE PREVENTION GUIDELINES

Fire prevention is the most important part of any fire safety program. That program, possibly more than any other, demands the complete cooperation of all persons in any way connected with the Unit Operations Laboratory course(s). Whenever modifying existing facilities or designing a new laboratory, the corresponding guidelines for laboratory design should be consulted.[1]

Trash, oily waste

Proper attention must be given to housekeeping, particularly to the segregation and disposal of combustible trash. The area around each experiment should be constantly policed by the group so that no combustible material is available in trash cans, even in the halls, where a carelessly discarded cigarette or match might start a fire. Metal, not plastic, trash containers should be used to avoid toxic fumes from burning plastic if a fire starts in a waste can. Oily wastes should not be mixed with wood wastes.

Isolation and storage cabinets

Isolation of the elements of the fire triangle through proper use and storage techniques is essential. Although open shelves can be used for nonhazardous chemicals, lockable cabinets must be used for toxic substances. Flammable liquids must be further segregated into lockable steel storage cabinets. The space between double walls must be filled with insulation to reduce heat transfer from surrounding areas. Such cabinets are preferably located outside the building in a secured location. Toxic chemicals that have been opened must be stored in an exhaust-ventilated cabinet or in a fume hood dedicated to storage only.

Other common-sense rules in laboratory and storage arrangement involve separating (by shelf or, better, by cabinet) acids and bases, oxidizers and flammable liquids, oxidizing and combustible gases; using ventilated storage compartments and/or facilities; etc. The amounts of flammable liquids that can be stored in the laboratory (ready-use supplies) may be limited by the provisions of 29 CFR 1910.106. If more restrictive state or local codes exist, they should be followed in the interests of fire prevention, even if the college/university is not legally bound by those codes. The fire hazard properties of flammable liquids, gases, and volatile solids can be found in NFPA 325M issued by the National Fire Protection Association.

Use least flammable and toxic materials possible

Reagents, solvents, and other chemicals having the lowest possible flammability and toxicity should be used for laboratory experiments and associated analytical work. In some cases, however, alternative, less hazardous analytical methods are not available. The NIOSH compendium of laboratory analytical methods should be used as a source of high-quality, reasonably safe procedures.[2] Other suitable sampling and analysis procedures can be found among those developed by EPA, ASTM, the Water Pollution Control Federation, etc.

Chemical substitutions

In many cases, changes can be made in the chemicals used in an experiment to decrease the hazards. The water-air-ammonia system can be substituted for the water-air-hydrogen chloride system. In many extractions, 1-butanol can be substituted for methanol. Flammable carrier solvents with high vapor pressures may, on occasion, be replaced by mineral oil in liquid-liquid extractors. The most inert, lowest vapor pressure, least flammable, lowest toxicity materials possible should always be used. If such materials will not satisfactorily perform in existing laboratory equipment, the equipment should be modified or replaced as soon as possible with apparatus that can use such low-hazard materials to demonstrate chemical engineering principles.

Solvent substitutions

Care must be taken with all such substitutions, as a change in solvent to decrease the flammability hazard may possibly expose the students to a different, more toxic solvent. Consider the data below for methyl-isobutyl ketone (MIBK) and acetone.

	MIBK	Acetone
flash point	64°F	0°F
lower explosive limit	1.2%	2.6%
upper explosive limit	8.0%	12%
auto ignition temperature	840°F	869°F
OSHA PEL	100 ppm	1000 ppm
ACGIH TLV (1988–89)	50 ppm	750 ppm
NIOSH REL (1989)	50 ppm	250 ppm

A change from acetone to MIBK would decrease the fire hazard by raising the flash point and decreasing the size and location of the flammable/explosive range in air. Such a change would also increase the effect of any potential exposure during the experiment. By all three measures, exposure to MIBK is at least five times more toxic than exposure to acetone, and requires a corresponding increase in the quality of engineering controls and other protective measures if MIBK is substituted for acetone as a means of reducing the fire hazard.

Fume hood face velocity requirement and its verification

All reactions should be conducted in properly designed bench-top or walk-in fume hoods that have been certified by the campus safety or health officer as having at least a 100 feet per minute hood face velocity at installation. Verification of the velocity must be done annually by college/university safety office personnel and by each group conducting an experiment for which a hood is required. Verification of the average face velocity by a hot-wire anemometer, micro-pitot-tube, or other device can be incorporated into many fluid-flow experiments, particularly experiments involving cooling towers and those determining fan performance curves.

Explosion-proof electrical fittings, etc.

Depending on the nature of the reactions or separations involved, the use of explosion-proof electrical fittings, switches, and motors may be required. They are much more expensive than standard electrical fittings or motors. Explosion-proof fittings, etc., are required when the local concentration of flammable material is greater than one-fourth the lower explosion limit (LEL) in air. This situation should never occur as a part of routine Unit Operations Laboratory work as the LEL usually represents an atmospheric concentration one thousand-fold higher than the permissible exposure limit (PEL).

Fire safety information sources

The campus fire marshal can assist the laboratory director in determining whether such explosion-proof electrical fittings, etc., are required. If he/she cannot provide the needed expertise, many other sources are available: the fire marshals and safety officers of the companies who hire the department's graduates and those who provide organized plant trips for student groups. The laboratory director should not hesitate to use his/her professional contacts to help provide a safer environment for the students. The laboratory director should also be able to obtain help from the nearest chapter or section of the American Society of Safety Engineers, the state health department, and loss prevention experts at major insurance carriers providing workers' compensation insurance to the campus. The fire safety programs at Oklahoma State University and the University of Maryland may be contacted for assistance on an advisory basis.

FLAMMABLE LIQUIDS

Any liquid that gives off flammable vapors at temperatures below 100°F at atmospheric pressure is known as a flammable liquid. Any liquid that gives off flammable vapors at temperatures of 100°F or higher is known as a combustible liquid. The lowest temperature at which such liquids form flammable vapor-air mixtures is known as the "flash-point." At this temperature, the vapor concentration corresponds roughly to the lower limit of flammability. As with flammable gas mixtures, however, flammable vapor-air mixtures must be ignited before they will burn. Elevated temperatures are needed for spontaneous ignition to occur. The definitions of the classes of combustible and flammable liquids are shown in Figure VII–3. Common liquids in the various classes are listed in Table VII–2.

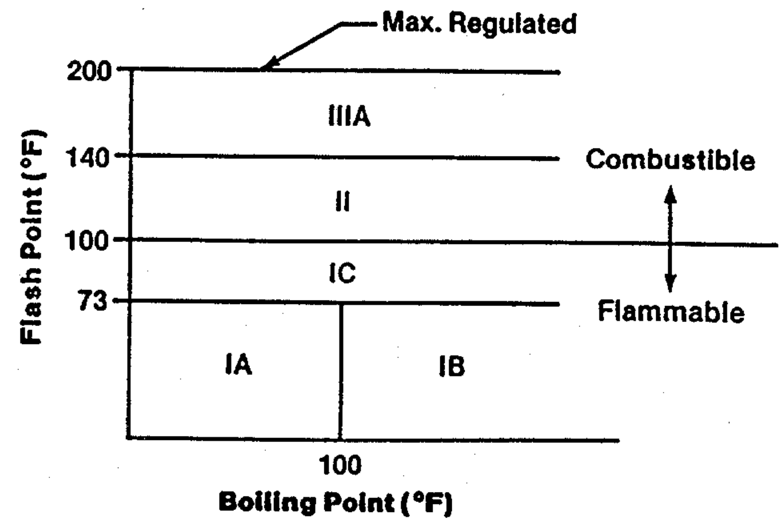

Figure VII-3. Classes of flammable and combustible liquids.
Adapted from internal working document developed by Occupational Safety and Health Branch, Division of Safety, National Institute of Health, Bethesda, MD.

Table VII-2

Usual Classes of Some Flammable/Combustible Liquids*

Flammable			Combustible
Class 1A (boiling point < 100°F)	Class 1B (boiling point > 100°F)	Class 1C	Class II
Acetaldehyde	Acetone	Amyl acetate†	Diesel fuel
Amylene (1-pentene)	Allyl acetone	Banana oil (isoamyl acetate)	Fuel oil
2-Butyne	Butyl acetate†	Butyl alcohol	Kerosene
1-Chloropropylene	Denatured alcohol	Isobutyl alcohol	Stoddard solvent
2-Chloropropylene	Ethyl acetate†	Methallyl alcohol	Anchor type car wash
Collodion	Ethyl alcohol	Methyl butyl ketone	Mineral spirits
Ethylamine	Ethyl butyl ether	Methyl isobutyl ketone	Jet fuels (Jet A & JP 5 & 6)
Ethyl chloride	Gasoline (all)	Propyl alcohol	0.6% Manganese naphthanate —all liquid
Ethylene oxide	Gin (ethyl alcohol)	Styrene	0.6% Cobalt naphthanate—all liquid
Ethyl ether	Heptane	Turpentine	Zirco catalyst 0.6% drier
Ethyl nitrite	Hexane	o-Xylene	Nuxtralead 0.36%
Formic acid	Isobutyl acetate	Xylol (o-xylene)	Troykyd anti-skin 0.13%
Furan	Isopropyl alcohol		
Isopentane	Isopropyl ether		
Isoprene	Methyl acetate		
Isopropenynl acetylene	Methyl alcohol		
Isopropylamine	Methyl ethyl ketone (MEK)		
Isopropyl chloride	Methyl propyl ketone		
Methyl ethyl ether	Methyl vinyl ketone		
Methyl formate	Naphtha V.M.&P		
Pentane	Toluene (toluol)		
1-Pentene (amylene)	Toluol†		
Petroleum ether	Jet fuels (Jet B & JP 4)		
Propylene oxide			
Vinyl ethyl ether			
Vinylidene chloride (dichloroethylene)			

*From: Flammable Standards Workshop, Course No. 110-10, OSHA Training Institute, Des Plaines, IL (1989).
†Lacquer thinner is made up of various percentages of these chemicals.

Temperature effects on flash point

When a liquid is placed in a closed container, its vapor exerts a pressure on the container walls. As the vapor pressure of the liquid changes exponentially with temperature, the concentration of vapor above a liquid in the closed container can be reduced by cooling or increased by heating. To prevent the formation of undesired flammable mixtures, liquids exposed to air should be kept at temperatures below their flash points. Where spray or mist can form, the student should use a fire-resistant fluid since sprays and mists of flammable and combustible liquids can burn at temperatures below the flash point. Reducing the operating temperature will reduce the hazards associated with the use of flammable chemicals, and reducing the pressure will reduce those hazards associated with leaks. The effect of temperature on the flammability limits of combustible vapors in air is shown in Figure VII–4.

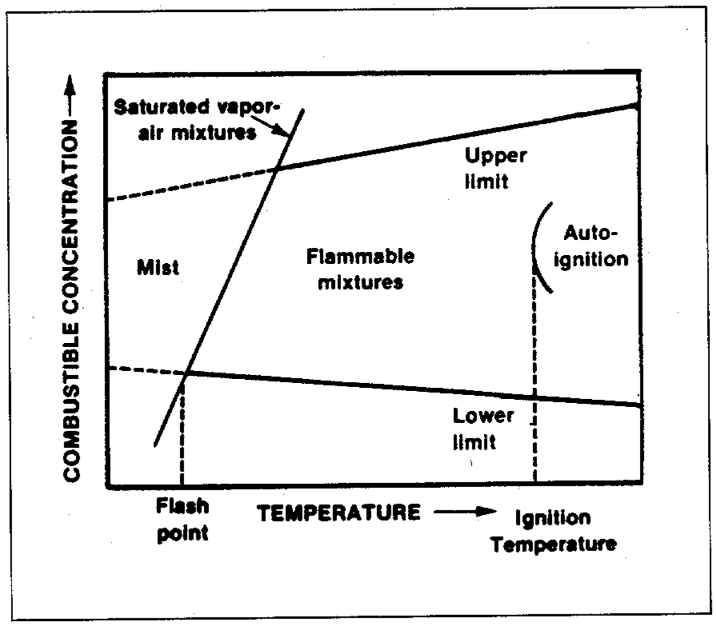

Figure VII–4. Effect of temperature on limits of flammability combustible vapor in air.

From: Zabetakis, M.G.: "Fire Safety," Safety Manual No. 13, Mine Safety and Health Administration, U.S. Dept. of Labor, Washington, DC (1976).

Solvent vapors and fire flashback

Most flammable liquids have relatively heavy (high density) vapors. Vapor trails have been known to ignite at a distance and flash back to the source of the vapors. Numerous deaths have been caused by the careless use of gasoline and other low-flash-point solvents (e.g., cleaning fluids) and by the fueling of gasoline engines in enclosed areas by people unaware of the tendency of heavy vapors to flow down and away from the fuel container.

PRESSURE RELIEF SYSTEMS

Pressure relief systems are incorporated in process and experimental systems to protect the equipment and ancillary piping from failure due to pressures above the design operating limits. The relief system, usually a rupture disc or a valve, must discharge to a safe place. In a process plant, such systems commonly vent to a flare if flammable, toxic, or carcinogenic substances are involved. In the Unit Operations Laboratory, since carcinogens and highly toxic substances should not be used, the relief system can discharge to a closed system. In an emergency, the discharge may be to a fume hood and from there, outside the building at an elevated level. Care must be taken so that no such discharge can be inducted into the building fresh air supply. The conditions under which such external venting can be permitted have been described.[3] Numerous references for the design of relief systems are available.[4–11]

Process interlocks

Although process interlocks are rarely found in laboratories, such safety systems are vital components of all good designs. A safety interlock or alarm is "any equipment or series of equipment whose proper functioning is essential to prevent or indicate hazardous process conditions that might endanger personnel or equipment."[12] Each interlock must be tested regularly by using a completely detailed written procedure. Process interlocks, if properly used, greatly decrease the probability that a malfunction will go undetected, that a segregated and tagged item of equipment will be returned to service, that all the precautions for "hot work" or entry into a confined space will not be taken, etc. When installed on or between parts of a system, process interlocks can initiate shut-down sequences in the event that process conditions are such that an emergency would otherwise occur. The care with which such interlocks are designed and incorporated into operator-controlled and computer-controlled processes is possibly more demanding than that required for the process itself. In the laboratory setting, safety interlocks are installed on experiments so that if a critical component (e.g., water flow to a reflux condenser) fails or runs wild (reboiler temperature controller locks "on"), the experiment will be shut down safely.

LEAKS

As in process plants, leaks will occur in laboratory situations. Process leaks can result from sampling, from material charging into batch reactors, or from filter presses. In the plant situation, leaks can occur when any equipment is opened or purged before maintenance. Leaks also occur during waste handling. Fugitive leaks (around valve stems and agitator shafts, from incompletely tightened tubing fittings, or from incorrectly assembled seals or loose flanges, etc.) can occur almost anywhere. Leaks due to materials handling in the laboratory result largely from dumping a bottle or other container of a liquid into a tank, open mixing, size reduction, or screening. After the leak has been located, the necessary repairs and/or maintenance should be effected by the shop technician, the teaching assistants (if qualified), or even the laboratory director. Under no circumstances should students be allowed to perform maintenance on any part of any experiment except under direct supervision of a qualified person.

Negative-pressure systems

Whenever the contaminants or experimental materials are highly toxic, the entire system should be operated under a negative pressure. In that way, any leaks will be inboard instead of into the laboratory. This approach should also be followed for any comminution, screening, dry blending, or pneumatic material transport unit operation. The use of negative pressure will keep the experimental materials inside the system and result in less general cleanup later.

GROUNDING AND BONDING

Ground defined

All vessels containing flammable and/or explosive materials (liquids and dusts) and all transfer devices (pumps, conveyors, etc.) must be grounded to minimize the possibility of disaster as a result of stray currents, differences in electrical potential between different parts of the system, and/or static electricity. Grounds consist of effective, large-diameter conductors between the vessel or apparatus and the earth. A multi-strand braided conductor or a single large-diameter conductor may be used. Either should have sufficiently low resistance so that stray currents will more readily flow through the ground loop than through the equipment. As the cold water system is buried in the soil, cold water pipes make excellent grounds. The OSHA grounding requirements are in 29 CFR 1926. (See also, Functions of grounding in ELECTRICAL HAZARDS, below.)

Bonding defined

When transferring flammable and/or explosive materials from a fixed storage container to another container for transportation, an electrical bond must be established between the two vessels (See Ref. 13, pp. 402–406). The reverse is also true, e.g., in pouring or pumping a flammable solvent from a 5-gallon can into a feed tank. Bonds or "bond-clips" are made from heavy-gauge conductors with heavy-duty alligator, bear-paw, or post connectors at each end. Metal-to-metal contact must be made at each end of the bond, even if that necessitates scraping away some paint on the experimental apparatus. No material transfer may be made unless the grounds and bonds are in place.

MACHINERY AND MACHINE GUARDING*

Many types of injuries ranging from minor lacerations to crushed or severed limbs, blindness, and death can result from the misuse of machines such as table saws, drill presses, band saws, grinders, etc.[14] If students have access to such machinery while constructing their equipment, they must receive adequate instructions in the use and limitations of each item and the machines must be fitted with the proper guards. Since many different types of models of machines are found in departmental shops, this module cannot address specific instructions or machines—only the basic principles of machine guarding are addressed with some examples. Manufacturers should be contacted to obtain copies of missing operating instructions and information on guarding. Many older machines will need to be retrofitted with guards as described in current OSHA and ANSI standards. Additional information can be obtained from the nearest OSHA area office. The laboratory director can learn if an on-site consultation visit can be arranged through the state consultation program.

Moving machinery areas to be safeguarded

A good rule to remember is that any machine part, function, or process that may cause injury must be safeguarded. Mechanical hazards occur in three basic areas where dangerous moving parts need safeguarding. These areas are

1. the point of operation: that point where work is performed on the material, such as cutting, shaping, boring, or forming of stock;
2. power transmission apparatus: all components of the mechanical system that transmit energy to the part of the machine performing the work including flywheels, pulleys, belts, connecting rods, couplings, cams, spindles, chains, cranks, and gears; and
3. other moving parts: all parts of the machine that move while the machine is working including reciprocating, rotating, and transverse moving parts, as well as feed mechanisms and auxiliary parts of the machine.

Types of hazardous mechanical motion

Hazards may also be categorized by the type of mechanical motions and actions present. These hazards can include the movement of rotating members, reciprocating arms, moving belts, meshing gears, cutting teeth, and any parts that impact or shear. These different types of hazardous mechanical motions and actions are basic to nearly all machines. Recognizing them is the first step toward providing protection from the dangers they present. The basic types of hazardous mechanical motions and actions are

1. Motions
   - rotating (including in-running nip points),
   - reciprocating,
   - transverse, and
2. Actions
   - cutting
   - punching
   - shearing
   - bending

Rotating motion

Rotating motion can be dangerous. Even slowly rotating smooth shafts can grip clothing, and through mere skin contact, force an arm or hand into a dangerous position. Contact with rotating parts can cause severe injuries. Collars, couplings, cams, clutches, flywheels, shaft ends, spindles, and horizontal or vertical shafting are some examples of common rotating mechanisms that may be hazardous. The danger increases when bolts, nicks, abrasions, and projecting keys or set screws on rotating parts are exposed.

In-running nip-points

In-running nip-point hazards are caused by the rotating parts on machinery. There are three main types of in-running nips. Parts can rotate in opposite directions while their axes are parallel to each other. These parts may contact (producing a nip point) or be close to each other. In the latter case, the stock fed between the rolls produces the nip

*Taken, in part, from U.S. Department of Labor: Concepts and Techniques of Machine Guarding, Publ. No. OSHA 3067. Washington, DC (1980).

points. This danger is common on machinery with intermeshing gears, rolling mills, and calenders. Another nip point is created between rotating and tangentially moving parts. Some examples would be the point of contact between a power transmission belt and its pulley, a chain and a sprocket, or a rack and pinion. Nip points can occur between rotating and fixed parts where a shearing, crushing, or abrading action is created. Examples are spoked handwheels or flywheels, screw conveyors, or the periphery of an abrasive wheel and an incorrectly adjusted work rest.

Reciprocating motion

Machines with reciprocating motions other than powered hacksaws are not likely to be found in a chemical engineering shop. These motions are hazardous because an individual may be struck by or caught between a moving and stationary part during the machine's back-and-forth or up-and-down motion.

Transverse motion

Transverse motion is movement in a straight, continuous line such as a belt on a pulley. Transverse motion creates a hazard because an individual may be struck or caught in a pinch or shear point by the moving part.

Cutting

Cutting action involves rotating, reciprocating, or transverse motion. The danger of cutting action exists at the point of operation where finger, head, and arm injuries can occur and where flying chips or scrap material can strike the eyes or face. Such hazards are present at the point of operation in cutting wood, metal, or other materials. Typical examples of mechanisms involving cutting hazards include bandsaws, circular saws, boring or drilling machines, turning machines (lathes), or milling machines.

Punching, shearing, bending

Punching, shearing, and bending actions are more apt to be done by hand rather than by machine in a chemical engineering shop, which decreases the hazard. In these actions, the danger occurs at the point of operation where stock is inserted, held, and withdrawn by hand.

Six requirements for mechanical hazard safeguards

To provide protection against mechanical hazards, safeguards must meet minimum general requirements:

1. Prevent contact: The safeguard must prevent hands, arms, or any other part of a person's body from making contact with dangerous moving parts. A good safeguarding system eliminates the possibility of the machine operator or another person placing their hands near hazardous moving parts.
2. Be secure: Students should not be able to easily remove or tamper with the safeguard. A safeguard that can easily be made ineffective is no safeguard at all. Guards and safety devices should be made of durable material that will withstand the conditions of normal use. They must be firmly secured to the machine.
3. Protect from falling objects: The safeguard should ensure that no objects can fall into moving parts. A small tool that is dropped into a cycling machine could easily become a projectile that could strike and injure someone.
4. Create no new hazards: A safeguard defeats its own purpose if it creates a hazard of its own such as a shear point, a jagged edge, or an unfinished surface that can cause a laceration; e.g., the edges of guards should be rolled or bolted in such a way that they eliminate sharp edges.
5. Create no interference: Any safeguard that impedes a person from performing the job quickly and comfortably might soon be overriden or disregarded. Proper safeguarding can relieve the operator's (whether student or technician) apprehensions about injury.
6. Allow safe lubrication: If possible, one should be able to lubricate the machine without removing safeguards. Locating oil reservoirs outside the guard, with a line leading to the lubrication point, will reduce the need for the operator or technician to enter or to insert any part of his/her body into the hazardous area.

Other hazards

Although this section concentrates attention on concepts and techniques for safeguarding mechanical motion, machines obviously present a variety of other hazards that cannot be ignored. Full discussion of these matters is beyond the scope of this module, but some nonmechanical hazards are briefly mentioned below to remind the reader of things, other than safeguarding moving parts, that can affect the safe operation of machinery.

Power sources, high pressure

When using electrically powered or controlled machines, the equipment as well as the electrical system itself must be properly grounded. Replacing frayed, exposed, or old wiring will also help protect the operator and others from electrical shocks or electrocution. Just as all power sources for machinery are potential sources of danger, and must be checked before use, high pressure systems, too, need careful inspection and maintenance to prevent possible failure from pulsation, vibration, or leaks. Such a failure could cause explosions or flying objects.

Noise

Machines often produce noise (unwanted sound), which can result in a number of hazards. Not only can noise startle and disrupt concentration, but it can interfere with communications, thus hindering safe job performance. Research has linked noise to a whole range of harmful health effects, from hearing loss and aural pain to nausea, fatigue, reduced muscle control, and emotional disturbances.[15-17] Engineering controls (such as the use of sound-damping materials) as well as less sophisticated hearing protection (such as ear plugs and muffs) have been suggested as ways of controlling the harmful effects of noise. Vibration, a related hazard that can cause noise and thus result in fatigue and illness, may be avoided if machines are properly aligned, supported, and, if necessary, anchored.

Toxic materials

Because some machines require the use of cutting fluids, coolants, and other potentially harmful substances, operators, maintenance workers, and others in the vicinity may need protection. These substances can cause ailments ranging from dermatitis to serious illnesses and disease. Specially constructed safeguards, ventilation, and protective equipment and clothing are possible temporary solutions to the problem of machinery-related chemical hazards until these hazards can be better controlled or eliminated.

Hazardous condition checklist

A checklist that can be used to identify hazardous conditions in shops or other areas where machines are used is included as Exhibit VII.1.

Operator training

Even the most elaborate safeguarding system cannot offer effective protection unless the operator knows how to use it and why. Specific and detailed training is therefore a crucial part of any effort to provide safeguarding against machine-related hazards. Thorough operator training should involve instruction or hands-on training involving

1. a description and identification of the hazards associated with particular machines;
2. the safeguards themselves, how they provide protection, and the hazards for which they are intended;
3. how to use the safeguards and why;
4. how and under what circumstances safeguards can be removed and by whom (in most cases, repair or maintenance personnel only); and
5. what to do (e.g., contact the shop technician or laboratory director) if a safeguard is damaged, missing, or unable to provide adequate protection.

Engineering controls

Effective engineering design should be implemented to eliminate as many of the machinery hazards as possible. Engineering controls that both eliminate exposure to the hazard at the source and that do not rely on the operator's behavior for their effectiveness offer the best and most reliable means of safeguarding against any remaining exposure hazards. Whenever an extra measure of protection is necessary, however, operators must wear protective clothing or personal protective equipment (PPE).

Exhibit VII.1. Checklist for Machine Safeguarding*

Answers to the following questions should help the interested reader determine the safeguarding needs of his or her own workplace, by drawing attention to hazardous conditions or practices requiring correction.

Requirements for All Safeguards

	Yes	No
1. Do the safeguards provided meet the minimum OSHA requirements?	______	______
2. Do the safeguards prevent workers' hands, arms, and other body parts from making contact with dangerous moving parts?	______	______
3. Are the safeguards firmly secured and not easily removable?	______	______
4. Do the safeguards ensure that no objects will fall into the moving parts?	______	______
5. Do the safeguards permit safe, comfortable, and relatively easy operation of the machine?	______	______
6. Can the machine be oiled without removing the safeguard?	______	______
7. Is there a system for shutting down the machinery before safeguards are removed?	______	______
8. Can the existing safeguards be improved?	______	______

Mechanical Hazards

The point of operation:

1. Is there a point-of-operation safeguard provided for the machine?	______	______
2. Does it keep the operator's hands, fingers, body out of the danger area?	______	______
3. Is there evidence that the safeguards have been tampered with or removed?	______	______
4. Could you suggest a more practical, effective safeguard?	______	______
5. Could changes be made on the machine to eliminate the point-of-operation hazard entirely?	______	______

Power transmission apparatus:

1. Are there any unguarded gears, sprockets, pulleys, or flywheels on the apparatus?	______	______
2. Are there any exposed belts or chain drives?	______	______
3. Are there any exposed set screws, key ways, collars, etc.?	______	______
4. Are starting and stopping controls within easy reach of the operator?	______	______
5. If there is more than one operator, are separate controls provided?	______	______

Other moving parts:

1. Are safeguards provided for all hazardous moving parts of the machine, including auxiliary parts?	______	______

Nonmechanical Hazards

1. Have appropriate measures been taken to safeguard workers against noise hazards?	______	______
2. Have special guards, enclosures, or personal protective equipment been provided, where necessary, to protect workers from exposure to harmful substances used in machine operation?	______	______

Electrical Hazards

1. Is the machine installed in accordance with National Fire Protection Association and National Electrical Code requirements? ______ ______
2. Are there loose conduit fittings? ______ ______
3. Is the machine properly grounded? ______ ______
4. Is the power supply correctly fused and protected? ______ ______
5. Do workers occasionally receive minor shocks while operating any of the machines? ______ ______

Training

1. Do operators and maintenance workers have the necessary training in how to use the safeguards and why? ______ ______
2. Have operators and maintenance workers been trained in where the safeguards are located, how they provide protection, and what hazards they protect against? ______ ______
3. Have operators and maintenance workers been trained in how and under what circumstances guards can be removed? ______ ______
4. Have workers been trained in the procedures to follow if they notice guards that are damaged, missing, or inadequate? ______ ______

Protective Equipment and Proper Clothing

1. Is protective equipment required? ______ ______
2. If protective equipment is required, is it appropriate for the job, in good condition, kept clean and sanitary, and stored carefully when not in use? ______ ______
3. Is the operator dressed safely for the job (i.e., no loose-fitting clothing or jewelry)? ______ ______

Machinery Maintenance and Repair

1. Have maintenance workers received up-to-date instruction on the machines they service? ______ ______
2. Do maintenance workers lock out the machine from its power sources before beginning repairs? ______ ______
3. Where several maintenance persons work on the same machine, are multiple lockout devices used? ______ ______
4. Do maintenance persons use appropriate and safe equipment in their repair work? ______ ______
5. Is the maintenance equipment itself properly guarded? ______ ______

From: Concepts and Techniques of Machine Guarding. Publication No. OSHA 3067, U.S. Dept. of Labor, Washington, DC (1980).

PPE requirements and hazards

If it is to provide adequate protection, the selected protective clothing and equipment must always be

1. appropriate for the particular hazards;
2. maintained in good condition;
3. properly stored when not in use to prevent damage or loss; and
4. kept clean and sanitary.

Note that protective clothing and equipment itself can create hazards. A protective glove that can become caught between rotating parts or a respirator facepiece that hinders the wearer's vision, for example, require alertness and careful supervision whenever they are used. Other aspects of the operator's dress may present additional safety hazards. Loose-fitting clothing might possibly become entangled in rotating spindles or other kinds of moving machinery. Jewelry, such as bracelets and rings, can catch on machine parts or stock and lead to serious injury by pulling a hand into the danger area.

HAND AND POWERED TOOLS*

Although most students will recognize that using a machine such as a table saw is dangerous, they often overlook the hazards[18] associated with hand and powered tools. Since students are much more apt to be using these tools, they must learn to recognize the hazards associated with the different types of tools and the safety precautions necessary to prevent these hazards.

Misuse

Hand tools are nonpowered and include anything from axes to wrenches. The greatest hazards posed by hand tools result from misuse and improper maintenance. Some examples of misuse are

1. using a chisel as a screwdriver or using a screwdriver as a chisel may cause the tip of the chisel or screwdriver to break and fly, hitting the user or other individuals;
2. using a tool, such as a hammer, with a loose, splintered, or cracked handle may cause the head of the tool to fly off and strike the user or another person; or
3. using a wrench if its jaws are sprung may cause it to slip and crush the user's hand or strike the user's face.

Training required

Students should be trained to select the right hand tool for the job and to inspect it for defects before use. They should be cautioned to direct saw blades and other tools away from aisles and other students working close by. Around flammable substances, sparks produced by iron or steel hand tools can be a dangerous ignition source. Where this hazard exists, spark-resistant tools made from brass, plastic, aluminum, leather, or wood must be provided and their use required.

Precautions

Powered tools can also be hazardous when improperly used. The following general precautions should be addressed when reviewing power tool safety with students:

1. Never carry a tool by the cord or hose.
2. Never yank the cord or hose to disconnect the tool from the receptacle.
3. Keep cords and hoses away from heat, oil, and sharp edges.
4. Disconnect tools when not in use, before servicing, and when changing accessories such as blades, bits, and cutters.
5. Keep all observers at a safe distance from the work area.
6. Secure work with clamps or a vise, freeing both hands to operate the tool.
7. Avoid accidental starting; do not hold a finger on the switch button while carrying a plugged-in tool.
8. Maintain tools with care. For best performance, keep tools sharp and clean. Follow instructions in the user's manual for lubricating and changing accessories.

*From U.S. Department of Labor: Hand and Power Tools, Publ. No. OSHA 3080 (rev.) Washington, DC (1986).

9. Keep good footing and maintain balance when using a power tool.
10. Wear proper apparel; loose clothing, ties, or jewelry can become caught in moving parts.
11. Remove all portable electric tools that are damaged, and tag them **DO NOT USE**. Identify the problem on the tag.

Guards

Just as with larger powered machines, hazardous moving parts of a power tool need to be safeguarded. For example, portable circular saws must be equipped with guards. An upper guard must cover the entire blade of the saw. A retractable lower guard must cover the teeth of the saw, except when it makes contact with the material being cut. The lower guard must automatically return to the covering position when the tool is withdrawn from the work. Safety guards must never be removed when the tool is being used. Guards should protect the operator and others from the point of operation, in-running nip points, rotating parts, and flying chips and sparks.

Safety switches

Safety switches ensure that powered tools can be readily turned off when necessary. The following hand-held powered tools must be equipped with a momentary contact ("dead man") "on-off" control switch: drills, grinders with wheels larger than 2 inches in diameter, disc sanders, belt sanders, reciprocating saws, saber saws, and other similar tools. (These tools may also be equipped with a lock-on control provided the same finger or fingers that turn it on can turn it off with a single motion.) Hand-held powered tools such as circular saws, chain saws, and percussion tools without positive accessory holding means must be equipped with a constant pressure switch that will shut off the power when the pressure is released.

Electrical hazards

Students using electric tools must be made aware of several dangers, the most serious of which is the possibility of electrocution. Among the chief hazards of electric-powered tools are burns and slight shocks, which can lead to injuries or even heart failure. Under certain conditions, even a small amount of current (50 milliamps) can result in fibrillation of the heart and eventual death. A shock can also cause the user to fall off a ladder or other elevated work surface. (See also ELECTRICAL HAZARDS, below.)

Grounded tools

To protect the user from shock, tools must either have a three-wire cord with ground and be grounded, be double insulated, or be powered by a low-voltage transformer. Three-wire cords contain two current-carrying conductors and a grounding conductor. One end of the grounding conductor connects to the tool's metal housing. The other end is grounded through a prong on the plug. Anytime an adapter is used to accommodate a two-hole receptacle, the adapter wire must be attached to a known ground. The third prong should never be removed from the plug. Double insulation is more convenient. The user and the tools are protected in two ways: by normal insulation on the wires inside, and by a housing that cannot conduct electricity to the generator in the event of a malfunction. (See also, Functions of grounding, below.)

Work practices for electric tools

The following general practices should be observed when using electric tools:

1. Electric tools should be operated within their design limitations.
2. Gloves and safety footwear are recommended while using electric tools.
3. When not in use, tools should be stored in a dry place.
4. Pneumatic, not electric, tools should be used in damp or wet locations.
5. Work areas should be well-lighted.

Abrasive wheel tools

Powered abrasive grinding, cutting, polishing, and wire buffing wheels create special safety problems because the tools may throw off flying fragments. Before an abrasive wheel is mounted, it should be inspected closely and sound- or ring-tested to be sure that it is free from cracks or defects. To test wheels, tap them gently with a light nonmetallic implement. If the wheel sounds cracked or dead, it could fly apart in operation and must not be used. A sound and undamaged wheel will give a clear metallic tone or "ring."

Checking the wheel

To prevent the wheel from cracking, the user should be sure it fits freely on the spindle. The spindle nut must be tightened enough to hold the wheel in place, but not tight enough to distort the flange. The manufacturer's recommendations must be followed. Care must be taken to ensure that the spindle wheel will not exceed the abrasive wheel specifications. Because a wheel can disintegrate (explode) during start-up, the user should never stand directly in front of the wheel as it accelerates to full operating speed.

Guards on portable grinders

Portable grinding tools need to be equipped with safety guards to protect the user not only from the moving wheel surface but also from flying fragments in case of breakage. Permissible guards for fixed grinding tools depend on the type of use. OSHA standards (29 CFR 1910.215) should be consulted to determine the type of guard required. Tool rests must be kept within 1/8-inch of the wheel to prevent the work from being jammed between the wheel and the rest and, perhaps, prevent the wheel from breaking. The tongue guard must not be more than 1/4-inch from the wheel. In addition, when using a powered grinder, always use eye protection, and turn off the power to the grinder when it is not in use.

Basic safety rules of power tools

Students using hand and powered tools are exposed to the hazards of falling, flying, abrasive, and splashing objects, or exposed to harmful dusts, fumes, mists, vapors, gases, or noise. They must not only be provided with the particular PPE necessary to protect them but must also be required to use it. All hazards involved in the use of hand and powered tools can be prevented by following five basic safety rules:

1. Keep all tools in good condition with regular maintenance.
2. Use the right tool for the job.
3. Examine each tool before use.
4. Operate tools only according to the manufacturer's instructions.
5. Provide and require the use of the correct PPE.

Other types of powered tools

In addition to electric power tools, other types of tools include pneumatic, liquid fuel, hydraulic, and powder-actuated. Each of these types has special safety precautions that should be followed during use. Since these types of tools will probably not be used in an institutional setting except by experienced contractors, they will not be specifically addressed in this module. If required, safety information can be obtained from the manufacturer or nearest OSHA office.

Tool checkout

One of the constant "battles" in any shop/laboratory situation is keeping tools from "walking off." Any tools borrowed from the shop must be checked out with a specific student being responsible. Frequently used small hand tools (e.g., wrenches, pliers, etc.) can be kept in the laboratory area for ready access. These small tools can be checked out to a lab group, or students can be required to purchase them. A central tool box can also be used but with greater risk of losses. Storing tools on wall-mounted holders, with each tool outlined, allows rapid selection of tools and a rapid check that all tools have been replaced before the end of the laboratory period.

ELECTRICAL HAZARDS*

Circuit defined

Ultimate ground

All Unit Operations Laboratory students have had electricity and magnetism sections in physics courses and probably one or two applied electrical engineering courses involving circuits and machinery. They should be required to review the concepts of circuits and grounds whenever possible electrical hazards exist. A circuit is a complete loop. Electric current can flow only if it returns to its source, i.e., completes the circuit. The path through which the current returns to its source is called the "return" or ground. The reason for the term "ground" is that the earth is used—literally—to provide the return path no matter what distance separates the equipment from the power source. Ground connections in the laboratory are normally made to the cold water system as its components provide a reliable, low-resistance path for contact with the earth.

*Taken, in part, from U.S. Department of Labor: Controlling Electrical Hazards, Publ. No. OSHA 3075 (rev.), Washington,, DC (1986) or from U.S. Department of Labor: Ground-Fault Protection on Construction Sites, Publ. No. 3007 (rev.), Washington, DC (1987).

Electric shock

Shock occurs when the body becomes a part of the circuit with current entering the body at one point and leaving at another.[19] Shock normally occurs in one of three ways. The person must come in contact with both wires of the electrical circuit; with one wire of an energized circuit and the ground; or with a metallic part that has become "hot" by being in contact with an energized wire, while the person is also in contact with the ground.

Effects of shock

The severity of the shock received when a person becomes a part of an electrical circuit is affected by three primary factors: the amount of current flowing through the body (measured in amperes); the path of the current through the body; and the length of time the body is in the circuit. Other factors that may affect the severity of shock are the frequency of the current, the phase of the heart cycle when shock occurs, and the general health of the person before the shock. The effects from electric shock depend upon the type of circuit, its voltage, resistance, amperage, pathway through the body, and duration of the contact. Effects can range from a barely perceptible tingle to immediate cardiac arrest.

Effects of electric current

Although there are no absolute limits or even known values that show the exact injury from any given amperage, Table VII–3 shows the general relationship between the degree of injury and amount of amperage for a 60-cycle hand-to-foot path of 1 second's duration of shock. As this table illustrates, a difference of less than 100 milliamperes exists between a current that is barely perceptible and one that can kill. Muscular contraction caused by electrical stimulation may not allow the victim to free himself/herself from the circuit, and the increased duration of exposure increases the dangers to the shock victim. For example, a current of 100 milliamperes for 3 seconds is equivalent to a current of 900 milliamperes applied for 0.03 second in causing fibrillation. The so-called low voltages can be extremely dangerous because, all other factors being equal, the degree of injury is proportional to the length of time the body is in the circuit. **LOW VOLTAGE DOES NOT IMPLY LOW HAZARD!**

Possible shock consequences

A severe shock can cause considerably more damage to the body than is visible. There may be internal hemorrhages and destruction of tissues, nerves, and muscles. In addition, shock may be only the beginning in a chain of events; the final injury may well be from a fall, cuts, burns, or broken bones. Electric shock can also cause injuries of an indirect or secondary nature in which involuntary muscle reaction from the electric

Table VII–3

Effects of Electrical Current in the Human Body* †

Current	Reaction
1 Milliampere	Perception level; just a faint tingle.
5 Milliamperes	Slight shock felt; not painful, but disturbing. Average individual can let go. Strong involuntary reactions to shocks in this range can, however, lead to injuries.
6–25 Milliamperes (women) 9–30 Milliamperes (men)	Painful shock, muscular control lost. This is called freezing current or the "let-go"‡ range.
50–150 Milliamperes	Extreme pain, respiratory arrest, severe muscular contractions.‡ Individual cannot let go. Death is possible.
1–4.3 Amperes §	Ventricular fibrillation (the rhythmic pumping action of the heart ceases). Muscular contraction and nerve damage occur. Death is most likely.
10+ Amperes	Cardiac arrest, severe burns, and probable death.

* From: Controlling Electrical Hazards, Publ. No. 3075, U.S. Dept. of Labor, Washington, DC (1986).

† A 60-cycle, hand-to-foot path lasting 1 second.

‡ If the extensor muscles are excited by the shock, the person may be thrown away from the circuit.

§ Where shock durations involve longer exposure times (5 seconds or greater) and where only minimum threshold fibrillation currents are considered, theoretical values are often calculated to be as little as 1/10 the fribrillation values shown.

shock can cause bruises, bone fractures, and even death resulting from collisions or falls. In some cases, injuries caused by electric shock can be a contributory cause of delayed fatalities.

Types of burns

The most common electric-shock-related injury is burn. Burns suffered in electrical accidents may be of three types: electrical burns, arc burns, and thermal contact burns. With electrical burns, when electrical current flows through tissues or bone, the heat generated by the current flow damages tissue. Electrical burns are one of the most serious injuries and should be given immediate attention. Arc or flash burns are the result of high temperatures close to the body produced by an electric arc or explosion. They should also be attended to promptly. Finally, thermal contact burns are those normally experienced when the skin comes in contact with hot surfaces of overheated electrical conductors, conduits, or other energized equipment. Additionally, clothing may be ignited in an electrical accident, and a thermal burn will result. All three types of burns may be produced simultaneously.

Factors causing electrical hazards

Electrical accidents appear to be caused by any one or any combination of three possible factors: unsafe equipment, unsafe installation, or both; workplaces made unsafe by the environment; and unsafe work practices. Possible ways to protect people from the hazards caused by electricity include insulation, guarding, grounding, mechanical devices, and safe work practices.

Insulators and insulation

One way to safeguard individuals from electrically energized wires and parts is through insulation. An insulator is any material with high resistance to electrical current. Insulators, such as glass, mica, rubber, and plastic, are put on conductors to prevent shock, fires, and short circuits. When preparing to work with electrical equipment, the insulation should be checked before making a connection to a power source to be sure there are no exposed wires. The insulation of flexible cords, such as extension cords, is particularly vulnerable to damage.

Guarding against electrical contact

Live parts of electric equipment must be guarded to prevent accidental contact. Live parts may be guarded by

1. locating in a room, vault, or similar enclosure accessible only to qualified persons;
2. using permanent, substantial partitions or screens to exclude unqualified persons;
3. locating on a suitable balcony, gallery, or platform elevated and arranged to exclude unqualified persons; or
4. elevating 8 feet or more above the floor.

Entrances to rooms and other guarded locations containing exposed live parts must be locked and marked with conspicuous warning signs forbidding unqualified persons to enter.

Functions of grounding

Grounding is another way to provide protection from electric shock; however, it is normally a secondary protective measure. By grounding a tool or electrical system, a low-resistance path to the earth through a ground connection or connections has been intentionally created. When properly done, this path offers sufficiently low resistance and has sufficient current-carrying capacity to prevent the buildup of voltages that may result in a personnel hazard. This precaution does not guarantee that no one will receive a shock, be injured, or be killed. It does, however, substantially reduce the possibilities of such accidents, especially when used in combination with other safety measures.

Ground-fault circuit interrupter utilization

A ground-fault circuit interrupter (GFCI) is a fast-acting circuit breaker that senses small imbalances in the circuit caused by leakages to ground.[20] When the leakage exceeds 5 $\pm$ 1 milliamperes, the GFCI interrupts the circuit quickly enough to prevent electrocution, in some cases in as little as 1/40 second. This protection is required in addition to, not as a substitute for, normal grounding requirements. Circuits for systems involving or using wet processes (fluid-flow experiments, heat exchangers, cooling towers, evaporators, etc.) should be equipped with GFCI's. That practice is also required for extension cords even if plugged into permanent wiring. Details of the OSHA standard for GFCI use are in 29 CFR 1926.404(b)(1)(ii).

Safe work practices for electrical equipment

Students working with electrical equipment must use safe work practices. All students must know how to shut off power to a piece of equipment by using either the power switch on the equipment or the circuit breaker. Circuit breakers or switch boxes must be secure but readily accessible. Each circuit must be clearly labeled as to the equipment or area that it activates. Students need to know how to use the master electrical switch under emergency conditions. (The circuits should be checked to ensure that room lighting is on a separate box.) Students should be taught the "left-hand rule." Anytime they prepare to turn the master switch back on, especially after changing a fuse, they should stand to the side, face the wall instead of the box, and use their left hand to push the switch back on. In this way, if the box explodes when power is restored, they are less likely to suffer severe burns to the face or even death.

"Left-hand" rule

Lockout and tagout

The accidental or unexpected sudden starting of electrical equipment can cause severe injury or death. Before ANY inspections or repairs are made—even on the so-called low-voltage circuits—the current should be turned off at the switch box and the switch padlocked in the OFF position. At the same time, the switch or controls of the machine or other equipment being locked out of service should be securely tagged to show which equipment or circuits are being worked on. Lockouts and tagouts should be removed only by the person(s) who installed them.

Checking electrical equipment prior to use

All electrical components and equipment must be inspected before use. Frayed or worn wiring and extension cords; cracked plugs, switches, or receptacle and switch-plate covers; missing grounds; and two-wire to three-wire plug adaptors with missing "pigtails" or ground prong all render the device or system unfit for use until repairs have been made. Only qualified personnel can make repairs: shop technicians or persons (teaching assistants, the laboratory director) certified as competent by an electrician. Chemical engineering students are not usually qualified to make repairs to or construct electrical equipment.

Reporting unsafe electrical conditions; repairs

Students must immediately report any unsafe electrical conditions to prevent an accidental shock. Damaged or unauthorized extension cords must be taken out of service immediately. Students must shut off power at the breaker before disconnecting a damaged cord. To ensure that someone else does not use equipment with a damaged power cord, the plug can be clipped off with a pair of wire cutters. Because most damage occurs at the plug, the electrician will repair it anyway. As noted above, all electrical work must be done by experienced personnel. Equipment to be repaired should be tagged out and repairs verified before reuse.

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SAMPLE QUIZ QUESTIONS

1. Define the following terms: LEL, UEL, autogenous combustion temperature, flammable mixture.
2. How should oxidants and flammable chemicals be stored in the Unit Operations Laboratory?
3. How can the formation of undesirable flammable mixtures be avoided?
4. What are the principal categories and sources of leaks in the Unit Operations Laboratory?
5. Describe the difference between "grounding" and "bonding." When is each used?
6. How does the "left-hand rule" protect you when you are operating high-energy electrical switches?
7. What is the "fire triangle?"
8. How are portable fire extinguishers selected? What type(s) of extinguisher should be used on the following types of fires:
   a) smouldering trash in a metal waste-can?
   b) a burning pool of liquid (type unknown) on the bench-top or on the floor?
   c) sparking in the 220-volt switchbox servicing the distillation column?

   What types of fire extinguisher would not be appropriate for those fires?
9. Why must you never use a carbon dioxide or Halon fire extinguisher to put out the fire in someone's hair?
10. What types of procedures must be carried out in a laboratory fume hood? Why?
11. Explain the differences between "capture" and "transport" velocities with regard to hoods. What is the minimum face velocity required for laboratory fume hoods? How is this velocity measured?
12. What external factors affect the proper use of fume hoods? How can the entrance velocity be affected by these factors?
13. How should all power cords be unplugged? What do you do if there is any visible damage to the extension cord or plugs you need to use for your experiment?
14. Why is a two- or four-plug box on the end of an extension cord not acceptable for laboratory (or home) use?
15. What is a pressure-relief device? How and why is it used under normal circumstances?
16. What is a process interlock? How and why are they used? Describe an interlock with which you are familiar and tell how it works.
17. What general criteria are used to select protective clothing and equipment?
18. What types of hazards are associated with the use of electric-powered tools in the laboratory?
19. What precautions are necessary to protect the user of an electric-powered tool from shock?
20. What factors affect the severity of an electric shock? In general, what is the minimum electric current that will result in a fatality?
21. What precautions should be taken to protect yourself and your group from an electric shock?

Unit VIII
INDUSTRIAL HYGIENE IN THE UNIT OPERATIONS LABORATORY

PURPOSE: To briefly review the general concepts of industrial hygiene affecting safety and health in the Unit Operations Laboratory.

OBJECTIVE: To discuss the general principles of industrial hygiene and the need for applying those principles to the laboratory situation.

1. Identification, evaluation, and control of health hazards
2. Routes of entry
3. Noise exposure evaluation
4. Material safety data sheets
5. Chemical exposure evaluation
6. Personal protective equipment
7. Chemical handling, transport, and storage
8. Waste disposal
9. Chemical spills

SPECIAL TERMS:

1. Chemical agents
2. Biological agents
3. Work environment
4. Epidemiology
5. Dose-response curve (ogive)
6. Route of exposure
7. Dermatitis
8. Chronic vs. acute exposure
9. Chemical pneumonitis
10. Pulmonary edema
11. Necrosis
12. Asphyxia
13. Cilia
14. Hair cells
15. Threshold shift
16. Time-weighted-average
17. Detector tube
18. Substrate

INTRODUCTION

Sources of health problems

Industrial hygiene is the science of protecting the health of individuals through control of the work environment. The scope of industrial hygiene is threefold: recognizing the source of health problems, evaluating the workplace, and developing corrective/control techniques. It begins with the recognition of health problems within the workplace. Some of the more frequently encountered causes of these problems are

1. chemical agents—liquids, dusts, fumes, mists, vapors, or gases;
2. physical energy—electromagnetic and ionizing radiations;
3. noise and vibration;
4. temperature and pressure extremes;
5. biological agents—insects, mites, molds, yeasts, fungi, bacteria, and viruses; and
6. others—monotony, repetitive motion, excessive loads, anxiety, and fatigue, etc.

These stresses must all be evaluated in terms of their danger to life and health as well as their influence on the natural bodily functions.

Evaluation of workplace/laboratory environment

The second activity encompassed within the scope of industrial hygiene is that of evaluation. The "work atmosphere" must be evaluated in terms of long-range as well as short-range effects on health. This evaluation can be done by compiling knowledge, experience, and quantitative data.

Typical control measures

Finally, industrial hygiene includes developing corrective measures or control techniques to eliminate existing problems. Many times these control procedures will include

1. reducing the number of persons exposed to the problem,
2. replacing harmful or toxic materials with less dangerous ones,
3. changing work processes to eliminate or minimize exposure,
4. adopting new ventilation procedures,
5. increasing distance and time between exposures to radiation,
6. introducing water to reduce dust emissions,
7. practicing good housekeeping, and
8. providing proper protective equipment.

Use of industrial hygienists to improve laboratory health and safety

The Unit Operations Laboratory director/instructor should rely not only on his/her own expertise in these situations, but also that of the college/university safety and health staffs and that of industrial hygienists, who can evaluate the laboratory environment for actual or potential hazards. Input should be sought whenever a new experiment is being developed or an existing experiment modified (change of chemicals, temperature, pressure, etc.) in any way that could allow or cause an unsafe situation to arise. If such qualified personnel are not available on campus, they can usually be obtained on request from many of the corporations who regularly hire the Department's graduates. Such persons, whether industrial hygienists or safety professionals, will form the core of available expertise when the students have left the college/university setting and enter the workplace.

HEALTH EFFECTS

Dose defined

All chemicals can be toxic to man under the right conditions, even some, such as water, not normally considered toxic. A "harmless" chemical can evoke a toxic response in a biological system if added in a sufficient amount. Conversely, for a chemical normally thought to be "toxic," there is a minimal concentration that will produce no toxic effect (exceptions to this rule may be some carcinogens such as asbestos). The toxic potential of a chemical is thus expressed by the relationship between the amount (the dose) of a chemical and the produced response.

Use of epidemiological data

Animal studies and epidemiological data are used to establish safe exposure limits for chemicals. These limits are continually being revised by ACGIH, NIOSH, and OSHA as more is learned about the actions of chemicals, especially as a result of chronic exposures. OSHA has recently revised its existing air contaminants standard, 29 CFR 1910.1000, by reducing the permissible exposure limit (PEL) on 212 previously regulated chemicals and setting PELs for 164 new substances.[1] All laboratory personnel and students should be aware that the absence of published exposure limits does not imply that a material is safe. Such a situation only means that the material has not been tested, or if it has, that the report has not been issued or that the research is incomplete.

Animal studies

Dose-response curve

When a chemical is being evaluated, animal studies are initially done to establish the range of responses (from "no effect" to "death of all animals") to the administration of a chemical. These data are used to plot a dose-response curve (an ogive) relating percent mortality (ordinate) to dose administered (abscissa). From this curve, the dose that will produce the death of 50% of the animals can be calculated. This value is commonly abbreviated as LD_{50} (lethal dose). It should be accompanied by an explanation of the species of experimental animal used, the route of administration of the compound, the vehicle used to dissolve or suspend the material if applicable, the time period over which the animals were observed, and a statement of the error of the estimated value, such as the probability range or confidence limits. If inhalation is the route of exposure, the dose is expressed as the concentration of the material in the air and the length of the exposure time is specified. In this case, the term LC_{50} (lethal concentration) is used to designate the concentration in air that may be expected to kill 50% of the animals exposed for the specified length of time.

Routes of exposure:
a. Inhalation

The laboratory director will obviously want to keep any exposures to a minimum. Understanding how chemicals can enter and affect the body is very important since the intensity of toxic action is a function of the concentration of the toxic agent that reaches the site of action. The route of exposure can influence the concentration reaching the site of action. In terms of effects, the most important route toxic chemicals can enter the body is through inhalation. The large surface area of the lungs (equivalent to a basketball court) and the close association with the vascular system (essentially two cells separate the air and blood) make rapid uptake possible. This situation is desirable with respect to oxygen, but very harmful when solvent vapors are involved.

b. Skin/eye contact

The second most important route of entry is contact with the skin and eyes. The mucous membranes and vascular bed of the eyes facilitate uptake of toxic vapors and gases. Toxic particles will be flushed into the nose through the tear ducts where they can be swallowed. Although skin is an effective barrier for many things, it is not perfect. In general, absorption of inorganic substances, including water, is negligible. On the other hand, absorption of fat-soluble substances (mainly organic compounds) is fairly rapid. Most substances that are both water- and fat-soluble, e.g., amines and nitriles, penetrate so rapidly that the rate of absorption is comparable to that of gastrointestinal or even pulmonary absorption. Substances that are readily absorbed, such as dimethyl sulfoxide (DMSO), can act as a carrier for other molecules that would not ordinarily be able to penetrate the skin. If the integrity of the skin is altered through abrasion or dermatitis, many substances that normally would be repelled by intact skin will be absorbed.

c. Ingestion

Precautions

Overt ingestion is not a frequent method of uptake but may occur accidentally through foolish mouth-pipetting or foolish use of food and drink containers to store chemicals. This route of entry can be significant in the case of chemicals such as lead, which can be absorbed faster than it is eliminated. Chronic exposure through poor hygiene practices can result in toxic levels being reached. Students must always wash their hands when leaving the laboratory and, of course, no eating, drinking, or smoking should be allowed in the laboratory. Covert ingestion occurs when the cilia lining the respiratory tract sweep trapped particles up to where they are swallowed. Absorption can then occur from the gastrointestinal tract.

Health effects

A wide variety of health effects can result from exposure to chemicals depending on the rate and route of exposure and the toxic effects to the body. If a material is taken into the body at a rate sufficiently slow that the rate of excretion and/or detoxification keeps pace with the intake, it is possible that no toxic response will occur, even though the same total amount of material taken in at a faster rate would be lethal. Hydrogen sulfide is a good example of such a material.

Solvent effects

Chemicals can affect every system of the body. Many solvents will affect liver chemistry since the liver is a primary detoxification site. Solvents may also cause narcosis through action on the central nervous system. Acute poisonings will be quickly apparent, but some chemicals have long-term effects, e.g., carcinogens or teratogens (causing birth defects). Obviously, any carcinogenic chemical, such as benzene, or any mutagenic or teratogenic chemical should not be used in the Unit Operations Laboratory.

Toxicity and health effects

Similar health effects are often common to similar chemical families, with the low molecular weight compounds usually, but not always, being the most toxic (due to faster absorption rates). Until the laboratory director can obtain a material safety data sheet (MSDS) for a specific chemical, he/she can often get a general indication of toxicity and health effects from the MSDS of a related chemical. Remember that PELs and threshold limit values (TLVs) are not absolute indicators of safety. Each person responds differently to chemical exposures, and some individuals are sensitive to very low levels. Many chemicals such as styrene, methylamine, and formaldehyde are sensitizers; exposures even to low levels may cause individuals to have very strong reactions to even minute traces.

Physical effects of chemicals

In addition to physiological effects on body systems, chemicals can also have physical effects. After repeated and prolonged contact, substances that have a solvent or emulsifying action can produce a dry, scaly, and fissured dermatitis. Students should never be allowed to use solvents to clean their skin and should be required to use gloves suitable for the solvents to which they may be exposed. Acids or alkaline-soluble gases, vapors, and liquids may dissolve in the aqueous protective film of the eye, in mucous membranes of the nose and throat, or in sweat and cause irritation at those sites. Direct contact with strong acids or bases can cause immediate tissue damage. This damage is also the reason that induction of vomiting is contraindicated because additional tissue damage will result from the second contact, which may lead to perforation of the esophagus. The resulting scarring of the esophagus can lead to long-term and even life-threatening consequences.

Respiratory system damage

Physical contact with excessive amounts of substances can directly irritate the lungs and gastrointestinal tract. This situation can result in inflammation of and reflex constriction of respiratory passages with resultant coughing and choking, vomiting, or diarrhea. Solubility is an important factor in determining the site or irritant action in the respiratory system. Highly soluble substances such as ammonia mainly affect the upper respiratory tract. Insoluble materials such as nitrogen dioxide primarily affect the lung. The direct contact of liquid aromatic hydrocarbons with the lung can cause chemical pneumonitis with pulmonary edema, hemorrhage, and tissue necrosis. Therefore, if these materials are ingested, the induction of vomiting is contraindicated because of possible aspiration of the hydrocarbon into the lungs.

Asphyxia

Inert gases such as nitrogen can lead to serious and often fatal effects simply by physical displacement of oxygen, which leads to asphyxia. Chemical asphyxiants such as carbon monoxide render the body incapable of utilizing an adequate oxygen supply. Since carbon monoxide binds more tightly with hemoglobin than oxygen, simply removing an individual from a contaminated atmosphere may not be adequate to prevent death.

Noise exposure

In addition to the health effect of exposure to chemicals, the effects of noise exposure must also be considered.[2,3,4] Prolonged exposure to high noise levels will result in permanent hearing loss. Unfortunately, there is generally no pain or discomfort associated with the damage to the ears so significant loss can occur before a person realizes it. Therefore, consistent use of hearing protection is very important.

Physiology of hearing

Sound waves in the air are converted by the eardrum and the bones of the middle ear into waves in the fluid filling the inner ear. This movement causes a membrane to vibrate against hair-like protrusions (cilia) from the "hair cells." Stimulation of hair cells generates a nervous impulse to the brain, which interprets the sound. Exposure to excessive noise levels causes damage to the hair cells. Sometimes this damage is reversible as in the case of a temporary threshold shift. The cilia of the hair cells are "bent over" similar to mashing down grass by walking on it. When this threshold shift occurs, more energy is required to stimulate the hair cells, i.e., the threshold of hearing has been shifted, hence the name. When the ear is no longer exposed to excessive noise, the cilia will gradually "recover" to an upright position.

Hearing threshold shift

With repeated exposure to excessive noise, the hair cells lose their ability to recover and are eventually destroyed. This results in a permanent hearing threshold shift. How quickly the damage occurs depends on the level and duration of the sound. The effect of noise on the hair cells can be compared with the effect of walking on a carpet. No difference in wear can be seen from one day to the next, but eventually the carpet will become threadbare in traffic areas.

Hearing loss

Because of the way the ear is constructed, hearing loss as a result of noise exposure occurs first at high frequencies, generally around 4,000 Hz, which is above the speech range of 500 to 2000 Hz. In a hearing conservation program, annual audiograms are made to look for this first "symptom" of noise damage. If exposure to excessive noise is allowed to continue, the area of loss will expand until it reaches the speech range. Since the loss is not uniform across all frequencies, reception becomes garbled and cannot be improved just by increasing the volume with a hearing aid. Even newer hearing aids that selectively amplify different frequencies cannot restore normal hearing.

MATERIAL SAFETY DATA SHEETS

MSDSs are developed by chemical manufacturers to meet the requirements of OSHA's hazard communication standard. Chemical manufacturers, importers, and distributors are required to send a MSDS with the first shipment of a chemical to a commercial user. If new information is received concerning the chemical, the manufacturer must update the MSDS within 3 months. The revised MSDS must then be sent with subsequent shipments.

Information available

The MSDS can be used to obtain hazard information about chemicals that are being considered for use in the Unit Operations Laboratory. The information on the MSDS will allow the laboratory director to compare health hazards and physical characteristics so that he/she can select the safest chemicals to use. Before each experiment, the laboratory director should require the students to read the MSDSs for chemicals that they will be using. They should be familiar with the chemical's hazards, appropriate PPE, and emergency procedures. Some of the terminology that they will encounter when using MSDSs has been included in Appendix F.

Emergency use of MSDS

A copy of the MSDS for every chemical used in the laboratory should be readily available in the laboratory area. Students can refer to them when needed, and in the event that someone is injured by a chemical, the appropriate MSDS can be taken with them to the emergency room. The MSDS will give the doctor information needed for treatment and has an emergency number to call for more detailed information.

HAZARD IDENTIFICATION

The laboratory (or work) environment is sampled to determine the existence and extent of any exposures to harmful chemicals or excessive noise. Before any control measures can be implemented, the source and magnitude of the problem must be identified. Sampling should be conducted under the "worst case" conditions that exist in the laboratory, excluding an emergency spill. If there is no hazard under the highest exposures that would normally occur, it can be reasonably assumed that all lesser conditions do not exceed published OSHA standards or other voluntary guidelines. If there is a hazard, then its magnitude is known and appropriate safeguards can be designed to protect the students and the laboratory personnel.

NOISE EXPOSURE EVALUATION

Noise exposure can result from mixers, grinders, power tools, steam/air exhaust, fans and drives, cooling towers and other large apparatus, and local exhaust ventilation systems.

In most cases, a hand-held sound level meter can be used to evaluate the range of exposures. Since most of these noise sources will be intermittent, OSHA 8-hour time-weighted-averages (TWA) will generally not be exceeded unless very high noise levels are involved (95+ dBA). Compliance, however, with the OSHA noise TWA requirement does not mean that precautions should not be taken. Short exposures to high noise levels can still cause damage—it just takes longer to become evident. Hearing protection should be mandatory around any operations with noise levels over 90 dBA. Extra protection can be achieved by instituting this requirement at 85 dBA.

Noise survey layout

A diagram of the layout of the Unit Operations Laboratory can be used for the noise survey. Noise level readings can be entered on the layout to show the areas where hearing protection is required. In addition to taking readings in locations where students will be working with a noisy piece of equipment, the noise levels for students working at adjacent "quiet" experiments should be checked. They may receive enough carry-over noise to also require the use of hearing protection.

Repeating noise surveys

Noise surveys should be repeated whenever new equipment/procedures are introduced into the laboratory. They should also be repeated on an annual basis. New equipment may initially operate below 90 dBA or even below 85 dBA, but as it ages and wears mechanically, noise levels will increase. Excessive noise levels may, therefore, develop over a period of time. Excessive and unusual noises, i.e., a belt squeaking, can be an indication of an impending mechanical breakdown. Many companies include noise and vibration surveys as part of their preventive maintenance programs. With monthly checks of mechanical equipment, repairs can be scheduled as part of routine maintenance and costly emergency shut-downs can be avoided.

CHEMICAL EXPOSURE EVALUATION

A total inventory should be made of all chemicals, reagents, and indicator fluids used in the laboratory. These items should be categorized with regard to location, quantity, and the person responsible for the material. With this information, a risk assessment can be made prior to exposure. Risk is defined as the product of frequency of exposure and magnitude. The techniques for conducting a risk assessment are presented later in this module.

Laboratory air measurement

Measurements of the air quality in the laboratory are made to determine whether a health hazard exists, to permit inferences of average and peak exposure levels, and to allow conclusions to be formulated regarding potential health effects. If the environment is found to be unsafe, some type of corrective action is required. The type depends on the toxicity and potential dosage associated with the exposure. If the environment appears safe with regard to chemical hazards, monitoring should continue at regular intervals. Monitoring is not the only clue that something is amiss: visible emissions, odors, etc., can (and usually do) prompt immediate repairs or instigation of emission control measures. Some compounds with odors that readily warn the laboratory personnel that there is a leak are acetic acid (vinegar), butyric and isobutyric acids (rancid butter), hydrogen sulfide (rotten eggs), C_1 and C_2 mercaptans (skunk), and low molecular weight aliphatic sulfides and disulfides (onion and garlic). Odor thresholds for many compounds are given in Appendix D.

Use of detector tubes

The type of emission and the frequency and duration of the releases will govern the frequency of sampling. The sampling time and volume are governed by the characteristics of the analyzer and the student exposure pattern. The use of interference-free detector tubes is often satisfactory. A pump is used to pull a metered amount of air through the reagent in the tube. The concentration of the chemical in the air is proportional to the length of stain (color change) in the reagent part of the tube. Multiple samples can usually be taken using the same tube to increase the sensitivity to low concentrations. The accuracy of detector tubes can vary by $\pm$ 25%, so they should be used for screening purposes only, not for exact measurements. Pumps and detector tubes from different manufacturers are not interchangeable.

Substrate sample collection

Precise measurement of air concentrations requires collection of a sample for analysis. The chemical must be collected on a suitable medium or substrate. Many solvents are adsorbed on charcoal using a low flow (50 to 200 cubic centimeters per minute) pump. Silica and nuisance dusts are collected on a tared filter, usually after passing the air through a 1-cm. body diameter cyclone, so that only the respirable fraction reaches the filter. This type of sampling requires a high-flow pump that can pull 1 to 3 liter per munute. An industrial hygienist can specify the sampling medium and equipment needed to monitor airborne concentrations in the laboratory and provide the details of the analysis procedure and calibration method.

Use of personal sampler in the laboratory

As most chemical engineering laboratory departments have a gas chromatograph available, concentrated air samples for analysis can be taken using charcoal tubes. These personal samplers, whether charcoal tubes or passive dosimetry types, are much preferred to area samples. In all cases, attempts should be made to sample under the worst-case conditions, major spills excluded. If this approach is selected, manufacturers' literature should be consulted as an aid to select the particular adsorbent tube required and to select the desorption solvent. As standard 8-hour OSHA samples are not practical in the laboratory environment, it must be assumed that the sample value was a "snapshot" of student exposure and was representative of full-shift (full-lab-period) sampling. If the appropriate exposure limits have been exceeded, corrective action to reduce the hazard must be effected before that experiment is operated again.

Requirements of sampling methods

The sampling method selected must be specific to the chemical(s) in question, sensitive, accurate, require a reasonable sampling time and volume, be inexpensive, and simple to perform.[5,6] When particulate emissions are involved, filters or total or respirable mass monitors may be used, as appropriate, for the application. Detector tubes may be used for "instant" readouts for some airborne toxic chemicals. The use of direct reading instruments in the laboratory situation is desirable but almost certainly prohibitively expensive.

EXPOSURE TYPES AND SOURCES

There are many types of chemical exposures in the laboratory. Equipment leaks, vaporization of spills, reactions, and the act of sampling can all lead to airborne emissions. Particulate emissions are the results of mechanical abrasion, the dispersion of chemicals existing as finely divided dry powders, catalyst powders, etc. Exposure to liquids may be caused by high pressure leaks resulting in aerosols. Other types of liquid exposures are spills, transfers between containers, and sampling. Gases and vapors are primarily introduced into the laboratory environment as the result of refrigerant leaks and inadvertent losses from cylinders during pressure regulator installation or cylinder changes.

Exposure source categories

Five categories of exposure sources may be encountered in the laboratory:

1. fugitive emissions from leaks around pump seals, valve stems, agitator shafts, and gaskets;
2. process leaks, predominantly spills associated with sampling and with filling the feed tanks for the various experiments;
3. leaks and spills associated with materials handling, primarily liquid transfers;
4. leaks from inadequate maintenance; and
5. leaks associated with waste handling.

VENTILATION REQUIREMENTS

Ventilation is an effective method for limiting exposure of students and laboratory personnel to airborne contaminants. If properly designed and maintained, ventilation systems can be more effective than many other approaches for preventing overexposure. The efficacy of such a ventilation system depends less on human error than do most other approaches, e.g., work practices, special respiratory protection, etc., all of which may involve human error.

Types of ventilation systems

There are three types of ventilation:

- local exhaust ventilation,
- general or dilution ventilation, and
- natural ventilation.

Local exhaust ventilation is generally preferable to the use of dilution ventilation, which, in turn, is preferable to natural ventilation. Replacement air is an essential part of any system.

Local exhaust ventilation

Local exhaust ventilation systems are used to enclose or partially enclose the contaminant source, such as a mixing point, feed tank for an extractor, bench grinder, etc. Systems of this type are designed to capture the contaminant with as little extraneous airflow as necessary from the surroundings. Details for the design and testing of local exhaust ventilation are covered in the ACGIH Industrial Ventilation Manual, now in its 20th edition.[7] Implementing the designs and fabrication of the systems should always be done by competent personnel using the most recent edition of the Manual. The performance of all such devices must be checked before use. A problem at installation is determining the proper rotation of the fan, especially if it has backward-curved blades. The direction of rotation is usually shown on the hub of the fan. Other precautions include scrupulously observing the manufacturer's specifications for fan rotation speed. Although increasing the fan speed by changing pulley ratios may solve a ventilation problem, excessive speed may cause the fan wheel to explode.

Fume hood ventilation requirements

Separate fans should be installed for each fume hood, and each fume hood should have a separate exhaust to prevent backflow into another hood. It is mandatory that no fume hood be in any way connected to the general building ventilation system. If anyone suspects that such is the case, releasing a small amount of ammonia (25 to 50 milliliters) from a household cleaning solution in the suspect fume hood should soon identify the faulty exhaust system design.

Ventilation aspects of fume hoods

In general, hoods or local exhaust ductwork systems should be designed to function properly without dampers. The ventilation aspects of fume hoods should be carefully checked. The face velocity should be at least 100 feet per minute. Care must be taken that material inside the hoods, glass apparatus, etc., does not interfere with the airflow patterns into and through the hood. If odors are detected outside the hood, first check the placement of items inside the hood.

Local exhaust ventilation system design

The design principles for a local exhaust ventilation system are those that the students have had in their fluid mechanics classes: the equivalent length and velocity pressure methods. The installation of a few pressure gauges in the ductwork or an inclined manometer with sufficient pressure taps can help the students verify the exhaust system flow rate or hood performance as a means of reinforcing the concepts taught in earlier courses.

Local exhaust hood types

Local exhaust hoods can be enclosures, receiving hoods, or remote hoods. Enclosures are used to surround hazard sources and may be partial or total. They use little external air to capture the emissions and move the contaminants into the containment and transport parts of the system. Booths are used for large-scale operations such as welding or spray painting—typically shop, not laboratory projects. An unshielded canopy hood is a receiving hood. All receiving hoods depend on the motion of the contaminant at its release point and are somewhat inefficient as they must draw in large quantities of air to capture the emissions. Canopy hoods are used for the control of sudden releases of vapors or for the control of emissions from hot processes. A remote hood is located some distance from the point of contaminant emission and depends on airflow for its effectiveness. As a result, the volume of air required for contaminant capture can be enormous.

Receiving hoods

Local exhaust hoods of the receiving type may have plain openings or be formed as a slot. Either type may be flanged to eliminate inward airflow from contaminant-free zones. Increasing the effectiveness of a hood by adding flanges may reduce the air-induction flow rate by up to 25%.

Capture velocity for hoods

Emission capture in front of the hood decreases rapidly with distance from the hood entrance. For this reason, the hood entrance should be as close as possible to the emission point. The air intake rate is determined by the distance from the hood opening to the contaminant source, the toxicity of the material, and the capture velocity, which, in turn, depends on the nature of the emissions (vaporous or particulate) and, if particles, their shape. (These factors affect drag coefficient and, hence, settling time, as the students should remember from settling calculations.) The capture velocity varies from 50 to 100 feet per minute for evaporation from tanks in still air up to 2000 feet per minute in the case of particles released with a high initial velocity, e.g., from a bench grinder into essentially still air.[7]

Hood design procedures

Design procedures for local exhaust ventilation (hoods) begin with the elimination of extraneous air currents by physical means or work-practice changes, selecting the type of hood needed for the specific application, estimating the required velocity to capture the contaminants, determining the design velocity to prevent settling in the ductwork if particulate matter is involved, and calculating all the pressure losses (entry, transition due to size or direction changes, duct) between the hood face and the entrance to the prime mover. Before the fan or blower can be sized, the pressure drop through the air cleaning system (cyclone, fabric filter, wet scrubber) must also be determined. In all cases, the hoods must be located so that the contaminated air is not drawn into or through the students' breathing zones.

Dilution ventilation

Dilution ventilation involves mixing the contaminants with sufficient air to reduce the concentration to a safe level. This approach may be the only feasible method for protecting the students and others in the laboratory from the myriad small leaks plaguing old and poorly-maintained equipment. Dilution ventilation has at least one major drawback: the volume of air that must be cleaned before being discharged to the ambient environment or recycled through the heating, ventilating, and air conditioning (HVAC) system to the laboratory and other parts of the building. The Industrial Ventilation Manual lists the dilution volumes required for many common solvents as well as methods to estimate for liquids not listed.[7] The dilution depends on the toxicity of the material, its liquid density, and its TLV.

Dilution and explosion limits

Although dilution ventilation can be used to reduce the concentration of a flammable vapor to one-fourth its lower explosive limit (LEL), that approach must not be used if people are exposed to such vapors. The LEL is many times (200 to 1000) greater than the PEL. If people are at risk and dilution ventilation must be used, sufficient diluent air must be provided to reduce the concentration of the contaminant below the PEL.

Replacement air

Replacement air must be provided to replenish the air removed by either type of exhaust ventilation. The location of the inlets for the replacement air system must be carefully located so that no contaminated air from fume hoods or other exhausts can be drawn into the fresh-air supply.

Natural ventilation

Natural ventilation occurs because buildings are not airtight. Temperature differences between the inside and outside environments and pressure due to strong winds, especially if gusty, can cause a building to "breathe."

LABELING

All chemical containers in the laboratory should be labeled with the identity of the contents. Solutions prepared in-house should also contain the date prepared, the name of the person who prepared it, and a disposal date.

Required chemical label information

Chemical manufacturers are required to ship chemicals with the identity, health hazards, and physical hazards on the label. Students should be instructed to review these labels and to avoid defacing or removing them. Material should be on hand to prepare a new label if the original is damaged or lost. The same information must be listed on all new containers into which the chemical has been dispensed or transferred.

PERSONAL PROTECTIVE EQUIPMENT

Students must understand that personal protective equipment (PPE) is a final barrier between them and a hazard. It does not remove the hazard and will only provide protection under proper use and within its design specifications. Students should be shown how to follow the manufacturer's instructions for use and care of PPE. Proper storage facilities should be provided in the lab where the PPE will be readily available.

MSDS gives PPE requirements

The MSDS will list recommended PPE for use with chemicals including the type of respirator. The laboratory director should have students check the MSDS for PPE requirements as part of their preparations for each experiment. They must then know where to obtain any necessary equipment.

CHEMICAL HANDLING, TRANSPORT, AND STORAGE

The handling, transport, and storage of all chemicals should be in accordance with the provisions for safe handling and use outlined in the corresponding MSDS. No corrosive or highly reactive chemical should be dispensed in containers larger than 1 pint (approximately 500 ml). Chemicals should be transported from the storage area to the experimental area in safety carriers available from any national-scale laboratory or safety supply company. The proper protective clothing specified in the MSDS should be worn whenever handling, transferring, or transporting any chemical. Compressed gases should be chained or strapped into a specially designed cylinder cart before moving.

Acute respiratory hazards

Many substances present acute respiratory hazards and should not be used without proper respiratory protection. The safest place to transfer or use such materials is in a properly designed and working fume hood. Some chemicals in this category are

ammonia (anhydrous)
ammonium hydroxide
carbon monoxide
chlorine
chloroform
fluorine
hydrochloric acid
hydrofluoric acid
hydrogen cyanide
hydrogen sulfide
nitric acid
phosgene
sulfur dioxide
sulfur trioxide
sulfuric acid

Absorbable solvents

Some solvents, e.g., dimethyl sulfoxide, are readily absorbed through intact skin and act as adjuvants, i.e., they can transport other toxic materials with them into the body. The use of proper protective clothing is necessary if such materials must be handled in the Unit Operations Laboratory.

Chemical dispensing and transfer

No chemical should be dispensed from any improperly labeled or unlabeled container. Whenever possible, transfers between containers should be done in a closed fashion, e.g., pumping a solvent from a drum into an extractor supply tank, to minimize emission of vapors and exposure of laboratory personnel. Proper grounding and bonding of the vessel(s) is required before transfer. When liquids must be dispensed from small bottles, use a funnel or stirring rod to prevent splashing. It may be necessary to review other chemical handling and transferring procedures with the students. Students in a Unit Operations Laboratory should have been exposed to such rules in at least six college chemistry courses. A quick review of such techniques is available.[8] Exposures during chemical handling or transfer can be estimated by standard industrial hygiene sampling techniques. At a minimum, the students should have indicator tubes and the correct pump available for use.

Storage of incompatible chemicals

Incompatible materials must be stored separately. Such combinations are acids and bases, flammable organics, and strong oxidants, etc. The list of incompatible materials in the MSDSs of all chemicals in the laboratory will serve as an invaluable aid when arranging storage facilities for maximum safety. As a general rule, only the required amounts of chemicals for a day's work should be kept in "ready use" storage in the laboratory. All other supplies should be kept in appropriate cabinets outside the laboratory as previously described.

WASTE DISPOSAL

The Resource Conservation and Recovery Act of 1977, the "Superfund" Law, and the Toxic Substances Control Act and their various amendments and extensions govern the disposal of hazardous wastes. The legal definitions of "hazardous," "waste," etc., are not the same as the common or intuitive definitions. Once a substance has been identified or labeled as a waste, it must be handled in accordance with the provisions of the applicable Act.[8] Waste handling for disposal purposes should not be the responsibility of any single department, such as that of chemical engineering, but of the safety officer of the college/university who may levy a disposal fee on all waste picked up. Therefore, the amount of materials used and wastes generated should be minimized not only to avoid the presence of hazardous materials, but also to avoid hefty pickup or processing fees. Every effort should be made so that hazardous wastes are separated from the general waste (paper, glass, soda-pop cans, other nonhazardous refuse).

Segregation and storage of wastes

All dilute acid wastes should be placed in clean, rinsed, 5-gallon containers or 55-gallon drums. The containers and drums should be lined with high-density polyethylene (HDPE) to minimize corrosion. The wastes from strong acids and oxidizing agents should be stored in used, rinsed, 1-gallon acid bottles with safety coating. Such wastes should not be mixed. Any waste solutions of organic solvents in water should be stored in containers lined with HDPE. Nonaqueous organic solvent wastes should be stored in Underwriters' Laboratory (UL)-approved waste cans. Solid wastes should be stored in 5-gallon buckets or pails with top closures. The various categories of wastes must not be mixed under any circumstances.*

Waste container labeling

The waste containers must be labeled as to waste type, approximate volume, pH (if aqueous), source/experiment, the name of the person adding the waste to the container, and the date added (Exhibit VIII.1). A waste must not be added to any container unless the waste is known to be compatible with the contents already in the container. Compatibility can only be ascertained by comparing the waste contents list to the incompatible chemicals list in the MSDS of the material to be added and by verifying that no incompatible materials are involved. All wastes must be picked up by the campus safety officer on a regular basis. No more than 55 gallons of wastes should be on hand at any time. The safety officer should be called for more frequent pickup, as needed.

Biological and radioactive wastes

Biological wastes should be incinerated. That task, too, is probably a defined responsibility of the campus health office or safety office. The disposal of radioactive wastes is governed by regulations of the Nuclear Regulatory Commission (NRC) or corresponding state agency. These disposal procedures are specified for the licensee in the campus radiation safety manual and must be strictly observed. If radioactive materials are used in the Unit Operations Laboratory, the supervising professor or laboratory director bears the direct responsibility for their proper use, safeguarding, and turn-in for disposal. Deviations from duly constituted regulations can result in loss of license. Repeated incidents can result in revocation of the institution's license.

CHEMICAL SPILLS

All spills of any chemical other than pure water should be reported immediately so that proper cleanup (and decontamination, if necessary) procedures can be initiated without delay. The teaching assistant should notify the laboratory director at once of any spilled mercury or any other unusually toxic or hazardous materials. He/she should have been previously trained to handle routine spills by containment, adsorption, or neutralization procedures as discussed in the NRC report.[9] Mercury adsorption kits and other appropriate spill kits should be available in at least two locations in the laboratory. Sufficient material should be on hand to handle a major spill from any of the experiments in progress. After cleaning the spill, the materials used should be segregated as solid wastes and turned over to the safety office for ultimate disposal.

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*Memorandum, Disposal of Acidic Wastes and Waste Bulking, by D.S. Kosson, Dept. Chem. Eng., Rutgers—The State University, Piscataway, NJ, Jan. 5, 1988.

Exhibit VIII.1. Waste Identification List*

Waste by Chemical Name	Volume added, gal.	pH†	Unit Ops Experiment	Date	Printed Name	Initials

*Use a separate container and list for each category of waste.
†Before adding, the pH of aqueous waste must be in the 6 $\leq$pH $\leq$8 range.

Spill cleanup procedures

When a spill occurs,[8] the student should take the following steps: 1) notify the teaching assistant/laboratory director and any adjacent groups; 2) remove contaminated clothing and follow by thorough washing of all exposed skin with only soap and water for at least 5 minutes; and 3) cleanup (by the student) under the supervision of the teaching assistant if no fire hazard exists (no flammable materials were involved). Adsorbents, e.g., vermicullite, Oil-Dri, Zorb-All, sodium bicarbonate, etc., should be used for cleanup. The cleanup crew should wear PPE, e.g., apron, splash goggles, respirator, gloves appropriate to the spilled material. Finally, the spill area should be thoroughly washed down with soap and water. If a flammable chemical has been spilled, shut down all sources of sparks (brush-type motors) and heat sources throughout the laboratory and all nearby equipment. Have the students and teaching assistant evacuate the laboratory until the spill has been contained and picked up. The laboratory director should either effect the cleanup or call the safety office for assistance.

Small spill cleanup

Small spills (less than 1/2-cup or about 100 ml) may be blotted up by paper towels provided the towels are placed in a solid-waste container and NOT thrown into a trash can. As with other wastes, care must be taken to avoid incompatible substances because of the greatly increased surface area provided by the towels. If a wire mesh (nonferrous) container is available (available at gourmet kitchen supply establishments), such paper towel wastes can be contained and allowed to evaporate in a working fume hood. The amount of the resultant air pollution can be calculated by the students and compared with the corresponding regulations to verify that they are not in violation.

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SAMPLE QUIZ QUESTIONS

1. How should liquids be dispensed from a 55-gallon drum? What precautions are required before the dispensing operation?
2. What are the proper uses of enclosures, receiving hoods, and remote hoods for the purpose of ventilation-system design?
3. Define "industrial hygiene" and its three components.
4. What is epidemiology? Why are epidemiologic studies useful to design and operating engineers?
5. What are the "routes of entry" or "portals of entry" of a toxic chemical into the human body?
6. What are the basic differences between physiologic and physical effects of chemicals on body systems?
7. Define asphyxia. How can it occur?
8. Why is the use of hearing protection necessary in high-noise (>85 dBA) environments?
9. What is a time-weighted-average, or TWA? How is it calculated?
10. What characteristics of chemical releases or emissions govern sampling frequency?
11. What are the general criteria for all airborne toxic contaminant sampling methods?
12. How should chemicals be transported? Explain your answer by describing the transport methods for a 1-gallon bottle of glacial acetic acid, a 2-pound box of sodium bicarbonate, and a 1-pint bottle of cyclohexane.

Unit IX

EXPERIMENT PREPARATIONS: PRELIMINARY DOCUMENTATION, HAZARDS, AND RISK ASSESSMENTS

PURPOSE:

To introduce the most common ways for the unit operations students to incorporate safety and health into their experiments.

OBJECTIVE:

To provide a systematic approach for incorporating safety and health principles into all phases of laboratory preparation and experimentation by

1. Including safety and health topics in prelaboratory assignments
2. Requiring a safety and health section in all preliminary reports
3. Identifying major health and safety considerations for each experiment
4. Locating emergency escape routes and safety equipment
5. Documenting of all aspects of the experiment
6. Student assignments and responsibilities
7. Procedures for cleaning up spills
8. Emergency shutdown procedures
9. Accident prevention methods
10. Introducing risk assessment

SPECIAL TERMS:

1. Accident
2. Risk
3. Injury
4. Risk assessment
5. Hazard
6. Preliminary hazard analysis (PHA)
7. Fault tree analysis (FTA)
8. Event tree analysis (ETA)
9. Failure mode and effects analysis (FMEA)
10. Hazard and operabilities study (HAZOP)
11. "What if . . ." analysis
12. Safety reviews

INTRODUCTION

Standard prelaboratory assignments should be made to each group about a week before beginning any experiment. These prelaboratory assignments have many purposes and are designed to help the students in

1. understanding the nature and scope of the experiment;
2. obtaining a clear understanding of the theoretical principles involved;
3. determining what equipment is available for use and what must be constructed;
4. preparing for any laboratory construction projects;
5. finding the safe operating limits for all equipment;
6. preparing the process flow and instrumentation drawings (PID);
7. locating analytical procedures;
8. ascertaining how to interpret, use, and present the experimental data;
9. conducting a hazard review for the experiment; and
10. formulating and reviewing safety procedures (includes review of all pertinent material safety data sheets [MSDS]).

The teaching assistants should have carried out a hazard evaluation before the school term started. Otherwise, the Laboratory Director will not be able to assess whether the students have picked out the most serious potential problems. Without such prior knowledge, the Laboratory Director would be unable to help the students with the development and description of the necessary safeguards for their protection and to minimize damage to the apparatus. Such safeguards may be the imposition of limits on certain process variables (allowed feed pressure to laboratory PRISM® membrane separators should be decreased from 120 to 90 psig, cooling water to overhead condenser for the distillation column will be at least 4 GPM, etc.) or the development of emergency evacuation routes for a particular experiment.

Use of safety and health resources

The students will not always know what resources are available for the experiment. They should be referred to the safety and health sections in the main and departmental libraries; given a list of fixed equipment, instrumentation, and laboratory facilities available to them; and given a clear understanding of what items they are allowed to make in the shop as opposed to those that the technician(s) or teaching assistant will prepare. Not only should the students be shown the location of all safety equipment, facilities, and supplies, they should receive instructions regarding their use. All students should have a copy of the departmental and laboratory safety regulations.

The appropriate MSDSs must be read to identify the chemical hazards for chronic and acute health effects, physical hazards, required personal protective equipment (PPE), and emergency procedures. With this information and the estimated quantities of each material to be used, the potential risks can be identified and steps can be taken for hazard control.

A preliminary report

A preliminary report should be required from each of the student groups before granting permission to start work. That report should contain, as one of its main features, a discussion of the safety and health hazards; a list of potential exposure sources, types, and amounts; and a review of the hazard analysis procedure and the nature of the risks involved (see below).

DOCUMENTATION BEFORE EXPERIMENTATION

The following documentation is required from each group before the group receives permission to begin the experiment.

- Process description and flow sheet
- Experimental conditions
- Equipment list with specifications
- Materials of construction
- Insulation requirements: thermal and electrical
- Special operating conditions required/to be avoided
- Emergency evacuation routes (must have two)
- Startup, operating, and shutdown procedures
- Data to be obtained
- Emergency shutdown procedures

- Experimental waste segregation and disposal methods
- Chemicals and materials lists and quantities required
- Copy of the MSDS for all chemicals
- Potential safety and health problems
- Personal protective equipment required (if none, so state)
- Potential environmental problems
- Location of all safety equipment
- Emergency evacuation routes (must have two)
- Safety checklist
- Labels for samples
- Student work/responsibility assignments

After this documentation in the preliminary laboratory report is reviewed and any deficiencies explained, the students must be given an opportunity to ask questions relating to safety and equipment operation. After answering these questions, the laboratory director should have the students execute a release from (Exhibit III.2) and obtain permission to start work (Exhibit V.1).

Responsibility for documentation preparation

The laboratory director should assign responsibility for preparing the documentation. It is unrealistic that each student can or should prepare all the documentation; the various items should be grouped into categories and each team member should be assigned one category. The first time the documentation is prepared will be the most difficult. After that, many items can be used as a boiler plate in preparing for the next experiment. The assignments should rotate with every experiment to avoid student burnout and to maximize participation and learning. Although all group members should participate in preparing the safety section, it should be prepared by the group leader or safety supervisor for the experiment, who is then responsible for its implementation.

Documentation information

For the documentation, all theory pertinent to the experiment should be reviewed, and a brief description of the statistical methods that will be used in data reduction should be prepared. The materials of construction documentation should specify glass, stainless steel, etc., used for items to be fabricated for the experiment and also specify any attendant operating problems, such a ''water hammer'' that would necessitate including a surge tank.

Experimental conditions should include temperatures, pressures, flow rates and compositions, critical levels to be maintained, chemical reactions involved (and energies released), noise problems and their control, and the rated pressures for any rupture disks and relief valves.

The estimate of possible exposures to hazardous and toxic chemicals can only be made after the flow diagram and all aspects of the experiment are thoroughly understood. A brief description of the method(s) to be used to check for actual exposures should be included. After the flow diagram has been prepared, the quantities of chemicals and supplies necessary for the experiment can be estimated. The procedure section of the preliminary report must describe all materials handling and transfer steps and any required safeguards, the waste handling and disposal techniques to be followed, and a list of required PPE.

Reducing potential hazards

While reviewing the proposed experimental materials and conditions, the laboratory director or teaching assistant should be alert for changes in materials or chemicals that would decrease fire or explosion hazards. Can the order of adding chemicals be changed to reduce a hazard? Can temperatures be reduced or pressures lowered? The reduced temperature will decrease vapor pressures and thus reduce the fire hazard. Lowered pressures will reduce the number and amount of fugitive emissions.

Approval of documentation

The student documentation should be checked by the teaching assistant. The laboratory director is responsible for double-checking the critical sections. For new and recently modified experiments, the laboratory director should check the normal startup, operating, and shutdown procedures; emergency shutdown procedure; evacuation plan; safety and health analysis; and preliminary hazard analysis. The laboratory director should verify completion of the safety check list before signing the permission-to-start form (Exhibit V.1). At this time, the students should be well-prepared to conduct the experiment safely and obtain the maximum amount of valid data with the minimum amount of wasted time and false starts. Any group who appears at the laboratory with an incomplete preliminary report should be refused entry until the report is complete and has been accepted. During the experiment, the group should be required to adhere to housekeeping standards and to report any needed maintenance or repairs.

Some critical questions to ask the students during the safety review are listed in the first two sections of Exhibit IX.1. The last section of Exhibit IX.1 contains questions that the laboratory director and teaching assistant should be able to answer affirmatively before signing the permission-to-start form. Any group with an incomplete preliminary report should be refused entry to the laboratory until the report is complete and has been accepted. An appropriate grade reduction for that experiment should be assessed.

STUDENT GROUPS

Students should have specific assignments within the team. The optimal approach would be to have sufficient equipment or experiments so that students can be moved between groups for the various projects. That method is followed in some theory classes and allows, sometimes forces, the students to develop leadership skills before entering the workforce. Unfortunately, a Unit Operations Laboratory usually has but one heat exchanger, one rotary filter press, one double-effect evaporator, one distillation column, etc. The students must be grouped and then assigned experiments in a strict rotation to avoid time conflicts.

Ways to assign students to groups

Students may be assigned to groups at random or by grade-point average (GPA), or they may be allowed to form their own groups. The random assignment method often appears arbitrary and capricious to the students. Assignment by GPA can be done in two ways: grouping students with similar GPAs or deliberately grouping one high-GPA student, one low-GPA student with two of "average" GPA. The former of these two methods is preferred as all members will have about the same capabilities and initiative. If the latter method is used, the 3.8/4.0 student may try to do everything to protect his/her A. The 2.1 student usually gets left out or is given "dogwork" to do, and the other students may drift or become as hired hands. Friction is bound to develop within the group, especially when the least-capable student is group leader.

Allowing the students to form their own groups is equally bad; someone will always be left out and the laboratory director must use his/her authority to force some tightly knit coterie to accept the outsider. Grouping by GPA is preferred. Students usually realize that they are about equal to the others in their group, so fewer problems with prima donnas or "goof balls" can be expected. It often happens that the low-GPA group does excellent work, sometimes better than that of the high-GPA group, just to prove that they are as good as the best.

STUDENT INDIVIDUAL ASSIGNMENTS

Typical assignments within the groups are group leader, safety director, design/operating engineer, and data collector. Some laboratory directors prefer that the leader does no work, only supervises the work of the others. In a three-member group, that approach seems to place an unnecessary burden on the other two group members. A better approach is for each member to be assigned specific duties and to be held accountable by the group for performance. The group should first attempt to deal with the problem of a noncontributing member. If they are unsuccessful, they should bring that problem directly to the laboratory director. This situation provides an opportunity to teach the students about conflict management or relational dynamics, as may be required. The laboratory director should not hesitate to call on the campus counseling center for assistance.

Group leader

Typical assignments for the leader include development of the following items:

- brief statement of the objectives of the experiment,
- brief summary of the approach to be followed to accomplish each objective,
- list of data required for each objective,
- description of how the group activities will be organized to meet the requirements of the prelaboratory report, and
- work assignments of each member of the group, including himself/herself.

Exhibit IX.1 Questions to be Asked During Safety Review*

Hazard Recognition

What materials, equipment, and procedures will be used in your experiment? ________

What are the intrinsic hazardous properties of the materials you plan to use? ________

Will other hazards be generated by using the materials as you have planned? ________

What quantity of materials do you actually need to conduct your experiment? ________

Are there characteristics associated wih the equipment and procedures you plan to use that could cause the release of hazardous materials into the laboratory? ________

Are there physical hazards associated with the equipment you plan to use? ________

Who may be exposed to the hazards associated with your experiment? Will your experiment generate wastes that may be hazardous ________ ________

Selection of Controls

Is the space available to you appropriate for your experiment? ________

Do you need special safety equipment to reduce exposure to hazardous materials? ________

What personal protective equipment is required to provide additional safety against accidental exposures? ________

Safety Awareness Questions for the Instructor/Teaching Assistant

Have I ensured that every individual in the lab group has had adequate safety instructions and training? ________

Have I informed all members of the group of potential hazards, required safeguards, waste handling procedures, and emergency procedures? ________

Am I prepared to provide proper safety supervision? ________

Have I ensured that every student who will be involved with each experiment is convinced that I am sincerely interested in safety? ________

*Adapted from internal working document developed by Occupational Safety and Health Branch, Division of Safety, National Institutes of Health, Bethesda, MD.

Group safety director

The safety director is primarily responsible for

- obtaining copies of the MSDS for each chemical for use by the group,
- identifying and evaluating potential hazards,
- conducting a continuing safety inspection of all aspects of the experiment from planning through execution stages,
- performing a preliminary hazard review of some aspect of the experiment and preparing that report for the laboratory director (see Preliminary Analysis, below),
- developing emergency procedures, and
- completing the safety checklist for the experiment.

The safety director cannot and should not carry out these responsibilities alone; another member of the group should assist to minimize oversights.

Group design/operating engineer

One responsibility of the design/operating engineer is to oversee the assembly of the experimental apparatus (if required). The primary responsibility of this group member is to prepare written procedures for the startup, normal operation/data collection, and shutdown phases of the experiment. He/she should also prepare the emergency shutdown procedure and assist the safety director in any way requested.

Group data collector

The data collector should become fully familiar with the theory behind the chemical engineering principles being demonstrated or examined so that he/she can explain them to the rest of the group. That way, all members will have a better idea of what they are doing, why, and above all, of the engineering significance of the results. The data collector should be responsible for obtaining or developing the necessary computer software for data analysis and for preparing the tables for data entry.

CONDUCT OF THE EXPERIMENT

The actions of the students during laboratory periods are governed by their assignments, as previously discussed. All students have the added responsibility to be continuously alert to the existence of safety and health problems that may arise during the experiment. Some departments have the policy of providing complete descriptions and instructions for every experiment, including what data to take and the precise intervals or values of the independent variables to use. Such an approach defrauds the student by reducing him/her to the level of a technician or helper.

Consider the opposite method: the students are told what to evaluate (i.e., the effect of solvent-to-feed ratio on agitated column performance), and they design the experiment. The laboratory director gives the assignment about 10 days before the students begin the actual laboratory work and requires a one-page proposal for an experimental design within 2 days. He/she reviews the typed proposal and discusses it with the group within 1 day. That schedule should leave students a week to prepare for the experiment. The students then assemble or fabricate the apparatus, if necessary, and prepare their preliminary report for approval. Depending on the complexity of the equipment and the potential safety problems, the students may be required to start up under supervision.

Ventilation

Work-area ventilation is usually not a problem unless the experiment involves hot and/or humid laboratory conditions. In those situations, extra ventilation or at least air circulation may be needed for comfort.

Spill prevention

Time should be set aside during each laboratory period or at the beginning of the course to discuss how to handle spills or leaks and their probable causes. Spills are most frequently the result of lack of attention. It is too easy to operate a drum pump (too fast) without first having checked the level in the drum. Suppose a 1-gallon bottle of acetic acid is being filled from a 55-gallon drum by using a drum pump. Once the syphon starts, the only way to stop it is to raise the suction end of the pump above the liquid level in the drum. A talkative and inattentive student or teaching assistant or professor can easily spill more than a quart of glacial acetic acid on the floor.

Spill containment

Given that this event (or one like it) will happen, how are the students to be prepared for such an occurrence? Transfers of this type can and should be done with the receiving vessel in a plastic wash-tub for containment. Setting the tub into a floor grate with a continuous water flush around it is an even better arrangement. Both the student using the drum pump and the one holding the bottle to be filled should be using the proper PPE. (Can the students name the items in the classroom?) Do they know to flood the area of the spill with water before trying any neutralization with baking soda? This scenario is but one of countless examples. Several examples pertinent to the laboratory situation could be developed and demonstrated using water, sand, etc. The entire sequence could be recorded on videotape for student viewing.

Special precautions are needed if a toxic or flammable chemical is released from a spill or equipment failure. In the first case, the flow of spilling material must be shut off; the spill must be diked to prevent its spread; and the spill must be reported, picked up, and disposed of properly. In the second case, the flow from the malfunctioning unit must be shut off, the power turned off, and assistance sought from the departmental shop technician or physical plant shops.

Warning properties

Some gases and vapors have warning properties—odor, color, taste—that indicate leaks more quickly than any analytical method. The average person can taste a sulfur dioxide leak from the absorber long before that leak can be detected with any but the most sophisticated research-grade instrumentation. Other chemicals have odoriferous vapors: benzyl cyanide (oil of almonds), iso-amyl acetate (banana oil), ammonia (sharp and irritating), sulfur dioxide (pungent). The odor properties of many chemicals are listed in Appendix D.

Reducing leaks

Small spills can and will occur as a result of carelessness, slippery fingers, overturned glassware, etc. A gentle admonition is all it takes if the students have come to believe in safety as a laboratory practice. Leaks are most likely to start around the packing nuts on valves or around unevenly tightened flanges. Students should not attempt to readjust the tension on any flange bolts if glass pipe is involved. A worker experienced with glass pipe should get a torque wrench and do it after draining that part of the system. Leaks around valve stems and around fittings should be eliminated or reduced by the teaching assistant; many undergraduate students tend to believe that nothing can be tight enough and thus may crack packing nuts or strip threads.

Defining an emergency

Before any laboratory work begins, the laboratory director will have to help students decide what situations or conditions constitute an emergency. Clear and unambiguous instructions and advice must be given the students so that if such an emergency happens, the students will recognize it and immediately take the proper steps for their protection. This part of the laboratory instruction ties together two of the students' efforts: preparation of emergency shutdown procedures and risk assessment.

Evacuation routes and fire drills

For all experiments, certain safety items must be considered: emergency evacuation routes (there must be two, with unhindered access from the experimental area to each) and the location of the nearest safety deluge shower, eye-wash fountain, fire extinguisher, and fire alarm. A drill should be planned and coordinated with the fire marshal. Campus emergency services must have advance notice: the specific date, time, and information about anticipated alarms and reports that might be received. A fire drill of the Unit Operations Laboratory could provide the fire marshal with a review of his staff and of the local emergency services and provide the laboratory director with a review of the laboratory's preparedness.

Evaluating an emergency shutdown

How well the students follow emergency shutdown and evacuation procedures can be observed if shutdown and evacuation becomes necessary. After the laboratory is back to normal, students can be asked to evaluate their own actions during the emergency. The students should be encouraged to also comment (anonymously, if they wish) about the actions of the laboratory director and those of the teaching assistants. From the critiques, areas that need improvement may be identified. It is almost certain that the students will have questions and comments that have not been asked or brought up before.

Sampling and analyzing the experimental environment

All students should be made aware of the need to analyze the experimental environment as the only effective and legally acceptable manner to demonstrate the absence of chemical hazards. Although area samples may be useful in estimating average airborne concentrations, as a rule, only breathing zone samples are acceptable to OSHA in the industrial environment, either for a full shift or for ceiling values. Grab samples are often used to assess the need for compliance sampling. At the minimum, the students should be provided with detector tubes and the corresponding pump, instructed in their use, and required to take several samples during each period if they are working with solvents or other toxic chemicals. Students readily accept the concept of the grab sample as an indicator of one aspect of the safety of their procedures. ''Rationing'' of the detector tubes is often necessary to ensure that each group will have at least two or three per day. If facilities are available, the use of charcoal adsorption tubes or passive dosimeters to determine the time-weighted-averages (TWAs) for possible solvent exposure will add to the students' appreciation of chemical toxicity.

Concluding the experiment

At the conclusion of the experiment, the students should disassemble the apparatus (if necessary); return any borrowed tools to the shop; and return unused supplies, instruments, and small equipment items to the storeroom. They should advise the teaching assistant of any breakage and nonfunctioning apparatus or instruments (timers, digital thermometers, etc.) so that those items can be replaced or repaired before the next laboratory session.

Vent, drain, shut off and check out

The students should turn off and vent all process steam lines, unplug any electric heaters, and drain and vent all systems. No system should be left pressurized. The students should segregate and properly dispose of or transfer to appropriate pickup containers all wastes generated by the experiment. These portions of the experiment termination routine should be supervised by the laboratory director or a teaching assistant. Finally, the students should clean up their work/experimental area and leave it neat and orderly before they are checked out of the laboratory. Good housekeeping practices and standards should be met throughout the experiment.

TEACHING HAZARD RECOGNITION

One of the most difficult aspects of including safety, health, and loss prevention in Unit Operations Laboratory courses involves teaching the students how to recognize that they have a problem or that they will have one if no corrective action is taken. The laboratory director may be able to recognize many such situations because of experience, but the students do not have comparable powers of observation and correlation. For example, if the laboratory director walked past the distillation column about halfway through the laboratory period and noticed that no distillate was being produced although the system was obviously on, his/her first reaction would probably be to check the temperature profile, the reflux rate, or the action on the trays. Finding excessive temperatures or no reflux or dry trays, he/she would immediately shut down the power to the reboiler. The laboratory director would know, based on experience, that the condenser must be plugged and that the relief valve was inoperative. This action—shutting off the power—was instinctive because of previous exposure to operating systems: shut it down to avoid watching it explode. Although preparing and using similar examples as teaching tools or quiz topics takes time, they are a relatively easy way to teach the students to think about safety in the laboratory.

ACCIDENT PREDICTION METHODS

Accident defined

All accident prevention methods involve risk assessment. For instructional purposes, an accident is defined as any unplanned event or sequence of events that results in personal injury or property damage, or both.[1,2] Personal injury includes fatalities and all lost-time injuries, whether partial or total, temporary or permanent. Risk is a measure of potential losses expressed in terms of probability and magnitude. The losses may be strictly economic (as in lost production due to an accident) or may be associated with human injury.

Risk assessment

To assess a risk,[3] four questions must be asked when preparing for an experiment in the Unit Operations Laboratory. These questions are

- What can happen to cause an accident?
- What is the probability of these events occurring?
- What can be the result of each of those events?
- How can each of those events be prevented or their effects at least minimized?

If risk assessment is treated in the laboratory with the same seriousness as it is in senior process/plant design courses, the students should perceive that safety and health are not just essential design components but are also required considerations of everything they do as practicing engineers.

Hazard defined

Six risk assessment methods are in common use. Some of them evaluate hazards in qualitative or relative terms, others in a quantitative manner. All begin with the realization that hazards cause accidents and that a preliminary hazard analysis is an essential initial step. A hazard is some "characteristic of the system that represents a potential for an accident with an undesirable consequence."[1] In other words, a hazard is any situation that might cause an accident to occur.

Preliminary hazard analysis approach

A preliminary hazard analysis (PHA) should be made early during the planning for or development of an experiment. The purpose of the PHA is to formulate a list of the potential hazards associated with the materials and apparatus proposed for or actually involved in the experiment. The PHA approach is applicable to existing unit operations experiments or to those that the students are designing and will construct, whether bench-scale or pilot-scale. The students should begin the PHA immediately after receiving their assignments.

The PHA consists of developing a list describing the known and potential hazards associated with

- all chemicals associated with the experiment, whether feeds, intermediates, products, or byproducts;
- the experimental apparatus;
- any safety-related problems such as the presence of incompatible chemicals, fire and explosion potential, extremes of temperature and/or pressure, etc.;
- environmental factors such as static electricity;
- equipment layout and assembly;
- operating procedures, including start-up, operation/data collection, normal and emergency shutdown; and
- safety equipment such as pressure-relief valves and personal protective equipment.[1]

Much of this information can be obtained from the MSDSs for the chemicals involved, from operating instructiions and limits in the manufacturers' brochures describing the apparatus.

Preliminary hazard analysis

A PHA can be conducted in terms of the nine steps as listed below:

1. System or subsystem identification,
2. Operating mode or condition,
3. Identification of hazardous element,
4. Trigger event causing hazardous condition,
5. Hazardous condition,
6. Trigger event causing potential accident,
7. Potential accident,
8. Possible effect(s) of the accident, and
9. Measures/methods to prevent/contain hazardous conditions.

PHA example

An example of a PHA for a laboratory-scale gas absorber using the air-water-ammonia system can be tabulated as the following:

1. Gas absorber,
2. Normal operation,
3. Ammonia supply,
4. Rupture of regulator diaphragm,
5. Excessive ammonia supplied to the packed tower exceeding absorption capacity,
6. Power not "on" for the vent fan blowing the lean gas discharge away from building,
7. Overhead "clean" gas stream dumps back into laboratory through general exhaust vent,
8. Overexposure of students to ammonia,
9. Relocate absorber exhaust line 6 feet above roof level on downwind side of prevailing winds, and require two people to verify that the fan is "on" and running before opening the ammonia main cylinder valve. Close main cylinder valve if regulator diaphragm ruptures.

Departmental use of student PHAs

These PHA exercises are simple to do and easy to understand. Each laboratory group should be required to conduct one PHA for each experiment. The laboratory director should keep a file of the student submissions, and to avoid duplication, the student groups should first check with him/her before preparing the PHA. A file of needed equipment modifications will thereby be generated for the next time the department chair needs a list of improvement items or new equipment.

RISK ASSESSMENT METHODS

Risk assessment methods in common use[1,3-5] in industry include

- "What if . . . ?" analysis,
- fault tree analysis (FTA),
- event tree analysis (ETA),
- failure mode and effects analysis (FMEA),
- hazard and operability studies (HAZOP), and
- safety reviews.

The "What if . . . ?" analysis does not involve relative ranking of the potential hazards. The purpose of a fault tree analysis (FTA) is to identify those combinations of equipment failure and human errors that can result in an accident.[2,3] Event tree analyses (ETA) are designed to identify the sequence of events that can result in an accident, given that an initiating event has occurred. An initiating event is one that will result in an action unless beneficial intervention occurs to prevent or mitigate the accident. Examples of beneficial intervention are low-liquid-level shutoff of a heater, opening of a pressure-relief valve, etc.

Purposes and attributes of FMEA

In the Unit Operations Laboratory setting, the purpose of a failure mode and effects analysis (FMEA) is to identify apparatus failure modes and the effect of such failures on the experiment. The results are qualitative in nature and often are based on a worst-case estimate of the consequences of the failure of individual pieces of the apparatus. Although experienced engineers should be able to assess failure probabilities using the Dow and Mond Fire and Explosion Indices,[6] junior and senior chemical engineering students lack the knowledge to estimate the frequency of equipment failure and the severity of such failures in terms of the hazards produced.

Purpose of HAZOP

Hazard and operability (HAZOP) studies were developed not only to identify hazards in a plant, but also to identify those operating situations that would, even if not hazardous, affect the plant's ability to produce its products at a profit. This technique of risk analysis requires a team of experienced people from all aspects of plant operations. It is, therefore, more suitable for use by students in the process/plant design course than those in the Unit Operations Laboratory.

"What if . . . ?" procedure

The "What if . . . ? procedure is prospective in nature and is one of the easiest for the students to use. The method involves questions, all beginning with, "What if . . .?" A different area (fire safety, electrical safety, chemical safety, etc.) can be assigned to each member of the laboratory group who must then develop the questions to pose to the rest of his/her team members. The questions can and should address all aspects of the experiment. Some of the questions associated with a distillation experiment might be

- What if cooling water control for the condenser is lost?
- What if the feed pump fails?
- What if the reflux pump fails?
- What if the reboiler heat input begins to increase beyond the control limit?
- What if a gasket between tray sections fails?

All the "What if . . . ?" questions involve an initiating event (one that can cause an accident unless mitigated in some way) and require an analysis of the process or sub-system so that its most probable response can be determined. The logical output is the identification and recommendation of appropriate hazard elimination procedures. For maximum effect, the "What if . . . ?" questions should follow the pattern of the experiment from start-up through shutdown.

Nature of FTA and ETA analysis

FTA and ETA are both retrospective in nature. They begin with the assumption that an accident has occurred and work backward to determine the sequence of initiating (fault) events that must occur to produce the "top" event (accident). The failure of mitigating events is included. The fault tree is a logic diagram that shows in sequential form (from the top down) the sequence of equipment failures and human errors that must occur for the faults to occur that could lead to the projected accident. The event tree focuses on the event that directly causes the accident (initial cause or event) and works backward to the final effects of each separate event.

Use of FTA in the laboratory

Assuming availability of probability data (e.g., anticipated feed pump failures per distillation experiment, frequency of tube failure in a steam-heated evaporator, frequency of ammonia regulator failure in an absorption experiment, etc.), FTA amd ETA lead to quantitative estimates of the most probable causes of an accident in ranked order. With that information in hand, appropriate preventive measures can be taken to protect the people and equipment in the laboratory. The problem, of course, is not so much in postulating accidents and identifying the events leading to the accidents or "top" events as it is obtaining the probability data. FTA and ETA thus are limited to qualitative results in the laboratory situation. Both can be carried out in the process and plant design course where the Dow Fire and Explosion Index[6] is more logically introduced.

Dow and Mond indices

The Dow and Mond Indices assign penalties to process materials and conditions that can cause or contribute to an accident. Credits are assigned to safety features, whether equipment or actions, that can prevent or mitigate an accident. The Mond Index is an extension of the Dow Index and adds toxicity to the characteristics (flammability and reactivity) normally used to assign a material factor to a process unit. The use of these indices as applied to loss of containment of "flammable, combustible, highly reactive, or toxic materials" has been summarized.[1]

Safety reviews

The safety review is a searching process designed (in its industrial application) to identify conditions that could lead to accidents. The review focuses on identifying major risk sources and, thus, depends on a PHA followed by one of the quantitative risk assessment methods. Such reviews in the plant setting are exhaustive (and exhausting) and involve inspections of all equipment, evaluation of the training of all personnel, assessment of the suitability and frequency of all safety system and interlock designs and testing procedures, review of all written procedures and observation of the extent to which they are followed, etc. At an individual plant site, safety reviews are carried out every 3 to 7 years.

Laboratory self-inspection

There is no counterpart to the safety review for the Unit Operations Laboratory. The closest camparable activity is probably a self-inspection performed at regular intervals by the campus health and safety offices, the college of engineering safety committee, and the departmental safety committee (see Appendix A).

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SAMPLE QUIZ QUESTIONS

1. How should chemical wastes be stored? Why are these precautions necessary?
2. What is the proper procedure for cleaning up a chemical spill in the Unit Operations Laboratory?
3. What are the safety and health topics to be covered in each prelaboratory preliminary report?
4. What safety documentation is required before each experiment? Where can that documentation be found?
5. What is a warning property of a gas or vapor? Give the warning properties of at least three chemicals in common use in the Unit Operations Laboratory.
6. Define the following terms: accident, risk, and hazard.
7. Name any risk assessment method and briefly describe it.
8. What are the required steps in a preliminary hazard analysis?
9. What is a safety review? How is it carried out?
10. What safety precautions are associated with the experiment you are now planning? What steps have you taken to minimize those potential hazards?

Unit X
HAZARD CONTROL

PURPOSE: To review the methods for hazard minimization and control

OBJECTIVE: To describe the requirements, principles, and control of potential and actual hazards in the Unit Operations Laboratory in terms of

1. Exposure limits
2. Control principles
3. Source controls
4. Safe work practices
5. Use of personal protective equipment

CONTROL REQUIREMENTS

Once the exposure levels in the Unit Operations Laboratory have been determined, the results must be interpreted in terms of potential or actual hazards. The first step is to compare the data with the exposure limits supplied on the material safety data sheets (MSDSs). Several types of exposure limits may be listed: ceiling, permissible exposure limit (PEL), and/or threshold limit values (TLVs).

Ceiling limits

A ceiling limit is established by OSHA for a substance that is relatively fast-acting. A ceiling limit is measured by one or more brief samples, usually 15 minutes in duration. Ceiling limits are listed as short-term exposure limits (STELs) by the American Conference of Governmental Industrial Hygienists (ACGIH). Allowable OSHA levels are given in 29 CFR 1910.1000, Tables Z-1-A and Z-2. Ceiling limits should not be exceeded during an 8-hour shift, except for a time period and a concentration not exceeding the maximum duration and peak concentration allowed by the Tables. Exposure times for STEL values are 15 minutes unless otherwise noted.

Permissible exposure limits

The PEL is the legally allowed (through OSHA), 8-hour, time-weighted-average (TWA) exposure in the workplace. These values are based on the best available data to set an upper limit to which the average worker can be exposed for an 8-hour workday, 5 days per week.[1] In calculating the TWA, excursions or short exposures above the PEL are allowed if they are compensated for by levels below the PEL so the average concentration over time does not exceed the PEL. These excursions however, must not exceed any established ceiling, peak, or STEL.

NIOSH recommended exposure limits

NIOSH periodically issues and revises recommended exposure limits (RELs) for potentially hazardous chemicals or conditions in the workplace. NIOSH also recommends preventive measures designed to reduce or eliminate the adverse health effects of these hazards. This information is contained in a readily understandable form as the "NIOSH Pocket Guide to Chemical Hazards" and in a supplement to "Morbidity and Mortality Weekly Report."[1,2] The NIOSH RELs and the NIOSH Criteria Documents, Special Hazard Reviews, Occupational Hazard Assessments, and Technical Guidelines are provided to OSHA for their use in developing health standards.

Threshold limit value

The TLV refers to airborne concentrations of substances established by ACGIH to represent conditions under which it is believed that nearly all workers may be repeatedly exposed, day after day, without adverse effects. The TLVs are regularly updated.

Minimum exposure standards do not guarantee safety

PELs, RELs, and even TLVs are minimal standards and not absolute guarantees of safety. It is possible for some individuals to suffer adverse effects at lower levels. Some chemicals, such as formaldehyde, are known to be sensitizers and will be indicated as such on the MSDS. In addition, the combined or synergistic effects of chemicals are not indicated by PELs or TLVs. Sometimes there may be such indications on the MSDS, but it is virtually impossible to identify all such effects given the number of chemicals in existence. Therefore, it is prudent to keep all exposures to chemicals to a minimum.

Effect of action level concentrations

If the exposure levels in the Unit Operations Laboratory are near or exceed the PEL or TLV, industrial hygiene practice requires either substituting a safer chemical and/or installing engineering controls to reduce exposures to a safe level. As a rule-of-thumb, one-half the PEL (or TLV) can be used as an action level (AL). Specific AL values are given in Subpart Z for chemicals covered by the various OSHA standards.[3] When discussing the need for engineering controls or other experimental changes, the students should be informed that OSHA procedures have been followed because they are applicable to industry. Many of those standards require biological monitoring (urine, blood, etc.) if the action level is exceeded as a safeguard against possible adverse human health effects. The rationale is that if the emissions are at the AL, they may reach the PEL before the next regularly scheduled (semi-annual or annual) monitoring cycle.

CONTROL PRINCIPLES

Reduce risk by reducing exposure

The principles of hazard control involve reducing risk by reducing exposure. Exposure is defined as the contact of the students or laboratory occupants with hazardous materials or conditions. A level of zero risk is unattainable. The laboratory director must, in conjunction with the departmental safety committee and the campus safety officer, decide upon the degree of risk to be tolerated in every aspect of the laboratory.

Exposure reduction techniques

The best way to control a hazard is to avoid creating it. If the hazard cannot be prevented, it can and must be minimized. Exposure reduction can be attained by engineering controls at the source, by creating transmission barriers (intervention) to separate the hazardous condition from the laboratory personnel, or by using the proper personal protective equipment (PPE). Engineering controls can range from local exhaust ventilation systems to pressure relief valves. The primary function of all engineering controls is to prevent creating any chemical, physical, or biological hazard.

Work practice controls

The general principles of work practice control as a way to minimize exposure to hazards should be covered in the Unit Operations Laboratory course. Safe work practices include proper housekeeping; proper handling, transfer, and storage of chemicals and other supplies and equipment; correct use of fume hoods when necessary; following all applicable safety rules; and being constantly alert for the presence and consequences of unsafe conditions or the unsafe acts of others. Specific standards exist for many other aspects of safe work practices such as isolation and purging of piping, equipment, and vessels of all types before working on or with them. This general area includes entry into confined spaces, hot work such as cutting or welding, working at elevated heights, and procedures for lock-out and tagging. Every engineering graduate needs to be aware of these standards. They are probably best introduced into the curriculum as examples or cautions in laboratory courses, or they can be specifically identified in case studies in the capstone process design courses.

Administrative control

Students should realize that administrative control (training, monitoring, shift rotation scheduling, good housekeeping, and scheduling of adequate preventive maintenance) is an approach used in industry to reduce exposures. The overly sensitive worker or one who has become sensitized to a particular chemical or physical hazard can be reassigned to other duties.

Use of PPE for hazard exposure control

PPE is used as a control approach to hazardous exposure when engineering controls are not available and/or when work practice controls are inadequate to reduce exposures to an acceptable level.[4] The PPE available to all persons in the Unit Operations Laboratory should include safety glasses, splash goggles, and safety face shields. Gloves, aprons, and rubber boots should be provided as appropriate for each experiment. Respirators (as discussed in Unit V) should be available for use by the teaching assistant and instructors during emergency shutdown and subsequent cleanup operations.

SOURCE CONTROLS

Many options are available to control hazardous conditions at the source. The process (experiment) can be changed. Less toxic or less flammable chemicals can be substituted for more hazardous materials. Often, the system can be operated at a lower temperature to reduce the vapor pressure and thereby reduce the severity of a possible exposure. Chemical hazards can be greatly reduced if open systems are eliminated or minimized. Reactive or flammable materials should be purged from the system by a nitrogen or steam flush before starting any kinetics experiment. That procedure will also exclude air; it is standard practice in industry and should also be followed in the laboratory. Wherever possible, the system pressure should be lowered. That should reduce the quantity and rates of leaks while the total energy level of the system is decreased.

Control by isolation, containment, and enclosure

Extremely hazardous experiments should not be assigned to Unit Operations Laboratory students. They lack the experience to handle such projects safely. The principles of isolation, containment, and enclosure can be discussed at the same time the proper use and operation of fume hoods are explained and demonstrated. Isolation refers to erecting a complete barrier between the hazard and the operator as required for the production of rocket fuel, explosives, etc. Containment, or partial isolation, can involve the use of blow-out walls or windows to direct the force of an explosion outward so as to avoid personnel injury. Rupture disks and relief valves serve the same purpose and are frequently incorporated in laboratory apparatus. Enclosures—fume hoods—are frequently used in unit operations and other laboratories when conducting bench-scale experiments or procedures and analytical determinations that involve highly toxic materials. If the system contains flammable chemicals, all electrical service to the hood must be explosion proof. An explosion-proof motor, fan, and drive must also be used in that situation. The hood exhaust must be located so that it cannot be drawn into the clean air supply for the building.

Control by local exhaust ventilation

Local exhaust ventilation is another approach to the control of hazardous emissions, whether chemical or physical in nature. All comminution and screening devices should be so equipped. So should all sanders, grinders, saws, and other dust-producing tools, whether portable or not, that are used by the students or technicians in the shop. Local exhaust ventilation should also be provided for all mass-transfer experiments that utilize toxic and/or flammable chemicals. The design of the ventilation system should conform to the recommended standards in the most recent edition of the ACGIH Ventilation Manual.[5]

Source control by work practices

Work practices can also be an effective source control. Simple acts, such as replacing vat and tank covers, closing openings in vessels, and cleaning up spills promptly, can directly reduce student exposure. If care is taken when handling granular and powdery materials, the potential for exposure to particulate matter is reduced, as is that for a dust explosion if the solid is combustible.

CONTROL OPTIONS

Many routes for controlling hazardous conditions can be found for most situations.[6] The most common are process change, operational change, and equipment change. Because many Unit Operations Laboratories use fixed pilot-scale equipment, the first two options are often the only two feasible. The control approach selected must be the one that will reduce the risk to the students and laboratory personnel to an acceptable level at an affordable cost. The alternative is to replace the experiment with one that is acceptable with regard to risk while still demonstrating the requisite chemical engineering principles. When trade-offs are made, they must always be in the direction of lower exposure, decreased risk, and reduced hazards. If it becomes apparent that a change in the experimental apparatus must be made, the students can be involved through their design or economics classes. The risk assessments can be made as part of the process design course. Present worth, annualized cost, etc., can be used to evaluate the total cost to the department of the various options.

Trade-offs in source control selection

When either selecting controls or modifying the apparatus for hazard reduction, several features must be considered, including reliability; maintenance; air collection, transport, and cleaning; and noise level. Above all, the entire system must operate in a fail-safe manner and the risks must be reduced to desired levels. No control approach should be accepted as complete unless it has been proven by peformance tests.

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SAMPLE QUIZ QUESTIONS

1. What is the basic principle of hazard control?
2. How can exposure to hazards be minimized?
3. What are "engineering controls"? What is their primary function?
4. What is meant by "safe work practices"? How are they developed? What are the common components of "safe work practices"?
5. What are the most common toxic source control elements?
6. When should local exhaust ventilation be used? Upon what principle are all such calculations based?
7. What are the three common methods for controlling hazardous conditions? Give an example of how each is used.
8. What factors must be considered when either selecting controls or modifying the experimental apparatus for hazard control?

APPENDIX A

Self-Inspection Checklist*

A "Checklist for Self-Inspection" for chemicals is shown in this appendix as an example of the material that can be obtained, usually at no charge from state offices: attorney general, the department of health, or the state OSHA. The office titles may vary from state to state; the functions do not. Other sources for such checklists are the worker's compensation and other insurance carriers used by the college/university.

Other checklists that should prove useful in the Unit Operations Laboratory are those for compressed gases, exhaust and ventilation, first aid, flammable and combustible liquids, housekeeping, metal (and other) shops, personal protective equipment, physical facilities, portable fire extinguishers, tools, and ventilation systems.

*This checklist was obtained from the Office of the Attorney General of the State of Texas.

CHEMICAL

Area Surveyed:	Inspected By:		
Date:	Date Reviewed By Faculty (initial):	Date Reviewed By Chairperson:	
STANDARDS/SAFETY GUIDELINES	NOTES	LOCATION	ACTION
THIS CHECKLIST IS OFFERED AS A GUIDELINE FOR LABS AND SHOULD NOT BE CONSTRUED AS COVERING ALL THE REQUIREMENTS UNDER 29 CFR, PART 1910 AND PART 1926 OR OTHER STANDARDS ADOPTED BY THE STATE UNDER ARTICLE 8309g. FURTHERMORE, OTHER SOURCES HAVE BEEN REFERENCED TO PROVIDE THIS VIABLE WORKING GUIDELINE.			
<u>GENERAL</u>			
1) Is an appropriate first aid cabinet furnished?			
2) Are portable fire extinguishers provided, installed and located in chemical laboratories in accordance with NFPA #10-1974?			
3) Are chemical containers free from decay or corrosion?			
4) Are boxes and glassware free of cracks and broken pieces and are electrical cords free of frayed or worn insulation?			
5) Is chemical storage orderly and are good housekeeping practices adhered to?			
6) Does illumination appear adequate?			
7) Are floors coated with nonskid materials and are they free of uneven and/or rough surfaces?			
8) Are laboratory operations reviewed periodically with special attention given to changes in the use of chemical reagents or procedures?			
9) Are operations updated after review?			

OBSERVATION KEY: ✓ — Meets Criteria X — Fails to meet Criteria U — Unknown NA — Not Applicable	COPIES TO: ☐ Faculty ☐ Chairperson ☐ Safety Committee	ACTION KEY: I — Immediate A — As Soon as Possible R — Routine

CHEMICAL

10) Are laboratory hoods located so as not to block egress from the laboratory in the event of a fire in the hood?			
11) Are the laboratory hoods' face velocities sufficient to assure capture velocity of the chemical vapors or gases?			
12) Are all service controls (electric, gas, water, and air) and electrical outlets external to the hood and within easy reach? (For older installations, additional external shutoff devices that are accessible and clearly marked should be installed. Internal electrical receptables should be sealed to prevent usage)			
13) Is disposal of chemical waste in accordance with approved methods?			
14) Are there established procedures for the use of open flames and spark-producing equipment?			
15) Are smoking areas designated?			
16) Are extension cords and portable electric equipment, tools and/or appliances used with care to eliminate tripping and electrical hazards?			
17) Are electric outlets, tools, appliances, etc., maintained free of physical or electrical defects?			
18) Is appropriate equipment guarding provided for shafts, gears, pulleys, belts, rolls, chains, agitators, grinders, etc.?			
19) Does inside flammable and combustible liquid storage conform to the requirements in the 29 CFR, Section 1910.106(d)?			
<u>PERSONNEL SAFETY</u>			
1) Are employees aware of the procedure and use of emergency equipment, i.e., fire extinguishers, eyewash station, deluge shower, etc.?			
2) Is employee training on dangerous materials, i.e., corrosive, toxic, explosive, etc., provided and documented?			
3) Are hazardous containers labeled "POISON," "CORROSIVE," "FLAMMABLE," etc.? (Unlabeled containers should be identified or disposed of.)			
4) Are safety pipette fillers used? (Pipetting by mouth shall be prohibited.)			
5) Are safety bottle carriers used for 5 pint bottles of acids, alkalis, or solvents?			
6) Are safety tongs used to grip heated beakers, flasks, distillers, etc.?			
7) Are appropriate aprons used, where applicable?			
8) Is hand protection used to guard against burns, caustics and contaminants?			
9) Are appropriate safety goggles/glasses/face shields used?			
10) Are respirators provided and used in hazardous vapor, fume or dust environments? (These respirators should provide adequate protection for the specific chemical.)			

OBSERVATION KEY: ✓ — Meets Criteria
X — Fails to meet Criteria
U — Unknown
NA — Not Applicable

COPIES TO: ☐ Faculty
☐ Chairperson
☐ Safety Committee

ACTION KEY:
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A — As Soon as Possible
R — Routine

CHEMICAL

11) Are protective work area shields provided to protect against flying debris and liquid from chemical or pressure explosions, vacuum implosions, broken connections, etc.?			
12) Are step stools and/or rolling lab ladders, with spring-loaded casters, provided?			
<u>FIRE SAFETY</u>			
1) Are emergency procedures established and do they include alarm actuation or alert and evacuation, equipment shutdown procedures and provisions for fire fighting action?			
2) Are fire prevention procedures established and adhered to, especially with regard to handling and storage of flammable and combustible liquids and hazardous materials?			
3) Are flammable chemicals stored in U.L. approved safety cans or permissible metal cans in U.L. approved safety cabinets?			
4) Are containers and cabinets labeled with warning signs, such as "CAUTION - FLAMMABLE MATERIALS - SMOKING, MATCHES, OR OPEN FLAME PROHIBITED?"			
5) Are oxidizing agents (oxides, peroxides, nitrates, chlorides, etc.) not stored in the same area with fuels, such as solvents, organic chemicals, dehydrating chemicals, reducing agents, etc.? (If they are located in the same room, they should be separated with a one hour fire-rated enclosure.)			
6) Are U.L. approved refuse cans provided for solvents? (Caution should be used to provide several cans for different chemicals so that incompatible mixtures will not inadvertently react and explode.)			
7) Are U.L. approved refuse containers provided for solvent and oil impregnated rags?			
8) Are burner safety lighters used?			
9) Are mixtures and/or use of the following items prohibited or conducted under controlled conditions? (These are random samples and do not constitute the total number of incompatible or unstable reagents.) (a) Mixtures of hypochlorite with organic compounds, i.e., carbon tetrachloride, benzene, etc., can burst into flame spontaneously. (b) Dry mixtures of acids and caustics in the presence of a very small amount of water, such as is present on high humidity days, can generate violent heat resulting in a possible fire. (c) Mixtures of calcium hypochlorite in turpentine can result in a possible explosion. (d) Highly oxidizing agents, such as benzoyl peroxide, acetyl peroxide and all other peroxide-forming agents, such as ethers, are unpredictable and highly sensitive to shock, vibration, friction, etc. (Shelf life should be strictly adhered to.) (e) Mixtures of perchloric acid and organic materials can result in an explosion.			

OBSERVATION KEY: ✓ — Meets Criteria
X — Fails to meet Criteria
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NA — Not Applicable

COPIES TO: ☐ Faculty
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CHEMICAL

(f) Picric acid is highly shock- and vibration-sensitive when it dries; therefore, it should be carefully and properly disposed of. (Quantities of picric acid should be held to a minimum. Caution should be used so that older bottles are not inadvertently shoved to the rear of stock.) 10) Is explosion-proof heating equipment (hotplate, heating oven, etc.) used in Class I, Group B, hazardous areas, i.e., areas where benzene, alcohol, acetone, propane, etc., is being used? 11) Are explosion-proof refrigerators used for volatile material storage and are they labeled to denote restricted use? STORAGE 1) Are bulk flammable reagents stored in an outside storage building? (Weekly department or area requirements may be kept inside the lab in approved safety cabinets.) [Ref: 29 CFR, Section 1910.106(d).] 2) Is ventilation adequate? (Stuffy, pungent odors, temperature outside of comfort zone, etc., denote inadequate ventilation.) 3) Is chemical storage orderly and in line with good housekeeping practices? 4) Are containers free of decay or corrosion? 5) Is there adequate shelving? (Shelving should be sturdy, secured, provided with edgeboards, impervious to reagents, etc.) 6) Are aisleways maintained unobstructed? 7) Are incompatible chemicals segregated? (Oxidizing agents should be kept away from flammable solvents; acetic acid away from nitric acid; perchloric acid away from alcohol; etc.) 8) Are toxic and carcinogenic chemicals, i.e., benzene, ethyl bromide, hydrogen sulfide, benzidine etc., identified and controlled? 9) Are potentially explosive chemicals, i.e., peroxides, perchloryl fluoride, monochloracetone, etc., identified and controlled? 10) Are oxidizing agents, i.e., oxides, peroxides, nitrates, nitrites, bromates, chromates, chlorates, dichromates, perchlorates, and permanganates, identified and controlled?			

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APPENDIX B
Safety and Health Publications

General

29 CFR 1900 to 1910: General Industry Standards
29 CFR 1926: Construction Industry Standards
OSHA 2019: OSHA Publications and Audiovisual Programs (1986 rev.)
OSHA 2056: All About OSHA (1985)
OSHA 2098: OSHA Inspections (1986)
OSHA 2254: Training Requirements in OSHA Standards and Training Guidelines (1985)
OSHA 2265: Material Safety Data Sheet (1977) (See Appendix F below.)
OSHA 3071: Job Hazard Analysis (1985 rev.)
OSHA 3077: Personal Protective Equipment (1983)
OSHA 3079: Respiratory Protection (1988 rev.)
OSHA 3081: OSHA Reference Book (1985)
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Undated publicationss are periodically updated. Request/use the most recent edition.

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National Safety and Health News
Occupational Safety and Health
Plant/Operations Progress
Professional Safety
Safety and Health

APPENDIX C

Personal Protective Equipment in the Unit Operations Laboratory

1. FOOTWEAR

   - Hard leather shoes (above-ankle height is recommended) must be worn at all times. The following footwear is not allowed:

     — Tennis shoes or sneakers
     — Suede leather
     — Soft leather
     — "Duck" or rubber shoes or boots
     — Sandals

2. GOGGLES

   - Goggles must be worn when operating the absorber, extractor, and distillation column; goggles provide eye protection from flying objects and caustic chemicals and solvents.
   - Contact lenses are prohibited because chemicals can seep behind them and damage the eye.

3. HARDHAT

   - A hardhat must be worn at all times; hardhats provide protection from falling objects and from striking the head against pipes and equipment.

4. APRONS

   - An apron must be worn when operating the gas absorber and the liquid-liquid extractor; aprons protect torso and upper legs from chemical spills.

5. GLOVES (see also Table V–1)

   - Leather (palm and finger) gloves must be worn when steam or hot liquids are used; gloves protect hands from burns and chemical spills.
   - Rubber gloves must be worn when operating the gas absorber and the liquid-liquid extractor.

6. REQUIRED CLOTHING

   - Long pants must be worn, and buttoned, long-sleeved shirts are recommended.
   - Neckties or dangling clothes or jewelry must not be worn.
   - Long hair must be so arranged that it will not become entangled in moving machine parts.

APPENDIX D

Warning Properties of Industrial Chemicals*

This Appendix provides a condensed source of chemical warning properties. The data listed are referenced by source, and the sources are abbreviated.† The University of California —Berkeley (UCB) data are unpublished; they have been derived by statistically analyzing 26 documentations of warning levels.

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*Taken from: Occupational Health Resource Center, Oregon Lung Association, 319 S.W. Washington, Suite 520, Portland, Oregon 97024.

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ANSI	AMERICAN NATIONAL STANDARDS INSTITUTE, INC.
ASTMB	AMERICAN SOCIETY OF TESTING MATERIAL BULLETIN
BROWNING	E. BROWNING
GLEASON	M.N. GLEASON
GRANT	W.M. GRANT
HIOS	HANDBOOK OF INDUSTRIAL ORGANIC SOLVENTS
HALEY	T.J. HALEY
ILO	INTERNATIONAL LABOR OFFICE
KIRK	R. KIRK
LITTLE	ARTHUR D. LITTLE
MAY	J. MAY
MCA	MANUFACTURING CHEMISTS ASSOCIATION
NIOSH	NATIIONAL INSTITUTE FOR OCCUPATIONAL SAFETY & HEALTH
NUS	NUS CORPORATION—A HALLIBURTON COMPANY
PATTY	F.A. PATTY
SAX	N. IRVING SAX
SPECTOR	W.S. SPECTOR
STERN	A.C. STERN
SUMMER	W. SUMMER
THIENES	C.H. THIENES
TLV	DOCUMENTATIONS OF TLV'S—4TH EDITION
UCB	UNIVERSITY OF CALIFORNIA—BERKELEY

CHEMICAL	ODOR THRESHOLD								
	AIHA	LITTLE	MAY	NUS	PATTY	SUMMER	TLV	UCB	MISCELLANEOUS
ACETALDEHYDE	2.3	0.21	0.031					0.050	STERN .066
ACETIC ACID		1.0	24.		10.			0.48	MCA 1.0, GLEASON 0.2
ACETIC ANHYDRIDE								0.13	USCG 0.14
ACETONE		100.						13.	
ACETONITRILE	40.							170.	
ACETYLENE								620.	
ACROLEIN	0.4	0.21	0.2	0.2		15.		0.16	STERN 1.8
ACRYLIC ACID								0.094	
ACRYLONITRILE		21.4		21.				17.	
ALLYL ALCOHOL				7.	<0.75			1.1	
ALLYL CHLORIDE		0.47						1.2	
AMINE DIMETHYL		0.047							
AMINE MONOM ETHYL		0.021							
AMINE TRIMETHYL		0.00021							
AMMONIA	1-5.	46.8						5.2	
N-AMYL ACETATE			0.08					0.054	
SEC-AMYL ACETATE								0.0020	
N-AMYL ALCOHOL			35.			10.			
ANILINE		1.0	7.					1.1	MCA 0.5, OTHER 1.0
ARSINE				0.21				0.50	
BENZENE		4.68						12.	
BENZYL CHLORIDE		0.047						0.044	
BENZYL SULFIDE		0.0021							
BIPHENYL								0.00083	
BROMINE		0.047	1.0		3.5			0.051	OTHER 0.05
BROMOFORM				530.				1.3	
BUTADIENE			0.16					1.6	
BUTANE								2,700.	
2-BUTANONE								5.4	
2-BUTOXY ETHANOL								0.10	
BUTYL ACETATE			20.			7.0			
N-BUTYL ACETATE								0.39	
SEC-BUTYL ACETATE			4.0			7.0		2.6	
TERT-BUTYL ACETATE			4.0			7.0		47.	

CHEMICAL	IRRITATION LEVEL: EYE	IRRITATION LEVEL: NASAL	IRRITATION LEVEL: THROAT	ODOR	THRESHOLD * LIMIT VALUE
ACETALDEHYDE	GRANT 50.0			GREEN, SWEET	100.0
ACETIC ACID	AIHA 10-15.0			SOUR, VINEGAR	10.0
ACETIC ANHYDRIDE	AIHA 5.0			VINEGAR, BURNING, PUNGENT	5.0
ACETONE				CHEMICAL SWEET, PUNGENT	750.0
ACETONITRILE		AIHA 500.0	AIHA 500.0	ETHER LIKE	40.0
ACETYLENE					
ACROLEIN	GRANT 0.5			SWEET, BURNT, PUNGENT	0.1
ACRYLIC ACID				ACRID	10.0
ACRYLONITRILE				ONION, GARLIC	
ALLYL ALCOHOL	PATTY 6.25	PATTY 0.78		MUSTARD LIKE, PUNGENT	2.0
ALLYL CHLORIDE	PATTY 50.0			ONION, GARLIC, GREEN	1.0
AMINE DIMETHYL				FISHY	
AMINE MONOM ETHYL				FISHY	
AMINE TRIMETHYL				FISHY	
AMMONIA	GRANT 140.0	AIHA 55-100.0		PUNGENT	25.0
N-AMYL ACETATE	AIHA 200.0	AIHA 200.0		SWEET, FRUITY	100.0
SEC-AMYL ACETATE	HIOS<125.0	-135<125.0	HIOS<125.0		125.0
N-AMYL ALCOHOL					
ANILINE				PUNGENT	2.0
ARSINE				GARLIC	0.05
BENZENE				SOLVENT	10.0
BENZYL CHLORIDE				SOLVENT	1.0
BENZYL SULFIDE				SULFIDY	
BIPHENYL					0.2
BROMINE	MCA/AIHA < 1.0			BLEACH	0.1
BROMOFORM				CHLOROFORM	0.5
BUTADIENE					1000.0
BUTANE					800.0
2-BUTANONE				ACETONE LIKE	
2-BUTOXY ETHANOL	BROWNING 113.0	BROWNING 113.0		MILD, ETHEREAL ODOR	25.0
BUTYL ACETATE	GRANT 300.0	GRANT 300.0		FRUITY	
N-BUTYL ACETATE				FRUITY	150.0
SEC-BUTYL ACETATE					200.0
TERT-BUTYL ACETATE	TLV 200.0	TL: 200.0			200.0

* TAKEN FROM ACGIH TLV'S, 1982 EDITION

				ODOR THRESHOLD					
PAGE -2-	AIHA	LITTLE	MAY	NUS	PATTY	SUMMER	TLV	UCB	MISCELLANEOUS
BUTYL ALCOHOL			11.		15.	11.		0.83	
SEC-BUTYL ALCOHOL,			43.0						
TERT-BUTYL ALCOHOL			73.0						
N-BUTYL LACTATE								7.0	
BUTYL MERCAPTAN								0.00097	
BUTYLAMINE					2-5.			1.8	
P-TERT-BUTYLTOLUENE					5.0			5.0	
BUTYRIC ACID		0.001							
CAMPHOR			1.6	1.6-200.		16.		0.27	
CARBON DIOXIDE			0.0081					74,000.	
CARBON DISULFIDE	1.2	0.21	0.0011			7.7		0.11	OTHER >1.
CARBON MONOXIDE								100,000	
CARBON TETRACHLORIDE	50.	100.		75.				96.	
CHLORAL		0.047							
CHLORINE		0.314	0.01			0.01		0.31	STERN 0.01
CHLORINE DIOXIDE			0.1					9.4	
CHLOROACETALDEHYDE									
ALPHA-CHLOROACETOPHENONE				1.0				0.035	
CHLOROBENZENE	60.							0.68	
CHLOROBROMOMETHANE					400.			400.	
CHLOROFORM	50.		200.	200.	200-300.			85.	
CHLOROPICRIN				1.				0.78	STERN 1.1
CHLOROPRENE								15.	
O-CHLOROTOLUENE								0.32	
CRESOL, ALL ISOMERS								0.00028	
CROTONALDEHYDE			0.035	7.				0.088	STERN 0.062
CUMENE			1.2					0.088	
CYCLOHEXANE			0.41	300.				25.	
CYCLOHEXANOL,				100.				0.15	
CYCLOHEXANONE								0.88	
CYCLOHEXENE			<300.					0.18	
CYCLOHEXYLAMINE								2.6	
CYCLOPENTADIENE								1.9	
DECABORANE								0.060	
DIACETONE ALCOHOL								0.28	
DIBORANE								2.5	

PAGE 2-A	IRRITATION LEVEL EYE	NASAL	THROAT	ODOR	THRESHOLD LIMIT VALUE
BUTYL ALCOHOL	TLV 55.0/PATTY 25.0	PATTY 25.0	PATTY 25.0	FRUITY	
SEC-BUTYL ALCOHOL					100.0
TERT-BUTYL ALCOHOL				CAMPHOR	100.0
N-BUTYL LACTATE					5.0
BUTYL MERCAPTAN				SKUNK	0.5
BUTYLAMINE		AIHA 10-15.0	10-15.0	AMMONIA LIKE	
P-TERT-BUTYLTOLUENE	ILO 5-8.0				10.0
BUTRYIC ACID				SOUR	
CAMPHOR	TLV 1.77	TLV 1.77	TLV 1.77		2.0
CARBON DIOXIDE				ODORLESS	5000.0
CARBON DISULFIDE				VEGETABLE SULFIDY	10.0
CARBON MONOXIDE				ODORLESS	50.0
CARBON TETRACHLORIDE				SWEET, PUNGENT	5.0
CHLORAL				SWEET	
CHLORINE	GRANT/PATTY 3-6.0	PATTY 3-6.0	PATTY 3-6.0	BLEACH, PUNGENT	1.0
CHLORINE DIOXIDE	TLV 5.0				0.1
CHLOROACETALDEHYDE		TLV 1.0			
ALPHA-CHLOROACETOPHENONE	TLV 0.04				0.05
CHLOROBENZENE				ALMOND LIKE	75.0
CHLOROBROMOMETHANE				CHLOROFORM LIKE	200.0
CHLOROFORM	PATTY 4096.0				10.0
CHLOROPICRIN	PATTY/TLV 0.3-0.37				0.1
CHLOROPRENE					10.0
O-CHLOROTOLUENE					50.0
CRESOL, ALL ISOMERS				PHENOL LIKE	5.0
CROTONALDEHYDE	GRANT/TLV 45.0				2.0
CUMEME					50.0
CYCLOHEXANE	TLV 300.0			CHLOROFORM LIKE	300.0
CYCLOHEXANOL	TLV 100.0	TLV 100.0	TLV 100.0	CAMPHOR LIKE	50.0
CYCLOHEXANONE				PEPPERMINT	25.0
CYCLOHEXENE	TLV 300.0				300.0
CYCLOHEXYLAMINE					10.0
CYCLOPENTADIENE				TURPENTINE LIKE	75.0
DECABORANE				BITTER CHOCOLATE, INTENSE	0.05
DIACETONE ALCOHOL					50.0
DIBORANE				NAUSEATING	

PAGE 3	AIHA	LITTLE	ODOR THRESHOLD MAY	NUS	PATTY	SUMMER	TLV	UCB	MISCELLANEOUS
O-DICHLOROBENZENE	2-4.		50.		50.			0.30	
P-DICHLOROBENZENE					15-30.			0.18	
1,3-DICHLORO-5,5-DIMETHYLHYDANTOIN			.01						
1,1-DICHLOROETHANE									NIOSH 200.
1,2-DICHLOROETHANE								88.	
1,2-DICHLOROETHYLENE			0.085	500.				17.	
DICHLOROETHYL ETHER				35.	15.				
B,B'DICHLOROETHYL ETHER								0.049	
DICYCLOPENDADIENE								0.0057	
DIETHANOLAMINE								0.27	
DIETHYLAMINE								0.13	USCG 0.14
DIETHYLAMINO ETHANOL								0.011	
DIETHYL KETONE								2.0	
DIGLYCIDYL ETHER				5.0					
DIISOBUTYL KETONE								0.11	
DIISOPROPYLAMINE								1.8	
DIMETHYL ACETAMIDE		46.8		46.0				47.0	
DIMETHYLAMINE			0.21			6.0		0.34	
DIMETHYLANILINE								0.013	
DIMETHYL FORMAMIDE		100.0		100.0				2.2	DEPT. OF TRANS 100.0
1,1-DIMETHYLHYDRAZINE								1.7	
DIMETHYLSULFIDE		0.001							
DIOXANE			170.0			170.0		24.0	
DIPHENYL SULFIDE		0.0047							
DIPROPYLENE GLYCOL METHYL ETHER									BROWNING 1000.0
EPICHLOROHYDRIN				10.0				0.93	
ETHANE								120,000.	
ETHANOL		10.0							
ETHANOLAMINE	2-3.0							2.6	
2-ETHOXYETHANOL								2.7	
2-ETHOXYETHYLACETATE								0.056	
ETHYL ACETATE			.0056			50.0		3.9	
ETHYL ACRYLATE	1.0	0.00047						0.0012	MCA 8.0
ETHYL ALCOHOL								84.0	
ETHYL BENZENE				200.0				2.3	USCG 140.0
ETHYL BROMIDE								3.1	

PAGE 3-A	IRRITATION LEVEL: EYE	IRRITATION LEVEL: NASAL	IRRITATION LEVEL: THROAT	ODOR	THRESHOLD LIMIT VALUE
O-DICHLOROBENZENE	AIHA 20-30.0				
P-DICHLOROBENZENE	PATTY 80-160.0			DISTINCT, AROMATIC	75.0
1,3-DICHLORO-5,5-DIMETHYLHYDANTOIN	PATTY 1.14				
1,1-DICHLOROETHANE				DISTINCT	200.0
1,2-DICHLOROETHANE				CHLOROFORM	
1,2-DICHLOROETHYLENE					200.0
DICHLOROETHYL ETHER	PATTY 100-260.0	PATTY 100-260.0	PATTY 100-260.0	CHLOROFORM	5.0
B,B'DICHLOROETHYL ETHER				CHLOROFORM	
DICYCLOPENDADIENE					5.0
DIETHANOLAMINE					3.0
DIETHYLAMINE	GRANT 50.0 (ANIMALS)			AMMONIACAL, STRONG	10.0
DIETHYLAMINO ETHANOL				AMMONIACAL, WEAK	10.0
DIETHYL KETONE				ACETONE LIKE	200.0
DIGLYCIDYL ETHER					0.1
DIISOBUTYL KETONE					25.0
DIISOPROPYLAMINE	GRANT 25-50.0			AMMONIA LIKE	5.0
DIMETHYL ACETAMIDE				BURNT, OILY	10.0
DIMETHYLAMINE	TLV 97-183.0 (ANIMALS)			AMMONIACAL	10.0
DIMETHYLANILINE					5.0
DIMETHYL FORMAMIDE				FISHY, PUNGENT	10.0
1,1-DIMETHYLHYDRAZINE				AMMONIACAL	0.5
DIMETHYLSULFIDE				FAINT ONION LIKE	
DIOXANE	GRANT>220.0/PATTY 300.0	PATTY 300.0	PATTY 300.0	ETHEREAL	25.0
DIPHENYL SULFIDE				BURNT, RUBBERY	
DIPROPYLENE GLYCOL METHYL ETHER				MILD ETHER	100.0
EPICHLOROHYDRIN	AIHA >100.0/NIOSH 20.0	AIHA >100.0/NIOSH 20.0		CHLOROFORM LIKE	2.0
ETHANE				ODORLESS	
ETHANOL				SWEET	
ETHANOLAMINE			AMMONIACAL	AMMONIACAL	3.0
2-ETHOXYETHANOL				ODORLESS	
2-ETHOXYETHYLACETATE	TLV 600.0 (ANIMALS)	TLV 600.0 (ANIMALS)			
ETHYL ACETATE	GRANT 200.0				400.0
ETHYL ACRYLATE	AIHA 272.0 (ANIMALS) MCA 75.0			HOT, PLASTIC, EARTHY	5.0
ETHYL ALCOHOL				ETHEREAL	1000.0
ETHYL BENZENE	AIHA 200.0			AROMATIC	100.0
ETHYL BROMIDE	AIHA 6500.0				200.0

PAGE -4-	AIHA	LITTLE	MAY	NUS	PATTY	SUMMER	TLV	UCB	MISCELLANEOUS
	ODOR THRESHOLD								
ETHYLAMINE								0.95	
ETHYL AMYL KETONE								6.0	
ETHYL CHLORIDE								4.2	
ETHYL ETHER			0.33					8.9	
ETHYL FORMATE								31.0	
ETHYL MERCAPTAN		0.001						0.00076	
ETHYL SILICATE								17.0	GRANT 85.0
ETHYLENE								290.0	
ETHYLENEDIAMINE	10.0			11.0				1.0	
ETHYLENE DIBROMIDE									ILO 10.0
ETHYLENEIMINE								1.5	
ETHYLENE OXIDE				500.0				430.0	
ETHYLIDENE NORBORNENE								0.014	
N-ETHYLMORPHOLINE							25.0	1.4	
FLUORINE								0.14	
FLUOROTRICHLOROMETHANE								5.0	
FORMALDEHYDE		1.0			1.0			0.83	
FORMIC ACID			21.0					49.0	
FURFURAL	0.25							0.078	
FURFURYL ALCOHOL								8.0	
HALOTHANE								33.0	
HEPTANE			50-220.			220.0		150.0	
HEXACHLOROCYCLOPENTADIENE								0.030	
HEXACHLOROETHANE								0.15	
HEXANE								130.0	
2-HEXANONE								0.076	
HEXONE								0.68	
SEC-HEXYL ACETATE							100.0		
HEXYLENE GLYCOL								50.0	
HYDRAZINE								3.7	
HYDROCHLORIC ACID GAS		10.0							
HYDROGEN BROMIDE							2.0	2.0	
HYDROGEN CHLORIDE				10.0				0.77	
HYDROGEN CYANIDE								0.58	
HYDROGEN FLUORIDE								0.042	
HYDROGEN SELENIDE			0.3	0.3		3.0		0.3	
HYDROGEN SULFIDE		0.00047						0.0081	

PAGE 4-A	IRRITATION LEVEL EYE	NASAL	THROAT	ODOR	THRESHOLD LIMIT VALUE
ETHYLAMINE	PATTY/TLV 100.0 (ANIMALS)			AMMONIA LIKE	10.0
ETHYL AMYL KETONE					25.0
ETHYL CHLORIDE				ETHER LIKE, PUNGENT	1000.0
ETHYL ETHER		PATTY 200.0			400.0
ETHYL FORMATE	TLV 330.0				100.0
ETHYL MERCAPTAN				EARTHY, SULFIDY, SKUNK	0.5
ETHYL SILICATE	GRANT 250.0	GRANT 250.0			10.0
ETHYLENE				SWEET	
ETHYLENEDIAMINE		TLV 100.0		AMMONIA LIKE	10.0
ETHYLENE DIBROMIDE				SWEET	
ETHYLENEIMINE				AMINE	0.5
ETHYLENE OXIDE					
ETHYLIDENE NORBORNENE					
N-ETHYLMORPHOLINE	GRANT 40.0/TLV 50-100.0	TLV 100.0	TLV 100.0	AMMONIACAL	5.0
FLUORINE	GRANT 25-100.0	GRANT 25-100.0			1.0
FLUOROTRICHLOROMETHANE				NEARLY ODORLESS	
FORMALDEHYDE	AIHA 2.0/GRANT 0.5-0.005			HAY	3.0
FORMIC ACID	TLV 15.0			PUNGENT, PENETRATING	5.0
FURFURAL	AIHA 20-50.0/GRANT 13.5				2.0
FURFURYL ALCOHOL					10.0
HALOTHANE				SWEET	
HEPTANE					400.0
HEXACHLOROCYCLOPENTADIENE					0.01
HEXACHLOROETHANE				CAMPHOR LIKE	10.0
HEXANE	TLV 1400-1500.0		TLV 1400-1500.0		50.0
2-HEXANONE					
HEXONE					
SEC-HEXYL ACETATE	TLV 100.0				50.0
HEXYLENE GLYCOL				NEARLY ODORLESS	
HYDRAZINE					0.1
HYDROCHLORIC ACID GAS				PUNGENT	
HYDROGEN BROMIDE		TLV 5.0	TLV 5.0		3.0
HYDROGEN CHLORIDE			TLV 35.0		
HYDROGEN CYANIDE				BITTER ALMONDS	
HYDROGEN FLUORIDE	GRANT 5.0	GRANT 5.0			3.0
HYDROGEN SELENIDE	GRANT 1.5				0.05

PAGE -5-	AIHA	LITTLE	MAY	NUS	PATTY	SUMMER	TLV	UCB	MISCELLANEOUS
			ODOR THRESHOLD						
INDENE								0.015	
IODOFORM								0.0050	
ISOAMYL ACETATE								0.025	HIOS 100.0
ISOAMYL ALCOHOL			≈35.0			≈10.0		0.042	
ISOBUTYL ACETATE			4.0			4.0		0.64	
ISOBUTYL ALCOHOL			40.0			40.0		1.6	
ISOPHORONE								0.20	
ISOPROPYL ACETATE			30.0					2.7	
ISOPROPYL ALCOHOL			45.0		200.0			22.0	
ISOPROPYL GLYCIDYL ETHER				300.0					
ISOPROPYLAMINE					5-10.0			1.2	
ISOPROPYLETHER					300.0			0.017	
LIQUEFIED PETROLEUM GAS (LPG)							20,000.		
MALEIC ANHYDRIDE	0.46							0.32	
MESITYL OXIDE								0.45	
METHANOL		1000.0		2000.0					
2-METHOXYETHANOL				500.0				2.3	
5-METHYL-3-HEPTANONE									SHELL 6.0
METHYL ACETATE			200.0	200.0		200.0		4.6	
METHYL ACETYLENE-PROPADIENE MIXTURE									DOW 100.0
METHYL ACRYLATE								0.0048	MCA 20.0
METHYL ACRYLONITRILE								7.0	
METHYL ALCOHOL	2000.		5900.			5900.	100.0		
METHYLAMINE								3.2	
METHYL CELLOSOLVE			60.0						
METHYL CHLORIDE		10.0	10.0					250.0	
METHYL CHLOROFORM	20-100.		400.0	500.0		400.0		120.0	
METHYL 2-CYANOACRYLATE								2.2	
METHYL FORMATE			2000.	2000.		2000.		600.0	
METHYL HYDRAZINE								1.7	
METHYL ISOAMYL KETONE								0.012	
METHYL ISOBUTYL CARBINOL							50.0	0.070	
METHYL ISOBUTYL KETONE		0.47							
METHYL ISOCYANATE							2.0	2.1	
METHYL ISOPROPYL KETONE								1.9	
METHYL MERCAPTAN		0.0021						0.0016	

PAGE 5-A	IRRITATION LEVEL EYE	NASAL	THROAT	ODOR	THRESHOLD LIMIT VALUE
INDENE					10.0
IODOFORM					.06
ISOAMYL ACETATE	HIOS 100.0	HIOS 100.0		BANANA LIKE	100.0
ISOAMYL ALCOHOL	PATTY 150.0	PATTY 150.0	PATTY 100.0		100.0
ISOBUTYL ACETATE	TLV 150.0			FRUITY	150.0
ISOBUTYL ALCOHOL	PATTY >100.0				50.0
ISOPHORONE					
ISOPROPYL ACETATE	PATTY 200.0				250.0
ISOPROPYL ALCOHOL	PATTY 400.0	PATTY 400.0	PATTY 400.0		400.0
ISOPROPYL GLYCIDYL ETHER					50.0
ISOPROPYLAMINE		PATTY 10-20.0	PATTY 10-20.0	AMINE	5.0
ISOPROPYLETHER	PATTY 500-800.0	PATTY 500-800.0		ETHEREAL	250.0
LIQUEFIED PETROLEUM GAS (LPG)					1000.0
MALEIC ANHYDRIDE	AIHA 1.37-1.83	AIHA 1.37-1.83			0.25
MESITYL OXIDE				HONEY LIKE	15.0
METHANOL				SWEET	200.0
2-METHOXYETHANOL					
5-METHYL-3-HEPTANONE	TLV 50.0	TLV 50.0			
METHYL ACETATE	GRANT 10,000.0	GRANT 10,000.0	GRANT 10,000.0		200.0
METHYL ACETYLENE-PROPADIENE MIXTURE				STRONG	1000.0
METHYL ACRYLATE	MCA 75.0	MCA 75.0	MCA 75.0		10.0
METHYL ACRYLONITRILE					1.0
METHYL ALCOHOL					200.0
METHYLAMINE				AMMONIACAL	10.0
METHYL CELLOSOLVE				SWEET ETHEREAL	
METHYL CHLORIDE	AIHA 500-1000.0				50.0
METHYL CHLOROFORM					350.0
METHYL 2-CYANOACRYLATE					2.0
METHYL FORMATE	GRANT 3500.0 (ANIMALS)				100.0
METHYL HYDRAZINE				AMMONIA LIKE	
METHYL ISOAMYL KETONE					50.0
METHYL ISOBUTYL CARBINOL	TLV 50.0				25.0
METHYL ISOBUTYL KETONE				SWEET	
METHYL ISOCYANATE	TLV 2.0				0.02
METHYL ISOPROPYL KETONE					200.0
METHYL MERCAPTAN				SULFIDY	0.5

				ODOR T..RESHOLD					
PAGE -6-	AIHA	LITTLE	MAY	NUS	PATTY	SUMMER	TLV	UCB	MISCELLANEOUS
METHYL METHACRYLATE		0.21	0.21					0.083	
ALPHA-METHYL STYRENE								0.29	
METHYL N-AMYL KETONE								0.35	
METHYLAMINE			3.3	10.0					
N-METHYLANILINE								1.7	
METHYLCYCLOHEXANE								630.0	SAX 500.0
METHYLCYCLOHEXANOL					500.0			500.0	
METHYLENE CHLORIDE		214.0	150.0			150.0			KIRK/SAX 25-50., SPECTOR 320.
METHYL ETHYL KETONE		10.0							
MONOCHLOROBENZENE		0.21							
MORPHOLINE								0.01	
NAPHTHALENE	0.3							0.84	
NICKEL CARBONYL					1-3.0			0.30	
NITRIC ACID			0.3-1.0						
NITROBENZENE		0.0047	1.9					0.018	STERN 1.9
NITROETHANE								2.1	
NITROGEN DIOXIDE	5.0			5.0				0.39	
NITROMETHANE								3.5	
1-NITROPROPANE	<300.0							11.0	
2-NITROPROPANE								70.0	
NITROTOLUENE								0.045	
NONANE								47.0	
OCTANE			150.0			150.0		48.0	
OSMIUM TEXTROXIDE								0.0019	
OXYGEN DIFLUORIDE								0.10	
OZONE			0.1			0.1		0.045	
PARACRESOL		0.001							
PARATHION									ASTMB 0.0
PARAXYLENE		0.47							
PENTABORANE								0.96	
PENTACHLOROETHYLENE								27.0	
PENTANE	1,000.0		2.2					400.0	
2-PENTANONE								11.0	
PERCHLOROETHYLENE		4.68							
PERCHLORYL FLUORIDE									SAX 10.0
PHENOL		0.047				3.0		0.040	MCA 0.3, THIENE/HALEY 5.0

PAGE 6-A	IRRITATION LEVEL: EYE	IRRITATION LEVEL: NASAL	IRRITATION LEVEL: THROAT	ODOR	THRESHOLD LIMIT VALUE
METHYL METHACRYLATE,				SULFIDY	100.0
ALPHA-METHYL STYRENE	TLV 200.0				50.0
METHYL N-AMYL KETONE					50.0
METHYLAMINE	PATTY 20-100.0			AMMONIACAL	10.0
N-METHYLANILINE					0.5
METHYLCYCLOHEXANE					400.0
METHYLCYCLOHEXANOL	HIOS 500.0			MENTHOL LIKE	50.0
METHYLENE CHLORIDE	TLV 5000.0			ETHER LIKE	100.0
METHYL ETHYL KETONE				SWEET	200.0
MONOCHLOROBENZENE				MOTH BALLS, ALMOND LIKE	
MORPHOLINE				AMINE	20.0
NAPHTHALENE	AIHA 15.0				10.0
NICKEL CARBONYL					0.05
NITRIC ACID			AIHA 62.0		2.0
NITROBENZENE				SHOE POLISH	1.0
NITROETHANE	AIHA 100.0				100.0
NITROGEN DIOXIDE	PATTY 10-20.0				3.0
NITROMETHANE	AIHA 500.0 (ANIMALS)				100.0
1-NITROPROPANE	GRANT 150.0				25.0
2-NITROPROPANE					
NITROTOLUENE					2.0
NONANE					200.0
OCTANE					300.0
OSMIUM TEXTROXIDE				PUNGENT	0.0002
OXYGEN DIFLUORIDE	AIHA > 0.5 (ANIMALS)				
OZONE	GRANT 1.0	GRANT 1.0	GRANT 1.0	SWEET, PUNGENT	0.1
PARACRESOL				TAR LIKE	
PARATHION					
PARAXYLENE				SWEET	
PENTABORANE					0.005
PENTACHLOROETHYLENE					
PENTANE					600.0
2-PENTANONE					
PERCHLOROETHYLENE				CHLORINATED SOLVENT	50.0
PERCHLORYL FLUORIDE					3.0
PHENOL	TLV 48.0	TLV 48.0	TLV 48.0	MEDICINAL	5.0

PAGE -7-	AIHA	LITTLE	ODOR THRESHOLD MAY	NUS	FATTY	SUMMER	TLV	UCB	MISCELLANEOUS
PHENYL ETHER			0.01					0.0012	STERN 0.001
PHENYL ETHER-BIPHENYL VAPOR MIXTURE					1.0		1.0		
PHOSGENE		1.0	0.5	1.0	0.5			3.90	ILO 0.125, THIENES/HALEY 1.0
PHOSPHINE		0.021	0.02		1.5-3.0			0.51	
PHTHALIC ANHYDRIDE								0.053	
PROPANE					20,000.			16,000.	
PROPIONIC ACID								0.16	
N-PROPYL ACETATE								0.67	
PROPYL ALCOHOL			30.0	200.0		30.0		2.6	
N-PROPYL NITRATE							50.0	50.0	
PROPYLENE								76.0	
PROPYLENE DICHLORIDE	23-130.0		50.0					0.25	
PROPYLENE GLYCOL 1-METHYLETHER								10.0	
PROPYLENE OXIDE					200.0			44.0	
PYRIDINE	5.0	0.021	0.013			0.012		0.17	STERN 0.23
QUINONE	0.1							0.084	
STODDARD SOLVENT	1.0		30.0						
STYRENE		0.047	0.08					0.32	
STYRENE MONOMER				200.0					
SULFUR DICHLORIDE		0.001							
SULFUR DIOXIDE		0.47					3-5.0	1.1	
1,1,2,2-TETRACHLOROETHANE					5.0			1.5	
TETRACHLOROETHYLENE			50.0						STERN 50.0
TETRAHYDROFURAN			30.0			30.0		2.0	
TOLUENE		2.14						2.9	ANSI 10-15.0
TOLUENE-2,4-DIISOCYANATE		2.14		2.0				0.17	
O-TOLUIDINE								0.25	MCA 0.0048-7.0
1,2,4-TRICHLOROBENZENE								1.4	
TRICHLOROETHYLENE		21.4						28.0	
1,2,3-TRICHLOROPROPANE							100.0		
1,1,2-TRICHLORO-1,2,2-TRIFLUOROETHANE								0.48	
TRIETHYLAMINE								0.48	
1,3,5-TRIMETHYL BENZENE								0.55	
TRIMETHYL PHOSPHITE								0.00010	
TURPENTINE				200.0	200.0				

PAGE 7-A	IRRITATION LEVEL: EYE	NASAL	THROAT	ODOR	THRESHOLD LIMIT VALUE
PHENYL ETHER	GRANT 3-4.0				1.0
PHENYL ETHER-BIPHENYL VAPOR	GRANT 3-4.0	GRANT 3-4.0	GRANT 3-4.0		
PHOSGENE	AIHA 1-2.0	PATTY 2.0	PATTY>2.0/TLV 3.0	MOLDY, HAY	0.1
PHOSPHINE				GARLIC	0.3
PHTHALIC ANHYDRIDE				MUSTARD, ONION	1.0
PROPANE				NATURAL GAS ODOR	
PROPIONIC ACID				PUNGENT	10.0
N-PROPYL ACETATE					200.0
PROPYL ALCOHOL	AIHA 5500.0	AIHA 5500.0		EHTYL ALCOHOL LIKE	200.0
N-PROPYL NITRATE				ETHEREAL	25.0
PROPYLENE					
PROPYLENE DICHLORIDE				CHLOROFORM LIKE	75.0
PROPYLENE GLYCOL 1-METHYLETHER					100.0
PROPYLENE OXIDE	GRANT 457.0 (ANIMALS)			ETHEREAL	20.0
PYRIDINE				BURNT, NAUSEATING	5.0
QUINONE	AIHA 0.1/GRANT 0.5				0.1
STODDARD SOLVENT	GRANT 400.0				100.0
STYRENE	AIHA 200-400.0			RUBBER, SOLVENTY	
STYRENE MONOMER					50.0
SULFUR DICHLORIDE				SULFIDY, CHLORINE, PUNGENT	
SULFUR DIOXIDE	PATTY 20.0	PATTY 6-12.0	PATTY 6-12.0	SHARP, PUNGENT	2.0
1,1,2,2-TETRACHLOROETHANE					
TETRACHLOROETHYLENE	PATTY 106.0/SPECTOR 206-235.	SPECTOR 513-690.0	SPECTOR 513-690.0		
TETRAHYDROFURAN				SULFUR	200.0
TOLUENE	GRANT 300-400.0			MOTHBALLS	100.0
TOLUENE-2,4-DIISOCYANATE				SHARP, MEDICATED BANDAGE	
O-TOLUIDINE				AROMATIC ANILINE LIKE	
1,2,4-TRICHLOROBENZENE					5.0
TRICHLOROETHYLENE				SOLVENTY, CHLOROFORM LIKE	50.0
1,2,3-TRICHLOROPROPANE	TLV 100.0	TLV 100.0	TLV 100.0	UNPLEASANT	50.0
1,1,2-TRICHLORO-1,2,2-TRIFLUOROETHANE				ODORLESS	1000.0
TRIETHYLAMINE	GRANT 50.0 (ANIMALS)			AMMONIACAL	
1,3,5-TRIMETHYL BENZENE					
TRIMETHYL PHOSPHITE					2.0
TURPENTINE	PATTY 200.0	PATTY 200.0		PINE LIKE	100.0

PAGE -8-	AIHA	LITTLE	MAY	NUS	PATTY	SUMMER	TLV	UCB	MISCELLANEOUS
				ODOR THRESHOLD					
VALERALDEHYDE								0.028	
VINYLACETATE								0.50	
VINYL CHLORIDE								3,000.	
VINYLIDENE CHLORIDE								190.0	
VINYL TOLUENE								10.0	
XYLENE								1.1	
2,4-XYLIDINE			0.0048					0.056	
MERCAPTANS									
ALLYL MERCAPTAN			0.00005						
I-AMYL MERCAPTAN			0.00043						
BENZYL MERCAPTAN									
BUTYL MERCAPTAN								0.00097	
I-BUTYL MERCAPTAN			0.00054						
N-BUTYL MERCAPTAN			0.00082						
CROTYL MERCAPTAN									
ETHYL MERCAPTAN		0.001						0.00076	
METHYL MERCAPTAN		0.0021						0.0016	
I-PENTYL MERCAPTAN			0.00021						
PERCHLOROMETHYL MERCAPTAN								0.00094	

	IRRITATION LEVEL				THRESHOLD
PAGE 8-A	EYE	NASAL	THROAT	ODOR	LIMIT VALUE
VALERALDEHYDE					50.0
VINYLACETATE					10.0
VINYL CHLORIDE				ETHEREAL	
VINYLIDENE CHLORIDE					
VINYL TOLUENE	ILO 50.0	ILO 50.0			50.0
XYLENE	AIHA 200.0	AIHA 200.0	AIHA 200.0		
2,4-XYLIDINE					
MERCAPTANS					
ALLYL MERCAPTAN				GARLIC	
1-AMYL MERCAPTAN					
BENZYL MERCAPTAN					
BUTYL MERCAPTAN					
1-BUTYL MERCAPTAN				SKUNK	
N-BUTYL MERCAPTAN				SKUNK	
CROTYL MERCAPTAN					
ETHYL MERCAPTAN				EARTHY, SULFIDY	0.5
METHYL MERCAPTAN				SULFIDY	0.5
1-PENTYL MERCAPTAN					
PERCHLOROMETHYL MERCAPTAN				SULFIDY	0.1

APPENDIX E

U.S. Government Agencies

OSHA Regional Hazard Communication Coordinators

Region I

Boston Regional Hazard Communication Coordinator
US Department of Labor—OSHA
133 Portland St
Boston, Massachusetts 02114
Comm. Phone: 617-565-7164
FTS Phone: 835-7164

Region II

New York Regional Hazard Communication Coordinator (Acting)
US Department of Labor—OSHA
201 Varick Street, Room 670
New York, New York 10014
Comm. Phone: 212-337-2348
FTS Phone: 660-2348

Region III

Philadelphia Regional Hazard Communication Coordinator
US Department of Labor—OSHA
Gateway Building, Suite 2100
3535 Market Street
Philadelphia, Pennsylvania 19104
Comm. Phone: 215-596-1201
FTS Phone: 596-1201

Region IV

Atlanta Regional Hazard Communication Coordinator
US Department of Labor—OSHA
1375 Peachtree Street, N.E.
Suite 587
Atlanta, Georgia 30367
Comm. Phone: 404-347-3573
FTS Phone 257-2281

Region V

Chicago Regional Hazard Communication Coordinator
US Department of Labor—OSHA
32nd Floor, Room 3244
230 South Dearborn Street
Chicago, Illinois 60604
Comm. Phone: 312-353-2220
FTS Phone: 353-2220

Region VI

Dallas Regional Hazard Communication Coordinator
US Department of Labor—OSHA
525 Griffin Square, Room 602
Dallas, Texas 75202
Comm. Phone: 214-767-4731
FTS Phone: 729-4752

Region VII

Kansas City Regional Hazard Communication Coordinator
US Department of Labor—OSHA
911 Walnut Street, Room 406
Kansas City, Missouri 64106
Comm. Phone: 816-426-5861
FTS Phone: 867-5861

Region VIII

Denver Regional Hazard Communication Coordinator
US Department of Labor—OSHA
Federal Building, Room 1576
1961 Stout Street
Denver, Colorado 80294
Comm. Phone: 303-844-3061
FTS Phone: 564-3061

Region IX

San Francisco Regional Hazard Communication Coordinator
US Department of Labor—OSHA
71 Stevenson Street, Room 415
San Francisco, California 94105
Comm. Phone: 415-995-5672
FTS Phone: 995-5683

Region X

Seattle Regional Hazard Communication Coordinator
US Department of Labor—OSHA
Federal Office Building, Room 6003
909 First Avenue
Seattle, Washington 98174
Comm. Phone: 206-442-5930
FTS Phone: 399-5930

OSHA Regional and Area Offices

Boston — Region I (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont)

Boston Regional Office
Regional Administrator
US Department of Labor—OSHA
133 Portland Street
Boston, Massachusetts 02114
Comm. Phone: 617-565-7164
FTS Phone: 835-7164

Boston Area Office
Regional Administrator
US Department of Labor—OSHA
400-2 Totten Pond Road 2nd Floor
Waltham, Massachusetts 02154
Comm. Phone: 617-647-8681
FTS Phone: 839-7681

Springfield Area Office
Area Director
US Department of Labor—OSHA
1550 Main Street Rm. 532
Springfield, Massachusetts 01103-1493
Comm. Phone: 413-785-0123
FTS Phone: 8365-9123

Concord Area Office
Area Director
US Department of Labor—OSHA
Federal Building Rm. 334
55 Pleasant Street
Concord, New Hampsshire 03301
Comm. Phone: 603-225-1629
FTS Phone: 834-4629

Providence Area Office
Area Director
US Department of Labor—OSHA
Federal Office Building
380 Westminister Mall Rm. 243
Providence, Rhode Island 02903
Comm. Phone: 401-528-4669
FTS Phone: 838-4667

Augusta Area Office
Area Director
US Department of Labor—OSHA
40 Western Avenue Rm. 121
Augusta, Maine 04330
Comm. Phone: 207-622-8417
FTS Phone: 833-6417

Hartford Area Office
Area Director
US Department of Labor—OSHA
Federal Office Building
450 Main Street Rm. 508
Hartford, Connecticut 06103
Comm. Phone: 203-240-3152
FTS Phone: 244-3152

New York City — Region II (New Jersey, New York and Puerto Rico)

New York Regional Office
Regional Administrator
US Department of Labor—OSHA
201 Varick Street Rm. 670
New York, NY 10014
Comm. Phone: 212-337-2378
FTS Phone: 660-2378

Manhattan Area Office
Area Director
US Department of Labor—OSHA
90 Church Street Rm. 1405
New York, New York 10007
Comm. Phone: 212-264-9840
FTS Phone: 264-9840

Long Island Area Office
Area Director
US Department of Labor—OSHA
990 Westbury Road
Westbury, New York 11590
Comm. Phone: 516-334-3344
FTS Phone: 265-2909

Queens Area Office
Area Director
US Department of Labor—OSHA
42-40 Bell Blvd 5th Floor
Bayside, New York 11361
Comm. Phone: 718-297-9060/9050
FTS Phone: None

Albany Area Office
Area Director
US Department of Labor—OSHA
Leo W. O'Brien Federal Building
Clinton Avenue & North Pearl Street Rm. 132
Albany, New York 12207
Comm. Phone: 518-472-6085
FTS Phone: 562-6085

Syracuse Area Office
Area Director
US Department of Labor—OSHA
100 South Clinton Street Rm. 1267
Syracuse, New York 13260
Comm. Phone: 315-423-5188
FTS Phone: 950-5188

Buffalo Area Office
Area Director
US Department of Labor—OSHA
5360 Genesee Street
Bowmansville, New York 14026
Comm. Phone: 716-684-3891/4018
FTS Phone: 684-3896

Puerto Rico Area Office
Area Director
US Department of Labor—OSHA
US Courthouse & FOB
Carlos Chardon Avenue Rm. 555
Hato Rey, Puerto Rico 00918
Comm. Phone: 809-753-4457/4072
FTS Phone: 753-4457

Hasbrouck Heights Area Office
Area Director
US Department of Labor—OSHA
Teterboro Airport Professional Building
500 Route 17 Rm. 206
Hasbrouck Heights, New Jersey 07604
Comm. Phone: 201-288-1700
FTS Phone: None

Avenel Area Office
Area Director
US Department of Labor—OSHA
Plaza 35 (Suite 205)
1030 Saint Georges Avenue
Avenel, New Jersey 07001
Comm. Phone: 201-750-3270
FTS Phone: 750-3270

Camden Area Office
Area Director
US Department of Labor—OSHA
Marlton Executive Park
701 Route 73 South, Bldg. 2
Marlton, New Jersey 08053
Comm. Phone: 609-757-5181
FTS Phone: 488-5181

Dover Area Office
Area Director
US Department of Labor—OSHA
2 East Blackwell Street
Dover, New Jersey 07801
Comm. Phone: 201-361-4050
FTS Phone: None

Philadelphia — Region III (Delaware, District of Columbia, Maryland, Pennsylvania, Virginia and West Virginia)

Philadelphia Regional Office
Regional Administrator
US Department of Labor—OSHA
Gateway Building Suite 2100
3535 Market Street
Philadelphia, Pennsylvania 19104
Comm. Phone: 215-596-1201
FTS Phone: 596-1201

Philadelphia Area Office
Area Director
US Department of Labor—OSHA
US Custom House Rm. 242
Second & Chestnut Street
Philadelphia, Pennsylvania 19106
Comm. Phone: 215-597-4955
FTS Phone: 597-4955

Division of 11(c) Programs
Supervisory Investigator
US Department of Labor—OSHA
Liberty Square 5th Floor
105 South 7th Street
Philadelphia, Pennsylvania 19106
Comm. Phone: 215-597-8064
FTS Phone: 597-8064

Pittsburgh Area Office
Area Director
US Department of Labor—OSHA
Federal Building Rm. 2236
1000 Liberty Avenue
Pittsburgh, Pennsylvania 15522
Comm. Phone: 412-644-2903
FTS Phone: 722-2903

Erie Area Office
Area Director
US Department of Labor—OSHA
3939 W. Ridge Rd., Suite B-12
Erie, Pennsylvania 16506
Comm. Phone: 814-833-5758

Wilkes-Barre Area Office
Area Director
US Department of Labor—OSHA
Penn Place Rm. 2005
20 North Pennsylvania Avenue
Wilkes-Barre, Pennsylvania 18701
Comm. Phone: 717-826-6538
FTS Phone: 592-6538

Allentown District Office
District Supervisor
US Department of Labor—OSHA
850 N. 5th Street
Allentown, Pennsylvania 18102
Comm. Phone: 215-776-4220
FTS Phone: 346-4220

Harrisburg Area Office
Area Director
US Department of Labor—OSHA
Progress Plaza
49 North Progress Street
Harrisburg, Pennsylvania 17109
Comm. Phone: 717-782-3902
FTS Phone: 590-3902

Wilmington District Office
District Supervisor
US Department of Labor—OSHA
Federal Office Building Rm. 1414
844 King Street
Wilmington, Delaware 19801
Comm. Phone: 302-573-6115
FTS Phone: 487-6115

Charleston Area Office
Area Director
US Department of Labor—OSHA
550 Eagan Street Rm. 206
Charleston, West Virginia 25301
Comm. Phone: 304-347-5937
FTS Phone: 903-5937

Baltimore Area Office
Area Director
US Department of Labor—OSHA
Federal Building Rm. 1110
Charles Center 31 Hopkins Plaza
Baltimore, Maryland 21201
Comm. Phone: 301-952-2840
FTS Phone: 922-2840

Norfolk District Office
District Supervisor
US Department of Labor—OSHA
Federal Office Building Rm. 835
200 Granby Mall
Mail Drawer 486
Norfolk, Virginia 23510
Comm. Phone: 804-441-3820
FTS Phone: 827-3820

Atlanta — Region IV (Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina and Tennessee)

Atlanta Regional Office
Regional Administrator
US Department of Labor—OSHA
1375 Peachtree Street, N.E., Suite 587
Atlanta, Georgia 30367
Comm. Phone: 404-347-3573
FTS Phone: 257-3573/2281

Atlanta Area Office
Area Director
US Department of Labor—OSHA
Building 10 Suite 33
LaVista Perimeter Office Park
Tucker, Georgia 30084
Comm. Phone: 404-331-4767/0353
FTS Phone: 242-4767

Savannah District Office
District Supervisor
US Department of Labor—OSHA
1600 Drayton Street
Savannah, Georgia 31401
Comm. Phone: 912-944-4393
FTS Phone: 248-4393

Birmingham Area Office
Area Director
US Department of Labor—OSHA
Todd Mall
2047 Canyon Road
Birmingham, Alabama 35216
Comm. Phone: 205-731-1534
FTS Phone: 229-1541

Mobile Area Office
Area Director
US Department of Labor—OSHA
3737 Government Blvd., Suite 100
Mobile, Alabama 36693
Comm. Phone: 205-690-2131
FTS Phone: 537-2131

Raleigh Area Office
Area Director
US Department of Labor—OSHA
Century Station Rm. 104
300 Fayetteville Street Mall
Raleigh, North Carolina 27601
Comm. Phone: 919-856-4770
FTS Phone: 672-4770

Columbia Area Office
Area Director
US Department of Labor—OSHA
1835 Assembly Street Rm. 29201
Columbia, South Carolina 29201
Comm. Phone: 803-765-5904
FTS Phone: 677-5904

Jackson Area Office
Area Director
US Department of Labor—OSHA
Federal Building Suite 1445
100 West Capitol Street
Jackson, Mississippi 39269
Comm. Phone: 601-965-4606
FTS Phone: 490-4606

Fort Lauderdale Area Office
Area Director
US Department of Labor—OSHA
Federal Building Rm. 302
299 East Broward Boulevard
Fort Lauderdale, Florida 33301
Comm. Phone: 305-527-7292
FTS Phone: 820-7292

Jacksonville Area Office
Area Director
US Department of Labor—OSHA
3100 University Blvd. South, Rm. 303
Jacksonville, Florida 32216
Comm. Phone: 904-791-2895
FTS Phone: 946-2895

Tampa Area Office
Area Director
US Department of Labor—OSHA
700 Twiggs Street Rm. 624
Tampa, Florida 33602
Comm. Phone: 813-228-2821
FTS Phone: 826-2821

Nashville Area Office
Area Director
US Department of Labor—OSHA
2002 Richard Jones Road Suite C-205
Nashville, Tennessee 37215
Comm. Phone: 615-736-5313
FTS Phone: 852-5313

Frankfort Area Office
Area Director
US Department of Labor—OSHA
John C. Watts Federal Building Rm. 108
330W Broadway
Frankfort, Kentucky 40601
Comm. Phone: 502-227-7024
FTS Phone: None

Chicago — Region V (Indiana, Illinois, Michigan, Minnesota, Ohio and Wisconsin)

Chicago Regional Office
Regional Administrator
US Department of Labor—OSHA
32nd Floor Rm. 3244
230 South Dearborn Street
Chicago, Illinois 60604
Comm. Phone: 312-353-2220
FTS Phone: 353-2220

Calumet City Area Office
Area Director
US Department of Labor—OSHA
1600 167th Street Suite 12
Calumet City, Illinois 60409
Comm. Phone: 312-891-3800
FTS Phone: 886-9887

Niles Area Office
Area Director
US Department of Labor—OSHA
6000 West Touhy Avenue
Niles, Illinois 60648
Comm. Phone: 312-631-8200
FTS Phone: None

Aurora Area Office
Area Director
US Department of Labor—OSHA
344 Smoke Tree Business Park
North Aurora, Illinois 60542
Comm. Phone: 312-896-8700
FTS Phone: 886-7713

Peoria Area Office
US Department of Labor—OSHA
2001 West Willow Knolls Road Suite #101
Peoria, Illinois 61614-1223
Comm. Phone: 309-671-7033
FTS Phone: 360-7033

Belleville District Office
District Supervisor
US Department of Labor—OSHA
218A West Main Street
Belleville, Illinois 62220
Comm. Phone: 618-277-5300
FTS Phone: None

Cincinnati Area Office
Area Director
US Department of Labor—OSHA
Federal Office Building Rm. 4028
550 Main Street
Cincinnati, Ohio 45202
Comm. Phone: 513-684-3784
FTS Phone: 684-3784

Cleveland Area Office
Area Director
US Department of Labor—OSHA
Federal Office Building Rm. 899
1240 East 9th Street
Cleveland, Ohio 44199
Comm. Phone: 216-522-3818
FTS Phone: 942-3818

Columbus Area Office
Area Director
US Department of Labor—OSHA
Federal Office Building Rm. 634
200 North High Street
Columbus, Ohio 43215
Comm. Phone: 614-469-5582
FTS Phone: 943-5582

Toledo Area Office
Area Director
US Department of Labor—OSHA
Federal Office Building Rm. 734
234 North Summit Street
Toledo, Ohio 43604
Comm. Phone: 419-259-7542
FTS Phone: 979-7542

Indianapolis Area Office
Area Director
US Department of Labor—OSHA
46 East Ohio Street Rm. 423
Indianapolis, Indiana 46204
Comm. Phone: 317-269-7290
FTS Phone: 331-7290

Minneapolis Area Office
Area Director
US Department of Labor—OSHA
110 South 4th Street Rm. 425
Minneapolis, Minnesota 55401
Comm. Phone: 612-348-1994
FTS Phone: 777-1994

Lansing Area Office
Area Director
US Department of Labor—OSHA
300 East Michigan Ave. Rm. 305
Lansing, Michigan 48933
Comm. Phone: 517-377-1892
FTS Phone: 374-1892

Appleton Area Office
Area Director
US Department of Labor—OSHA
2618 North Ballard Road
Appleton, Wisconsin 54915
Comm. Phone: 414-734-4521
FTS Phone: None

Milwaukee Area Office
Area Director
US Department of Labor—OSHA
310 West Wisconsin Avenue, Suite 1180
Milwaukee, Wisconsin 53203
Comm. Phone: 414-291-3315
FTS Phone: 362-3315

Madison Area Office
Area Director
US Department of Labor—OSHA
2934 Fish Hatchery Road, Suite 225
Madison, Wisconsin 53713
Comm. Phone: 608-264-5388
FTS Phone: 364-5388

Eau Claire District Office
District Supervisor
US Department of Labor—OSHA
Federal Building US Courthouse
500 Barstow Street Rm. B-9
Eau Claire, Wisconsin 54701
Comm. Phone: 715-832-9019
FTS Phone: None

Dallas — Region VI (Arkansas, Louisiana, New Mexico, Oklahoma and Texas)

Dallas Regional Office
Regional Administrator
US Department of Labor—OSHA
525 Griffin Street Rm. 602
Dallas, Texas 75202
Comm. Phone: 214-767-4731
FTS Phone: 729-4731

Dallas Area Office
Area Director
US Department of Labor—OSHA
8344 East R.L. Thornton Freeway, Suite 42
Dallas, Texas 75228
Comm. Phone: 214-259-6683
FTS Phone: 729-5347

Corpus Christi Area Office
Area Director
US Department of Labor—OSHA
Government Plaza Rm. 300
400 Mann Street
Corpus Christi, Texas 78401
Comm. Phone: 512-888-3257
FTS Phone: 529-3257

Austin Area Office
Area Director
US Department of Labor—OSHA
611 East 6th Street Rm. 303
Austin, Texas 78701
Comm. Phone: 512-482-5783
FTS Phone: 770-5783

Lubbock Area Office
Area Director
US Department of Labor—OSHA
Federal Building Rm. 421
1205 Texas Avenue
Lubbock, Texas 79401
Comm. Phone: 806-743-7681
FTS Phone: 738-7681

Houston Area Office
Area Director
US Department of Labor—OSHA
2320 LaBranch Street Rm. 1103
Houston, Texas 77004
Comm. Phone: 713-750-1727
FTS Phone: 526-6727

Fort Worth Area Office
Area Director
US Department of Labor—OSHA
Texas Commerce Bank Bldg. Suite 401
860 W. Airport Freeway
Hurst, Texas 76054
Comm. Phone: 817-581-7303
FTS Phone: 581-7025

Little Rock Area Office
Area Director
US Department of Labor—OSHA
Savers Building Suite 828
320 West Capitol Avenue
Little Rock, Arkansas 72201
Comm. Phone: 501-378-6291
FTS Phone: 740-6291

Baton Rouge Area Office
Area Director
US Department of Labor—OSHA
Hoover Annex Suite 200
2156 Wooddale Boulevard
Baton Rouge, Louisiana 70806
Comm. Phone: 504-389-0474
FTS Phone: 687-0474

Albuquerque Area Office
Area Director
US Department of Labor—OSHA
320 Central Avenue, S.W., Suite 13
Albuquerque, New Mexico 87102
Comm. Phone: 505776-3411
FTS Phone: 474-3411

Oklahoma City Area Office
Area Director
Main Place
420 West Main Suite 725
Oklahoma City, Oklahoma 73102
Comm. Phone: 405-231-5351
FTS Phone: 736-5351

Kansas City — Region VII (Iowa, Kansas, Missouri and Nebraska)

Kansas City Regional Office
Regional Administrator
US Department of Labor—OSHA
911 Qalnut Street Rm. 406
Kansas City, Missouri 64106
Comm. Phone: 816-426-5861
FTS Phone: 867-5861

Kansas City Area Office
Area Director
US Department of Labor—OSHA
911 Walnut Street Rm. 2202
Kansas City, Missouri 64106
Comm. Phone: 816-426-2756
FTS Phone: 867-2756

St. Louis Area Office
Area Director
US Department of Labor—OSHA
4300 Goodfellow Boulevard—Building 105E
St. Louis, Missouri 63120
Comm. Phone: 314-263-2749
FTS Phone: 273-2749

Des Moines Area Office
Area Director
US Department of Labor—OSHA
210 Walnut Street Rm. 815
Des Moines, Iowa 50309
Comm. Phone: 515-284-4794
FTS Phone: 862-4794

Omaha Area Office
Area Director
US Department of Labor—OSHA
Overland—Wolf Building Rm. 100
6910 Pacific Street
Omaha, Nebraska 68106
Comm. Phone: 402-221-3182
FTS Phone: 864-3182

Wichita Area Office
Area Director
US Department of Labor—OSHA
216 North Waco Suite B
Wichita, Kansas 67202
Comm. Phone: 316-269-6644
FTS Phone: 752-6644

Denver — Region VIII (Colorado, Montana, North Dakota, South Dakota, Utah and Wyoming)

Denver Regional Office
Regional Administrator
US Department of Labor—OSHA
Federal Building Rm. 1576
1961 Stout Street
Denver, Colorado 80294
Comm. Phone: 303-844-3061
FTS Phone: 564-3061

Denver Area Office
Area Director
US Department of Labor—OSHA
1244 Speer Blvd., Suite 360
Denver, Colorado 80204
Comm. Phone: 303-844-5285
FTS Phone: 564-5285
Toll Free: 1-800-332-5858

Billings Area Office
Area Director
US Department of Labor—OSHA
19 North 25th Street
Billings, Montana 59101
Comm. Phone: 406-657-6649
FTS Phone: 585-6649
Toll Free: 1-800-332-7087

Bismarck Area Office
Area Director
US Department of Labor—OSHA
Federal Building Rm. 348
PO Box 2439
Bismarck, North Dakota 58502
Comm. Phone: 701-255-6690
FTS Phone: 783-4521

Salt Lake City Area Office
Area Office
US Department of Labor—OSHA
1781 South 300 West
Salt Lake City, Utah 84115
Comm. Phone: 801-524-5082
FTS Phone: 588-5082

San Francisco — Region IX (Arizona, California, Hawaii, Nevada)

San Francisco Regional Office
Regional Administrator
US Department of Labor—OSHA
71 Stevenson Street Rm. 415
San Francisco, California 94105
Comm. Phone: 415-995-5672
FTS Phone: 995-5672

Long Beach Area Office
Area Director
US Department of Labor—OSHA
400 Oceangate Suite 530
Long Beach, California 90802
Comm. Phone: 213-514-6387
FTS Phone: 795-6387

Sacramento Area Office
Area Director
US Department of Labor—OSHA
2422 Arden Way Suite A-1
Sacramento, California 95825
Comm. Phone: 916-646-9220
FTS Phone: None

San Diego Area Office
Area Director
US Department of Labor—OSHA
9619 Chesapeake Dr. Suite 300
San Diego, California 92123
Comm. Phone: 619-569-9071
FTS Phone: None

Walnut Creek Area Office
Area Director
US Department of Labor—OSHA
801 Ygnacio Valley Road, Suite 205
Walnut Creek, California 94596-3823
Comm. Phone: 415-943-1973
FTS Phone: None

West Covina Area Office
Area Director
US Department of Labor—OSHA
100 N. Citrus Avenue, Suite 240
(Coast Savings Building)
West Covina, California 91791
Comm. Phone: 818-915-1558
FTS Phone: None

Los Angeles Area Office
Area Director
US Department of Labor—OSHA
3325 Wilshire Blvd. Suite 601
Los Angeles, California 90010
Comm. Phone: 213-252-7829
FTS Phone: 983-7829

San Jose Area Office
Area Director
US Department of Labor—OSHA
950 Bascom Suite 3120
San Jose, California 95128
Comm. Phone: 408-291-4600
FTS Phone: 466-4600

Phoenix Area Office
Area Director
US Department of Labor—OSHA
3221 North 16th Street Suite 100
Phoenix, Arizona 85016
Comm. Phone: 602-241-2007
FTS Phone: 261-2007

Honolulu Area Office
Area Director
US Department of Labor—OSHA
300 Ala Moana Boulevard Suite 5122
PO Box 50072
Honolulu, Hawaii 96850
Comm. Phone: 808-541-2685
FTS Phone: 551-2685

Seattle — Region X (Alaska, Idaho, Oregon and Washington)

Seattle Regional Office
Regional Administrator
US Department of Labor—OSHA
Federal Office Building Rm. 6003
9091st Avenue
Seattle, Washington 98174
Comm. Phone: 206-442-5930
FTS Phone: 399-5930

Bellevue Area Office
Area Director
US Department of Labor—OSHA
121 — 107th Avenue, N.E.
Bellevue, Washington 98004
Comm. Phone: 206-442-7520
FTS Phone: 399-7520

Anchorage Area Office
Area Director
US Department of Labor—OSHA
Federal Building F210
701 C Street Box 29
Anchorage, Alaska 99513
Comm. Phone: 097-271-5152
FTS Phone: None

Boise Area Office
Area Director
US Department of Labor—OSHA
Room 324, Federal Building/USCH
550 West Fort Street, Box 007
Boise, Idaho 83724
Comm. Phone: 208-334-1867
FTS Phone: 554-1867

Portland Area Office
Area Director
US Department of Labor—OSHA
1220 Southwest 3rd Avenue Rm. 640
Portland, Oregon 97204
Comm. Phone: 503-221-2251
FTS Phone: 423-2251

Other Relevant Addresses

OSHA Training Institute
(Training and education)
Director
Office of Training and Education
US Department of Labor
1555 Times Drive
Des Plaines, Illinois 60018
312-297-4810

Cincinnati Laboratory
(Technical equipment calibratiion and repair)
Director
OSHA Cincinnati Laboratory
USPO Building, Rm. 108
5th & Walnut Streets
Cincinnati, Ohio 45202
513-684-2531

Salt Lake City Laboratory
(Chemical analyses of monitoring samples)
Director
SLC Analytical Laboratory
Chemical Analyses of Monitoring Samples
P.O. Box 15200
1781 South 300 West
Salt Lake City, Utah 84115
801-524-5287

Health Response Unit, SLC
(Health and industrial hygiene assistance)
Director
Health Response Unit—OSHA
P.O. Box 15200
1781 South 300 West
Salt Lake City, Utah 84115
801-524-5896

Organization and Administration of NIOSH

To address health and safety problems of American workers, NIOSH employs trained scientists: physicians, nurses, engineers with various specialities, chemists, physicists, industrial hygienists, epidemiologists, toxicologists, behavioral scientists, ergonomists, psychologists, and sociologists, as well as statisticians, educational specialists, and writers.

NIOSH has offices in four locations: headquarters at the CDC facility in Atlanta, Ga.; a liaison office in Washington, D.C.; and laboratories in Morgantown, W.Va., and Cincinnati, Ohio. NIOSH industrial hygienists are also assigned to U.S. Public Health Service regional offices in Atlanta, Boston and Denver.

NIOSH Headquarters
Building 1, Room 3007
Centers for Disease Control
1600 Clifton Road
Atlanta, Georgia 30333
(404) 639-3061

NIOSH Washington Office
200 Independence Ave. SW
Washington, DC 20201
(202) 472-7134

Appalachian Laboratories
944 Chestnut Ridge Rd.
Morgantown, WV 26505-2888

Div of Respiratory Disease Studies
Studies of occupational respiratory diseases; mandated medical examinations of coal miners.
(304) 291-4474

Div of Safety Research
Respirator certifications; surveillance and studies to reduce musculoskeletal and traumatic work-related injuries and death.
(304) 291-4595

Cincinnati Laboratories
4676 Columbia Parkway
Cincinnati, OH 45226-1998

Robert A. Taft Laboratories

Div of Biomedical & Behavioral Science
Laboratory and worksite studies on toxicology, ergonomics, stress, and effects of physical agents.
(513) 533-8465

Div of Standards Development & Technology Transfer
NIOSH scientific policy development; clearinghouse of technical information on occupational safety and health.
(513) 533-8302

Div of Training & Manpower Development
Training and education programs for occupational health and safety personnel.
(513) 533-8221

Alice Hamilton Laboratories

Div of Physical Sciences & Engineering
Analytic support for research; methods/equipment to control and measure occupational health hazards.
(513) 841-4321

Div of Surveillance, Hazard Evaluations & Field Studies
Surveillance and industry-wide studies; health hazard evaluations and technical assistance on request.
(513) 841-4428

ENVIRONMENTAL PROTECTION AGENCY REGIONAL OFFICES

Region I
(CT, MA, ME, NH, RI, VT)
John F. Kennedy Federal Building
Boston, MA 02203
Telephone: (617) 565-3424

Region II
(NJ, NY, Puerto Rico, Virgin Islands)
26 Federal Plaza
New York, NY 10278
Telephone: (212) 264-2515

Region III
(DC, DE, MD, PA, VA, WV)
841 Chestnut Street
Philadelphia, PA 19107
Telephone: (215) 597-9370

Region IV
(AL, FL, GA, KY, MS, NC, SC, TN)
345 Courtland Street, N.E.
Atlanta, GA 30365
Telephone: (404) 374-3004

Region V
(IL, IN, MI, MN, OH, WI)
230 E. Dearborn Street
Chicago, IL 60604
Telephone: (312) 353-2072

Region VI
(AR, LA, NM, OK, TX)
1445 Ross Avenue
Dallas, TX 75202
Telephone: (214) 655-2200

Region VII
(IA, KS, MO, NE)
726 Minnesota Avenue
Kansas City, KS 66101
Telephone: (913) 236-2803

Region VIII
(CO, MT, ND, SD, UT, WY)
999-18th Street
Denver, CO 80202
Telephone: (303) 293-1692

Region IX
(American Samoa, AZ, CA, Guam, HI, NV, Pacific Trust Territories)
215 Fremont Street
San Francisco, CA 94105
Telephone: (415) 974-8083

Region X
(AK, ID, OR, WA)
1200 6th Avenue
Seattle, WA 98101
Telephone: (206) 442-1465

APPENDIX F

Material Safety Data Sheet (MSDS)*

Introduction

The Material Safety Data Sheet (MSDS) is a detailed information bulletin prepared by the manufacturer or importer of a chemical that describes the physical and health hazards, routes of exposure, precautions for safe handling and use, emergency and first-aid procedures, and control measures. Information on an MSDS aids in the selection of safe products and helps prepare employers and employees to respond effectively to daily exposure situations as well as to emergency situations.

The MSDS's are a comprehensive source of information for all types of employers. There may be information on the MSDS that is useful to you or not important to the safety and health in your particular operation. Concentrate on the information that is applicable to your situation. Generally, hazard information and protective measures should be the focus of concern.

This kit contains a glossary of terms used on MSDS's. Some employers who are not very familiar with chemical terminology may find this helpful in reading and understanding MSDS's.

OSHA Requirements

Employers must maintain a complete and accurate MSDS for each hazardous chemical that is used in the facility. They are entitled to obtain this information automatically upon purchase of the material. When new and significant information becomes available concerning a product's hazards or ways to protect against the hazards, chemical manufacturers importers, or distributors must add it to their MSDS within three months and provide it to their customers with the next shipment of the chemical. Employers must have an MSDS for each hazardous chemical used in the workplace. If there are multiple suppliers of the same chemical, there is no need to retain multiple MSDS's for that chemical.

While MSDS's are not required to be physically attached to a shipment, they must accompany or precede the shipment. When the manufacturer/supplier fails to send an MSDS with a shipment labeled as a hazardous chemical, the employer must obtain one from the chemical manufacturer, importer, or distributor as soon as possible. Similarly, if the MSDS is incomplete or unclear, the employer should contact the manufacturer or importer to get clarification or obtain missing information.

When an employer is unable to obtain an MSDS from a supplier or manufacturer, he/she should submit a written complaint, with complete background information, to the nearest OSHA area office. OSHA will then, at the same time, call and send a certified letter to the supplier or manufacturer to obtain the needed information. If the supplier or manufacturer still fails to respond within a reasonable time, OSHA will inspect the supplier or manufacturer and take appropriate enforcement action.

Section of an MSDS and Their Significance

OSHA specifies the information to be included on an MSDS, but does not prescribe the precise format for an MSDS. A non-mandatory MSDS form (see blank OSHA Form 174 at the end of this section) that meets the Hazard Communication Standard requirements has been issued and can be used as is or expanded as needed. The MSDS must be in English and must include at least the following information.

Section I. Chemical Identity

- The chemical and common name(s) must be provided for single chemical substances.

- An identity on the MSDS must be cross-referenced to the identity found on the label.

Section II. Hazardous Ingredients

- For a hazardous chemical mixture that has been tested as a whole to determine its hazards, the chemical and common names of the ingredients that are associated with the hazards, and the common name of the mixture must be listed.

- If the chemical is a mixture that has not been tested as a whole, the chemical and common names of all ingredients determined to be health hazards and comprising 1 percent or greater of the composition must be listed.

- Chemical and common names of carcinogens must be listed if they are present in the mixture at levels of 0.1 percent or greater.

*This information in Appendix F is a portion of the following source: U.S. Department of Labor: "Hazard Communication—A Compliance Kit," Publ. No. OSHA 3104. Washington, DC (1988).

- All components of a mixture that have been determined to present a physical hazard must be listed.

- Chemical and common names of all ingredients determined to be health hazards and comprising less than 1 percent (0.1 percent for carcinogens) of the mixture must also be listed if they can still exceed an established Permissible Exposure Limit (PEL) or Threshold Limit Value (TLV) or present a health risk to exposed employees in these concentrations.

Section III. Physical and Chemical Characteristics

- The physical and chemical characteristics of the hazardous substance must be listed. These include items such as boiling and freezing points, density, vapor pressure, specific gravity, solubility, volatility, and product's general appearance and odor. These characteristics provide important information for designing safe and healthful work practices.

Section IV. Fire and Explosion Hazard Data

- The compound's potential for fire and explosion must be described. Also, the fire hazards of the chemical and the conditions under which it could ignite or explode must be identified. Recommended extinguishing agents and fire-fighting methods must be described.

Section V. Reactivity Data

- This section presents information about other chemicals and substances with which the chemical is incompatible, or with which it reacts. Information on any hazardous decomposition products, such as carbon monoxide, must be included.

Section VI. Health Hazards

- The acute and chronic health hazards of the chemical, together with signs and symptoms of exposure, must be listed. In addition, any medical conditions that are aggravated by exposure to the compound, must be included. The specific types of chemical health hazards defined in the standard include carcinogens, corrosives, toxins, irritants, sensitizers, mutagens, teratogens, and effects on target organs (i.e., liver, kidney, nervous system, blood, lungs, mucous membranes, reproductive system, skin, eyes, etc.).

- The route of entry section describes the primary pathway by which the chemical enters the body. There are three principal routes of entry: inhalation, skin, and ingestion.

- This section of the MSDS supplies the OSHA PEL, the ACGIH TLV, and other exposure levels used or recommended by the chemical manufacturer.

- If the compound is listed as a carcinogen (cancer-causing agent) by OSHA, the National Toxicology Program (NTP), or the International Agency for Research on Cancer (IARC), this information must be indicated on the MSDS.

Section VII. Precautions for Safe Handling and Use

- The standard requires the preparer to describe the precautions for safe handling and use. These include recommended industrial hygiene practices, precautions to be taken during repair and maintenance of equipment, and procedures for cleaning up spills and leaks. Some manufacturers also use this section to include useful information not specifically required by the standard, such as EPA waste disposal methods and state and local requirements.

Section VIII. Control Measures

- The standard requires the preparer of the MSDS to list any generally applicable control measures. These include engineering controls, safe handling procedures, and personal protective equipment. Information is often included on the use of goggles, gloves, body suits, respirators, and face shields.

Employer Responsibilities

Employers must ensure that each employee has basic knowledge of how to find information on an MSDS and how to properly make use of that information. Employers also must ensure the following:

- Complete and accurate MSDS's are made available during each work shift to employees when they are in their work areas.

- Information is provided for each hazardous chemical.

Material Safety Data Sheet

May be used to comply with OSHA's Hazard Communication Standard, 29 CFR 1910.1200. Standard must be consulted for specific requirements.

U.S. Department of Labor
Occupational Safety and Health Administration
(Non-Mandatory Form)
Form Approved
OMB No. 1218-0072

IDENTITY *(As Used on Label and List)*	*Note: Blank spaces are not permitted. If any item is not applicable, or no information is available, the space must be marked to indicate that.*

Section I

Manufacturer's Name	Emergency Telephone Number
Address *(Number, Street, City, State, and ZIP Code)*	Telephone Number for Information
	Date Prepared
	Signature of Preparer *(optional)*

Section II — Hazardous Ingredients/Identity Information

Hazardous Components (Specific Chemical Identity; Common Name(s))	OSHA PEL	ACGIH TLV	Other Limits Recommended	% *(optional)*

Section III — Physical/Chemical Characteristics

Boiling Point		Specific Gravity (H_2O = 1)	
Vapor Pressure (mm Hg.)		Melting Point	
Vapor Density (AIR = 1)		Evaporation Rate (Butyl Acetate = 1)	
Solubility in Water			
Appearance and Odor			

Section IV — Fire and Explosion Hazard Data

Flash Point (Method Used)	Flammable Limits	LEL	UEL
Extinguishing Media			
Special Fire Fighting Procedures			
Unusual Fire and Explosion Hazards			

(Reproduce locally)

OSHA 174, Sept. 1985

Section V — Reactivity Data

Stability	Unstable		Conditions to Avoid
	Stable		

Incompatibility (*Materials to Avoid*)

Hazardous Decomposition or Byproducts

Hazardous Polymerization	May Occur		Conditions to Avoid
	Will Not Occur		

Section VI — Health Hazard Data

Route(s) of Entry: Inhalation? Skin? Ingestion?

Health Hazards (*Acute and Chronic*)

Carcinogenicity: NTP? IARC Monographs? OSHA Regulated?

Signs and Symptoms of Exposure

Medical Conditions
Generally Aggravated by Exposure

Emergency and First Aid Procedures

Section VII — Precautions for Safe Handling and Use

Steps to Be Taken in Case Material Is Released or Spilled

Waste Disposal Method

Precautions to Be Taken in Handling and Storing

Other Precautions

Section VIII — Control Measures

Respiratory Protection (*Specify Type*)

Ventilation	Local Exhaust	Special
	Mechanical (*General*)	Other

Protective Gloves	Eye Protection

Other Protective Clothing or Equipment

Work/Hygienic Practices

Material Safety Data Sheet Checklist

You must ensure that each MSDS contains the following information:

1. Product or chemical identity used on the label. ______
2. Manufacturer's name and address. ______
3. Chemical and common names of each hazardous ingredient. ______
4. Name, address, and phone number for hazard and emergency information. ______
5. Preparation or revision date. ______
6. The hazardous chemical's physical and chemical characteristics, such as vapor pressure and flashpoint. ______
7. Physical hazards, including the potential for fire, explosion, and reactivity. ______
8. Known health hazards. ______
9. OSHA permissible exposure limit (PEL), ACGIH threshold limit value (TLV), or other exposure limits. ______
10. Emergency and first-aid procedures. ______
11. Whether OSHA, NTP† or IARC‡ lists the ingredient as a carcinogen. ______
12. Precautions for safe handling and use. ______
13. Control measures such as engineering controls, work practices, hygienic practices or personal protective equipment required. ______
14. Primary routes of entry. ______
15. Procedures for spills, leaks, and clean-up. ______

†National Toxicology Program.
‡International Agency for Research on Cancer.

MSDS Glossary

MSDS Glossary

The following glossary presents brief explanations of acronyms and common terms frequently used by chemical manufacturers in their MSDS's.

ACGIH American Conference of Governmental Industrial Hygienists is an organization of professional personnel in governmental agencies or educational institutions engaged in occupational safety and health programs. ACGIH establishes recommended occupational exposure limits for chemical substances and physical agents. See TLV.

Acid Any chemical that undergoes dissociation in water with the formation of hydrogen ions. Acids have a sour taste and may cause severe skin burns. Acids turn litmus paper red and have pH values of 0 to 6.

Acute Effect Adverse effect on a human or animal that has severe symptoms developing rapidly and coming quickly to a crisis.

Acute Toxicity Acute effects resulting from a single dose of, or exposure to, a substance. Ordinarily used to denote effects in experimental animals.

Adenocarcinoma A tumor with glandular (secreting) elements.

Adenosis Any disease of a gland.

Adhesion A union of two surfaces that are normally separate.

Aerosol A fine aerial suspension of particles sufficiently small in size to confer some degree of stability from sedimentation (e.g., smoke or fog).

Air-Line Respirator A respirator that is connected to a compressed breathable air source by a hose of small inside diameter. The air is delivered continuously or intermittently in a sufficient volume to meet the wearer's breathing requirements.

Air-Purifying Respirator A respirator that uses chemicals to remove specific gases and vapors from the air or that uses a mechanical filter to remove particulate matter. An air-purifying respirator must only be used when there is sufficient oxygen to sustain life and the air contaminant level is below the concentration limits of the device.

Alkali Any chemical substance that forms soluble soaps with fatty acids. Alkalis are also referred to as bases. They may cause severe burns to the skin. Alkalis turn litmus paper blue and have pH values from 8 to l4.

Allergic Reaction An abnormal physiological response to chemical or physical stimuli.

Amenorrhea Absence of menstruation.

Anesthetic A chemical that causes a total or partial loss of sensation. Overexposure to anesthetics can cause impaired judgment, dizziness, drowsiness, headache, unconsciousness, and even death. Examples include alcohol, paint remover, and degreasers.

ANSI American National Standards Institute is a privately funded, voluntary membership organization that identifies industrial and public needs for national consensus standards and coordinates development of such standards.

Antidote A remedy to relieve, prevent, or counteract the effects of a poison.

API American Petroleum Institute is a organization of the petroleum industry.

Appearance A description of a substance at normal room temperature and normal atmospheric conditions. Appearance includes the color, size, and consistency of a material.

Aquatic Toxicity The adverse effects to marine life that result from being exposed to a toxic substance.

Asphyxiant A vapor or gas that can cause unconsciousness or death by suffocation (lack of oxygen). Most simple asphyxiants are harmful to the body only when they become so concentrated that they reduce oxygen in the air (normally about 21 percent) to dangerous levels (18 percent or lower). Asphyxiation is one of the principal potential hazards of working in confined and enclosed spaces.

ASTM American Society for Testing and Materials is the world's largest source of voluntary consensus standards for materials, products, systems, and services. ASTM is a resource for sampling and testing methods, health and safety aspects of materials, safe performance guidelines, effects of physical and biological agents and chemicals.

Asymptomatic Showing no symptoms.

Atm Atmosphere, a unit of pressure equal to 760 mmHg (mercury) at sea level.

Atmosphere-Supplying Respirator A respirator that provides breathable air from a source independent of the surrounding atmosphere. There are two types: air-line and self-contained breathing apparatus.

Auto-Ignition Temperature The temperature to which a closed, or nearly closed container must be heated in order that the flammable liquid, when introduced into the container, will ignite spontaneously or burn.

BAL British Anti-Lewisite - A name for the drug dimecaprol—a treatment for toxic inhalations.

Base A substance that (1) liberates hydroxide (OH) ions when dissolved in water, (2) receives hydrogen ions from a strong acid to form a weaker acid, and (3) neutralizes an acid. Bases react with acids to form salts and water. Bases have a pH greater than 7 and turn litmus paper blue. See Alkali.

BCM Blood-clotting mechanism effects.

Benign Not recurrent or not tending to progress. Not cancerous.

Biodegradable Capable of being broken down into innocuous products by the action of living things.

Biopsy Removal and examination of tissue from the living body.

BLD Blood effects.

Boiling Points—BP The temperature at which a liquid changes to a vapor state at a given pressure. The boiling point usually expressed in degrees Fahrenheit at sea level pressure (760 mmHg, or one atmosphere). For mixtures, the **initial** boiling point or the **boiling range** may be given.

Flammable materials with low boiling points generally present special fire hazards. Some approximate boiling points:

Propane	−44°F
Anhydrous Ammonia	−28°F
Butane	31°F
Gasoline	100°F
Allyl Chloride	113°F
Ethylene Glycol	387°F

BOM, or BuMines Bureau of Mines, U.S. Department of Interior.

Bonding The interconnecting of two objects by means of a clamp and bare wire. Its purpose is to equalize the electrical potential between the objects to prevent a static discharge when transferring a flammable liquid from one container to another. The conductive path is provided by clamps that make contact with the charged object and a low resistance flexible cable which allows the charge to equalize. See Grounding.

Bulk Density Mass of powdered or granulated solid material per unit of volume.

C Centigrade, a unit of temperature.

Ceiling Limit (PEL or TLV) The maximum allowable human exposure limit for an airborne substance which is not to be exceeded even momentarily. Also see PEL and TLV.

ca Approximately.

CAA Clean Air Act was enacted to regulate/reduce air pollution. CAA is administered by U.S. Environmental Protection Agency.

Carcinogen A substance or agent capable of causing or producing cancer in mammals, including humans. A chemical is considered to be a carcinogen if

(a) It has been evaluated by the International Agency for Research on Cancer (IARC) and found to be a carcinogen or potential carcinogen; or

(b) It is listed as a carcinogen or potential carcinogen in the **Annual Report on Carcinogens** published by the National Toxicology Program (NTP) (latest edition); or

(c) It is regulated by OSHA as a carcinogen.

Carcinogenicity The ability to produce cancer.

Carcinoma A malignant tumor. A form of cancer.

CAS Chemical Abstracts Service is an organization under the American Chemical Society. CAS abstracts and indexes chemical literature from all over the world in "Chemical Abstracts." "CAS Numbers" are used to identify specific chemicals or mixtures.

Caustic See Alkali.

cc Cubic centimeter is a volume measurement in the metric system that is equal in capacity to one milliliter (ml). One quart is about 946 cubic centimeters.

Central Nervous System The brain and spinal cord. These organs supervise and coordinate the activity of the entire nervous system. Sensory impulses are transmitted into the central nervous system, and motor impulses are transmitted out.

CERCLA Comprehensive Environmental Response, Compensation, and Liability Act of 1980. The Act requires that the Coast Guard National Response Center be notified in the event of a hazardous substance release. The Act also provides for a fund (the Superfund) to be used for the cleanup of abandoned hazardous waste disposal sites.

CFR Code of Federal Regulations. A collection of the regulations that have been promulgated under United States Law.

Chemical An element (e.g., chlorine) or a compound (e.g., sodium bicarbonate) produced by chemical reaction.

Chemical Cartridge Respirator A respirator that uses various chemical substances to purify inhaled air of certain gases and vapors. This type respirator is effective for concentrations no more than ten times the TLV of the contaminant, if the contaminant has warning properties (odor or irritation) below the TLV.

Chemical Family A group of single elements or compounds with a common general name. Example: acetone, methyl ethyl ketone (MEK), and methyl isobutyl ketone (MIBK) are of the "Ketone" family; acrolein, furfural, and acetaldehyde are of the "aldehyde" family.

Chemical Name The name given to a chemical in the nomenclature system developed by the International Union of Pure and Applied Chemistry (IUPAC) or the Chemical Abstracts Service (CAS). The scientific designation of a chemical or a name that will clearly identify the chemical for hazard evaluation purposes.

Chemical Pneumonitis. Inflammation of the lungs caused by accumulation of fluids due to chemical irritation.

CHEMTREC Chemical Transportation Emergency Center is a national center established by the Chemical Manufacturers Association (CMA) to relay pertinent emergency information concerning specific chemicals on requests from individuals. CHEMTREC has a 24-hour toll-free telephone number (800-424-9300) to help respond to chemical transportation emergencies.

Chronic Effect An adverse effect on a human or animal body, with symptoms that develop slowly over a long period of time or that recur frequently. Also see Acute.

Chronic Exposure Long-term contact with a substance.

Chronic Toxicity Adverse (chronic) effects resulting from repeated doses of or exposures to a substance over a relatively prolonged period of time. Ordinarily used to denote effects in experimental animals.

Clean Air Act See CAA.

Clean Water Act Federal law enacted to regulate/reduce water pollution. CWA is administered by EPA.

CMA Chemical Manufactures Association. See CHEMTREC.

CO Carbon monoxide is a colorless, odorless, flammable, and very toxic gas produced by the incomplete combustion of carbon. It is also a byproduct of many chemical processes. A chemical asphyiant; it reduces the blood's ability to carry oxygen. Hemoglobin absorbs CO two hundred times more readily than it does oxygen.

CO_2 Carbon dioxide is a heavy, colorless gas that is produced by the combustion and decomposition of organic substances and as a byproduct of many chemical processes. CO_2 will not burn and is relatively nontoxic (although high concentrations, especially in confined spaces, can create hazardous oxygen-deficient environments).

COC Cleveland Open Cup is a flash point test method.

Combustible A term used by NFPA, DOT, and others to classify certain liquids that will burn, on the basis of flash points. Both NFPA and DOT generally define "combustible liquids" as having a flash point of 100°F (37.8°C) or higher but below 200°F (93.3°C). Also see "flammable." Non-liquid substances such as wood and paper are classified as "ordinary combustibles" by NFPA.

Combustible Liquid Any liquid having a flashpoint at or above 100°F (37.8°C), but below 200°F (93.3°C), except any mixture having components with flashpoints of 200°F (93.3°C) or higher, the total volume of which makes up ninety-nine (99) percent or more of the total volume of the mixture.

Common Name Any means used to identify a chemical other than its chemical name (e.g., code name, code number, trade name, brand name, or generic name). See Generic.

Compressed Gas:

(a) A gas or mixture of gases having, in a container, an absolute pressure exceeding 40 pounds per square inch (psi) at 70°F (21.1°C); or

(b) A gas or mixture of gases having, in a container, an absolute pressure exceeding 104 psi at 130°F (54.4°C) regardless of the pressure at 70°F (21.1°C); or

(c) A liquid having a vapor pressure exceeding 40 psi at 100°F (37.8°C) as determined by ASTM D-323-72.

Conc See Concentration.

Concentration The relative amount of a substance when combined or mixed with other substances. Examples: 2 ppm hydrogen sulfide in air, or a 50 percent caustic solution.

Conditions to Avoid Conditions encountered during handling or storage that could cause a substance to become unstable.

Confined Space Any area that has limited openings for entry and exit that would make escape difficult in an emergency, has a lack of ventilation, contains known and potential hazards, and is not intended nor designated for continuous human occupancy.

Conjunctivitis Inflammation of the conjunctiva, the delicate membrane that lines the eyelids and covers the eyeballs.

Container Any bag, barrel, bottle, box, can, cylinder, drum, reaction vessel, storage tank, or the like that contains a hazardous chemical. For purposes of MSDS or HCS, pipes or piping systems are not considered to be containers.

Corrosive A chemical that causes visible destruction of, or irreversible alterations in, living tissue by chemical action at the site of contact. For example, a chemical is considered to be corrosive if, when tested on the intact skin of albino rabbits by the method described by the DOT in Appendix A to 49 CFR Part 173, it destroys or changes irreversibly the structure of the tissue at the site of contact following an exposure period of 4 hours. This term shall not refer to action on inanimate surfaces.

CPSC Consumer Products Safety Commission has responsibility for regulating hazardous materials when they appear in consumer goods. For CPSC purposes, hazards are defined in the Hazardous Substances Act and the Poison Prevention Packaging Act of 1970.

Curettage Cleansing of a diseased surface.

Cutaneous Toxicity See "Dermal Toxicity."

CWA Clean Water Act was enacted to regulate/reduce water pollution. It is administered by EPA.

Cyst A sac containing a liquid. Most cysts are harmless.

Cytology The scientific study of cells.

Decomposition Breakdown of a material or substance (by heat, chemical reaction, electrolysis, decay, or other processes) into parts or elements or simpler compounds.

Density The mass (weight) per unit volume of a substance. For example, lead is much more dense than aluminum.

Depressant A substance that reduces a bodily functional activity or an instinctive desire, such as appetite.

Dermal Relating to the skin.

Dermal Toxicity Adverse effects resulting from skin exposure to a substance. Ordinarily used to denote effects in experimental animals.

DHHS U.S. Department of Health and Human Services (replaced U.S. Department of Health, Education and Welfare). NIOSH and the Public Health Service (PHS) are part of DHHS.

Dike A barrier constructed to control or confine hazardous substances and prevent them from entering sewers, ditches, streams, or other flowing waters.

Dilution Ventilation Air flow designed to dilute contaminants to acceptable levels. Also see general ventilation or exhaust.

DOL U.S. Department of Labor. OSHA and MSHA are part of DOL.

DOT U.S. Department of Transportation regulates transportation of chemicals and other substances.

Dry Chemical A powdered fire-extinguishing agent usually composed of sodium bicarbonate, potassium bicarbonate, etc.

Dysmenorrhea Painful menstruation.

Dsyplasia An abnormality of development.

Dyspnea A sense of difficulty in breathing; shortness of breath.

Ectopic pregnancy The fertilized ovum becomes implanted outside of the uterus.

Edema An abnormal accumulation of clear watery fluid in the tissues.

Endocrine glands Glands that regulate body activity by secreting hormones.

Endometrium The mucous membrane lining the uterus.

Environmental Toxicity Information obtained as a result of conducting environmental testing designed to study the effects on aquatic and plant life.

EPA U.S. Environmental Protection Agency.

Epidemiology Science concerned with the study of disease in a general population. Determination of the incidence (rate of occurrence) and distribution of a particular disease (as by age, sex, or occupation) which may provide information about the cause of the disease.

Epithelium The covering of internal and external surfaces of the body.

Estrogen Principal female sex hormone.

Evaporation Rate The rate at which a material will vaporize (evaporate) when compared to the known rate of vaporization of a standard material. The evaporation rate can be useful in evaluating the health and fire hazards of a material. The designated standard material is usually normal butyl acetate (NBUAC or n-BuAc), with a vaporization rate designated as 1.0. Vaporization rates of other solvents or materials are then classified as:

- FAST evaporating if greater than 3.0. Examples: Methyl Ethyl Ketone = 3.8, Acetone = 5.6, Hexane = 8.3.
- MEDIUM evaporating if 0.8 to 3.0. Examples: 190 proof (95%) Ethyl Alcohol = 1.4, VM&P Naphtha = 1.4, MIBK = 1.6.
- SLOW evaporating if less than 0.8. Examples: Xylene = 0.6, Isobutyl Alcohol = 0.6, Normal Butyl Alcohol = 0.4, Water = 0.3, Mineral Spirits = 0.1.

Explosive A chemical that causes a sudden, almost instantaneous release of pressure, gas, and heat when subjected to sudden shock, pressure, or high temperature.

Exposure or Exposed State of being open and vulnerable to a hazardous chemical by inhalation, ingestion, skin contact, absorption, or any other course; includes potential (accidental or possible) exposure.

Extinguishing Media The firefighting substance to be used to control a material in the event of a fire. It is usually identified by its generic name, such as fog, foam, water, etc.

Eye Protection Recommended safety glasses, chemical splash goggles, face shields, etc. to be utilized when handling a hazardous material.

F Fahrenheit is a scale for measuring temperature. On the Fahrenheit scale, water boils at 212°F and freezes at 32°F.

f/cc Fibers per cubic centimeter of air.

FDA U.S. Food and Drug Administration.

Fetal Pertaining to the fetus.

Fetus The developing young in the uterus from the seventh week of gestation until birth.

Fibrosis An abnormal thickening of fibrous connective tissue, usually in the lungs.

FIFRA Federal Insecticide, Fungicide, and Rodenticide Act requires that certain useful poisons, such as chemical pesticides, sold to the public contain labels that carry health hazard warnings to protect users. It is administered by EPA.

First Aid Emergency measures to be taken when a person is suffering from overexposure to a hazardous material, before regular medical help can be obtained.

Flammable A chemical that includes one of the following categories:

(a) "Aerosol, flammable." An aerosol that, when tested by the method described in 16 CFR 1500.45, yields a flame projection exceeding 18 inches at full valve opening, or a flashback (a flame extending back to the valve) at any degree of valve opening;

(b) "Gas, flammable." (1) A gas that, at ambient temperature and pressure, forms a flammable mixture with air at a concentration of 13 percent by volume or less; or (2) A gas that, at ambient temperature and pressure, forms a range of flammable mixtures with air wider than 12 percent by volume, regardless of the lower limit;

(c) "Liquid, flammable." Any liquid having a flashpoint below 100°F (37.8°C), except any mixture having components with flashpoints of 100°F (37.8°C) or higher, the total of which make up 99 percent or more of the total volume of mixture.

(d) "Solid, flammable." A solid, other than a blasting agent or explosive as defined in 1910.109(a), that is liable to cause fire through friction, absorption of moisture, spontaneous chemical change, or retained heat from manufacturing or processing, or which can be ignited readily and when ignited burns so vigorously and persistently as to create a serious hazard. A solid is a flammable solid if, when tested by the method described in 16 CFR 1500.44, it ignites and burns with a self-sustained flame at a rate greater than one-tenth of an inch per second along its major axis.

Flashback Occurs when flame from a torch burns back into the tip, the torch, or the hose. It is often accompanied by a hissing or squealing sound with a smoky or sharp-pointed flame.

Flashpoint The minimum temperature at which a liquid gives off a vapor in sufficient concentration to ignite when tested by the following methods:

(a) Tagliabue Closed Tester (see American National Standard Method of Test for Flash Point by Tag Closed Tester, Z11.24 1979 [ASTM D56-79]).

(b) Pensky-Martens Closed Tester (see American National Standard Method of Test for Flash Point by Pensky-Martens Closed Tester, Z11.7-1979 [ASTM D93-79]).

(c) Setaflash Closed Tester (see American National Standard Method of Test for Flash Point by Setaflash Closed Tester [ASTM D 3278-78]).

Foreseeable Emergency Any potential occurrence such as, but not limited to, equipment failure, rupture of containers, or failure of control equipment which could result in an uncontrolled release of a hazardous chemical into the workplace.

Formula The scientific expression of the chemical composition of a material (e.g., water is H_2O, sulfuric acid is H_2SO_4, sulfur dioxide is SO_2).

Fume A solid condensation particle of extremely small diameter, commonly generated from molten metal as metal fume.

g Gram is a metric unit of weight. One ounce U.S. (avoirdupois) is about 28.4 grams.

General Exhaust A system for exhausting air containing contaminants from a general work area. Also see Local Exhaust.

Generic Name A designation or identification used to identify a chemical by other than its chemical name (e.g., code name, code number, trade name, and brand name).

Genetic Pertaining to or carried by genes. Hereditary.

Gestation The development of the fetus in the uterus from conception to birth; pregnancy.

g/kg Grams per kilogram is an expression of dose used in oral and dermal toxicology testing to denote grams of a substance dosed per kilogram of animal body weight. Also see "kg" (kilogram).

Grounding The procedure used to carry an electrical charge to ground through a conductive path. A typical ground may be connected directly to a conductive water pipe or to a grounding bus and ground rod. See Bonding.

Gynecology The study of the reproductive organs in women.

Hand Protection Specific type of gloves or other hand protection required to prevent harmful exposure to hazardous materials.

Hazardous Chemical Any chemical whose presence or use is a physical hazard or a health hazard.

Hazardous Warning Words, pictures, symbols, or combination thereof presented on a label or other appropriate form to inform of the presence of various materials.

HCS Hazard Communication Standard is an OSHA regulation issued under 29 CFR Part 1910.1200.

Health Hazard A chemical for which there is significant evidence, based on at least one study conducted in accordance with established scientific principles, that acute or chronic health effects may occur in exposed employees. The term "health hazard" includes chemicals that are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents that act on the hematopoietic system, and agents that damage the lungs, skin, eyes, or mucous membranes.

Hemoglobin An iron-containing conjugated protein or respiratory pigment occurring in the red blood cells of vertebrates.

Hematoma A blood clot under the surface of the skin.

Hematopoietic System The blood-forming mechanism of the human body.

Hematuria The presence of blood in the urine.

Hepatotoxin A substance that causes injury to the liver.

Highly toxic A chemical in any of the following categories:

(a) A chemical with a median lethal dose (LD_{50}) of 50 milligrams or less per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 grams each.

(b) A chemical with a median lethal dose (LD_{50}) of 200 milligrams or less per kilogram of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between 2 and 3 kilograms each.

(c) A chemical that has a median lethal concentration (LC_{50}) in air of 200 parts per million by volume or less of gas or vapor, or 2 milligrams per liter or less of mist, fume, or dust, when administered by continuous inhalation for 1 hour (or less if death occurs within 1 hour) to albino rats weighing between 200 and 300 grams each.

Hormones Act as chemical messengers to body organs.

Hyperplasia Increase in volume of a tissue or organ caused by the growth of new cells.

IARC International Agency for Research on Cancer.

Ignitable Capable of being set afire.

Impervious A material that does not allow another substance to pass through or penetrate it.

Incompatible Materials that could cause dangerous reactions by direct contact with one another.

Ingestion Taking in by the mouth.

Inhal See inhalation.

Inhalation Breathing in of a substance in the form of a gas, vapor, fume, mist, or dust.

Inhibitor A chemical added to another substance to prevent an unwanted chemical change.

Insol See insoluble.

Insoluble Incapable of being dissolved in a liquid.

Intrauterine Within the uterus.

Irritant A chemical, which is not corrosive, that causes a reversible inflammatory effect on living tissue by chemical action at the site of contact. A chemical is a skin irritant if, when tested on the intact skin of albino rabbits by the methods of 16 CFR 1500 41 for 4 hours exposure or by other appropriate techniques, it results in an empirical score of 5 or more. A chemical is an eye irritant if so determined under the procedure listed in 16 CFR 1500.42 or other appropriate techniques.

Irritating As defined by DOT, a property of a liquid or solid substance which, upon contact with fire or when exposed to air, gives off dangerous or intensely irritating fumes (not including poisonous materials). See Poison, Class A and Poison, Class B.

kg Kilogram is a metric unit of weight, about 2.2 U.S. pounds. Also see "g/kg," "g," and "mg."

L Liter is a metric unit of capacity. A U.S. quart is about 9/10 of a liter.

Lacrimation Secretion and discharge of tears.

Label Notice attached to a container, bearing information concerning its contents.

Lactation The secretion of milk by the breasts.

LC Lethal concentration is the concentration of a substance being tested that will kill.

LCL Lethal concentration, low, lowest concentration of a gas or vapor capable of killing a specified species over a specified time.

LC_{50} The concentration of a material in air that will kill 50 percent of a group of test animals with a single exposure (usually 1 to 4 hours). The LC_{50} is expressed as parts of material per million parts of air, by volume (ppm) for gases and vapors, or as micrograms of material per liter of air (g/l) or milligrams of material per cubic meter of air (mg/m^3) for dusts and mists, as well as for gases and vapors.

LD Lethal dose is the quantity of a substance being tested that will kill.

LDL Lethal dose low, lowest administered dose of a material capable of killing a specified test species.

LD_{50} A single dose of a material expected to kill 50 percent of a group of test animals. The LD_{50} dose is usually expressed as milligrams or grams of material per kilogram of animal body weight (mg/kg or g/kg). The material may be administered by mouth or applied to the skin.

LEL, or LFL Lower explosive limit, or lower flammable limit, of a vapor or gas; the lowest concentration (lowest percentage of the substance in air) that will produce a flash of fire when an ignition source (heat, arc, or flame) is present. At concentrations lower than the LEL, the mixture is too "lean" to burn. Also see "UEL."

Lesion Any damage to a tissue.

Lfm Linear feet per minute, a unit of air velocity.

Local Exhaust A system for capturing and exhausting contaminants from the air at the point where the contaminants are produced (welding, grinding, sanding, other processes or operations). Also see General Exhaust.

M Meter is a unit of length in the metric system. One meter is about 39 inches.

m^3 Cubic meter is a metric measure of volume, approximately 35.3 cubic feet or 1.3 cubic yards.

Malaise A feeling of general discomfort, distress, or uneasiness, an out-of-sorts feeling.

Malignant Tending to become progressively worse and to result in death.

Mammary Pertaining to the breast.

Mechanical Exhaust A powered device, such as a motor-driven fan or air steam venturi tube, for exhausting contaminants from a workplace, vessel, or enclosure.

Mechanical Filter Respirator A respirator used to protect against airborne particulate matter like dusts, mists, metal fume, and smoke. Mechanical filter respirators do not provide protection against gases, vapors, or oxygen deficient atmospheres.

Melting Point The temperature at which a solid substance changes to a liquid state.

Menorrhagia Excessive menstruation.

Menstruation Periodic discharge of blood from the vagina of a nonpregnant uterus.

Metabolism Physical and chemical processes taking place among the ions, atoms, and molecules of the body.

Metastasis The transfer of disease from one organ or part to another not directly connected with it.

Meter A unit of length; equivalent to 39.37 inches.

mg Milligram is a metric unit of weight that is one-thousandth of a gram.

mg/kg Milligrams of substance per kilogram of body weight is an expression of toxicological dose.

mg/m^3 Milligrams per cubic meter is a unit for expressing concentrations of dusts, gases, or mists in air.

Micron (Micrometer) A unit of length equal to one-millionth of a meter; approximately 0.000039 of an inch.

Mist Suspended liquid droplets generated by condensation from the gaseous to the liquid state, or by breaking up a liquid into a dispersed state, such as splashing, foaming or atomizing. Mist is formed when a finely divided liquid is suspended in air.

Mixture Any combination of two or more chemicals if the combination is not, in whole or part, the result of a chemical reaction.

Mld Mild

ml Milliliter is a metric unit of capacity, equal in volume to 1 cubic centimeter (cc), or approximately one-sixteenth of a cubic inch. One-thousandth of a liter.

mmHg Millimeters (mm) of mercury (Hg) is a unit of measurement for low pressures or partial vacuums.

Molecular Weight Weight (mass) of a molecule based on the sum of the atomic weights of the atoms that make up the molecule.

mppcf Million particles per cubic foot is a unit for expressing concentration of particles of a substance suspended in air. Exposure limits for mineral dusts (silica, graphite, Portland cement, nuisance dusts, and others), formerly expressed as mppcf, are now more commonly expressed in mg/m^3.

MSDS Material Safety Data Sheet.

MSHA Mine Safety and Health Administration, U.S. Department of Labor.

Mutagen A substance or agent capable of altering the genetic material in a living cell.

MW See molecular weight.

N_2 Nitrogen is a colorless, odorless, and tasteless gas that will not burn and will not support combustion. The earth's atmosphere (air) is about 78 percent nitrogen. At higher concentrations, nitrogen can displace oxygen and become a lethal asphyxiant. See Asphyxiant.

Narcosis A state of stupor, unconsciousness, or arrested activity produced by the influence of narcotics or other chemicals.

Nausea Tendency to vomit, feeling of sickness at the stomach.

NCI National Cancer Institute is that part of the National Institutes of Health that studies cancer causes and prevention as well as diagnosis, treatment, and rehabilitation of cancer patients.

NFPA National Fire Protection Association is an international membership organization which promotes/improves fire protection and prevention and establishes safeguards against loss of life and property by fire. Best known on the industrial scene for the National Fire Codes—16 volumes of codes, standards, recommended practices and manuals developed (and periodically updated) by NFPA technical committees. Among these is NFPA 704M, the code for showing hazards of materials as they might be encountered under fire or related emergency conditions, using the familiar diamond-shaped label or placard with appropriate numbers or symbols.

Neo See neoplasia.

Neonatal The first 4 weeks after birth.

Neoplasia A condition characterized by the presence of new growths (tumors).

Nephrotoxin A substance that causes injury to the kidneys.

Neurotoxin A material that affects the nerve cells and may produce emotional or behavioral abnormalities.

Neutralize To eliminate potential hazards by inactivating strong acids, caustics, and oxidizers. For example, acids can be neutralized by adding an appropriate amount of caustic substance to the spill.

ng nanogram, one-billionth of a gram.

NIOSH National Institute for Occupational Safety and Health, U.S. Public Health Service, U.S. Department of Health and Human Services (DHHS), among other activities, tests and certifies respiratory protective devices and air sampling detector tubes, recommends occupational exposure limits for various substances, and assists OSHA and MSHA in occupational safety and health investigations and research.

Nonflammable Not easily ignited, or if ignited, not burning rapidly.

Non-Sparking Tools Tools made from beryllium-copper or aluminum-bronze greatly reduce the possibility of igniting dusts, gases, or flammable vapors. Although these tools may emit some sparks when striking metal, the sparks have a low heat content and are not likely to ignite most flammable liquids.

NO_x Oxides of nitrogen which are undesirable air pollutants. NO emissions are regulated by EPA under the Clean Air Act.

NPIRS National Pesticide Information Retrieval System is an automated data base operated by Purdue University containing information on EPA registered pesticides, including reference file MSDS's.

NRC National Response Center is a notification center that must be called when significant oil or chemical spills or other environment-related accidents occur. The toll-free telephone number is 1-800-424-8802.

NTP National Toxicology Program. The NTP publishes an Annual Report on Carcinogens.

Odor A description of the smell of the substance.

Odor Threshold The lowest concentration of a substance's vapor, in air, that can be smelled.

Olfactory Relating to the sense of smell.

Oral Used in or taken into the body through the mouth.

Oral Toxicity Adverse effects resulting from taking a substance into the body by mouth. Ordinarily used to denote effects in experimental animals.

Organic Peroxide An organic compound that contains the bivalent -O-O structure and may be considered a structural derivative of hydrogen peroxide where one or both of the hydrogen atoms has been replaced by an organic radical.

Organogenesis The formation of organs during development.

OSHA Occupational Safety and Health Administration, U.S. Department of Labor.

Ovary The female sex gland in which ova are formed.

Overexposure Exposure to a hazardous material beyond the allowable exposure limits.

Oxidation In a literal sense, oxidation is a reaction in which a substance combines with oxygen provided by an oxidizer or oxidizing agent. See Oxidizing Agent.

Oxidizer A chemical other than a blasting agent or explosive that initiates or promotes combustion in other materials, causing fire either by itself or through the release of oxygen or other gases.

Oxidizing Agent A chemical or substance that brings about an oxidation reaction. The agent may (1) provide the oxygen to the substance being oxidized (in which case the agent has to be oxygen or contain oxygen), or (2) it may receive electrons being transferred from the substance undergoing oxidation (chlorine is a good oxidizing agent for electron-transfer purposes, even though it contains no oxygen).

Pathologic Pertaining to or caused by disease.

Pathology Scientific study of alterations produced by disease.

PEL Permissible Exposure Limit is an occupational exposure limit established by OSHA's regulatory authority. It may be a time-weighted average (TWA) limit or a maximum concentration exposure limit.

Percent Volatile Percent volatile by volume is the percentage of a liquid or solid (by volume) that will evaporate at an ambient temperature of 70°F (unless some other temperature is specified). Examples: butane, gasoline, and paint thinner (mineral spirits) are 100 percent volatile; their individual evaporation rates vary, but in time, each will evaporate completely.

pH The symbol relating the hydrogen ion (H^+) concentration to that of a given standard solution. A pH of 7 is neutral. Numbers increasing from 7 to 14 indicate greater alkalinity. Numbers decreasing from 7 to 0 indicate greater acidity.

Physical Hazard Means a chemical for which there is scientifically valid evidence that it is a combustible liquid, a compressed gas, explosive, flammable, an organic peroxide, an oxidizer, pyrophoric, unstable (reactive) or water-reactive.

Placenta A structure that grows on the wall of the uterus during pregnancy, through which the fetus is nourished.

PMCC Pensky-Martens Closed Cup. See Flashpoint.

Pneumoconiosis A condition of the lung in which there is permanent deposition of particulate matter and the tissue reaction to its presence. It may range from relatively harmless forms of iron oxide deposition to destructive forms of silicosis.

Poison, Class A A DOT term for extremely dangerous poisons—poisonous gases or liquids that, in very small amounts, either as gas or as vapor of the liquid, mixed with air, are dangerous to life. Examples: phosgene, cyanogen, hydrocyanic acid, nitrogen peroxide.

Poison, Class B A DOT term for liquid, solid, paste or semisolid substances—other than Class A poisons or irritating materials—that are known (or presumed on the basis of animal tests) to be so toxic to humans that they are a hazard to health during transportation.

Polymerization A chemical reaction in which one or more small molecules combine to form larger molecules. A hazardous polymerization is such a reaction that takes place at a rate that releases large amounts of energy. If hazardous polymerization can occur with a given material, the MSDS usually will list conditions that could start the reaction and—since the material usually contains a polymerization inhibitor—the length of time during which the inhibitor will be effective.

ppb Parts per billion is the concentration of a gas or vapor in air—parts (by volume) of the gas or vapor in a billion parts of air. Usually used to express extremely low concentrations of unusually toxic gases or vapors; also the concentration of a particular substance in a liquid or solid.

ppm Parts per million is the concentration of a gas or vapor in air—parts (by volume) of the gas or vapor in a million parts of air; also the concentration of a particulate in a liquid or solid.

Prenatal Preceding birth.

psi Pounds per square inch (for MSDS purposes) is the pressure a material exerts on the walls of a confining vessel or enclosure. For technical accuracy, pressure must be expressed as psig (pounds per square inch gauge) or psia (pounds per square inch absolute; that is, gauge pressure plus sea level atmospheric pressure, or psig plus approximately 14.7 pounds per square inch). Also see mmHg.

Pul See pulmonary.

Pulmonary Relating to, or associated with, the lungs.

Pulmonary Edema Fluid in the lungs.

Pyrophoric A chemical that will ignite spontaneously in air at a temperature of 13°F (54.4°C) or below.

Reaction A chemical transformation or change. The interaction of two or more substances to form new substances.

Reactive See Unstable.

Reactivity Chemical reaction with the release of energy. Undesirable effects—such as pressure buildup, temperature increase, formation of noxious, toxic or corrosive byproducts—may occur because of the reactivity of a substance to heating, burning, direct contact with other materials, or other conditions in use or in storage.

Reducing agent In a reduction reaction (which always occurs simultaneously with an oxidation reaction) the reducing agent is the chemical or substance which (1) combines with oxygen or (2) loses electrons to the reaction. See Oxidation.

REL The NIOSH REL (Recommended Exposure Limit) is the highest allowable airborne concentration which is not expected to injure the workers. It may be expressed as a ceiling limit or as a time-weighted average (TWA).

Reproductive Toxin Substances that affect either male or female reproductive systems and may impair the ability to have children.

Respiratory Protection Devices that will protect the wearer's respiratory system from overexposure by inhalation to airborne contaminants. Respiratory protection is used when a worker must work in an area where he/she might be exposed to concentration in excess of the allowable exposure limit.

Respiratory System The breathing system that includes the lungs and the air passages (trachea or "windpipe," larynx, mouth, and nose) to the air outside the body, plus the associated nervous and circulatory supply.

Routes of Entry The means by which material may gain access to the body, for example, inhalation, ingestion, and skin contact.

RCRA Resource Conservation and Recovery Act is environmental legislation aimed at controlling the generation, treating, storage, transportation and disposal of hazardous wastes. It is administered by EPA.

Sarcoma A tumor that is often malignant.

Self-Contained Breathing Apparatus A respiratory protection device that consists of a supply or a means of respirable air, oxygen, or oxygen-generating material, carried by the wearer.

Sensitizer A chemical that causes a substantial proportion of exposed people or animals to develop an allergic reaction in normal tissue after repeated exposure to the chemical.

SETA Setaflash Closed Tester. See Flashpoint.

Silicosis A disease of the lungs (fibrosis) caused by the inhalation of silica dust.

Skn Skin.

"Skin" A notation (sometimes used with PEL or TLV exposure data) that indicates that the stated substance may be absorbed by the skin, mucous membranes, and eyes—either airborne or by direct contact—and that this additional exposure must be considered part of the total exposure to avoid exceeding the PEL or TLV for that substance.

Skin Absorption Ability of some hazardous chemicals to pass directly through the skin and enter the bloodstream.

Skin Sensitizer See Sensitizer.

Skin Toxicity See Dermal Toxicity.

Solubility in Water A term expressing the percentage of a material (by weight) that will dissolve in water at ambient temperature. Solubility information can be useful in determining spill cleanup methods and reextinguishing agents and methods for a material.

Solvent A substance, usually a liquid, in which other substances are dissolved. The most common solvent is water.

SOx Oxides of sulfur.

Species On the MSDS's, species refers to the test animals—usually rats, mice, or rabbits—used to obtain the toxicity test data reported.

Specific Chemical Identity The chemical name, Chemical Abstracts Service (CAS) Registry Number, or any precise chemical designation of a substance.

Specific Gravity The weight of a material compared to the weight of an equal volume of water is an expression of the density (or heaviness) of a material. Insoluble materials with specific gravity of less than 1.0 will float in (or on) water. Insoluble materials with specific gravity greater than 1.0 will sink in water. Most (but not all) flammable liquids have specific gravity less than 1.0 and, if not soluble, will float on water—an important consideration for fire suppression.

Spill or Leak Procedures The methods, equipment, and precautions that should be used to control or clean up a leak or spill.

Splash-Proof Goggles Eye protection made of a noncorrosive material that fits snugly against the face, and has indirect ventilation ports.

Spontaneously Combustible A material that ignites as a result of retained heat from processing, or that will oxidize to generate heat and ignite, or that absorbs moisture to generate heat and ignite.

Squamous Scaly or platelike.

Stability The ability of a material to remain unchanged. For MSDS purposes, a material is stable if it remains in the same form under expected and reasonable conditions of storage or use. Conditions that may cause instability (dangerous change) are stated; for example, temperatures above 150°F.; shock from dropping.

STEL Short-Term Exposure Limit (ACGIH terminology). See TLV.

Stenosis Narrowing of a body passage or opening.

Steroid A complex molecule among which are the male and female sex hormones.

Subcutaneous Beneath the layers of the skin.

Supplied-Air Respirators Air line respirators of self-contained breathing apparatus.

Sys System or systemic.

Systemic Poison A poison that spreads throughout the body, affecting all body systems and organs. Its adverse effect is not localized in one spot or area.

Systemic Toxicity Adverse effects caused by a substance that affects the body in a general rather than local manner.

Synonym Another name or names by which a material is known. Methyl alcohol, for example, is known as methanol or wood alcohol.

Target Organ Effects The following is a target organ categorization of effects that may occur, including examples of signs and symptoms and chemicals that have been found to cause such effects. These examples are presented to illustrate the range and diversity of effects and hazards found in the workplace, and the broad scope employers must consider in this area, but they are not intended to be all inclusive.

(a) Hepatotoxins	Chemicals that produce liver damage.
Signs and Symptoms	Jaundice; liver enlargement.
Chemicals	Carbon tetrachloride; nitrosamines.

(b) Nephrotoxins		Chemicals that produce kidney damage.
	Signs and Symptoms	Edema; proteinuria.
	Chemicals	Halogenated hydrocarbons; uranium.
(c) Neurotoxins		Chemicals that produce their primary toxic effects on the nervous system.
	Signs and Symptoms	Narcosis; behavioral changes; decrease in motor functions.
	Chemicals	Mercury, carbon disulfide.
(d) Agents that act on blood hematopoietic system		Decrease hemoglobin function; deprive the body tissues of oxygen.
	Signs and Symptoms	Cyanosis; loss of consciousness.
	Chemicals	Carbon monoxide; cyanides
(e) Agents that damage the lung		Chemicals that irritate or damage the pulmonary tissue.
	Signs and Symptoms	Cough, tightness in chest, shortness of breath.
	Chemicals	Silica; asbestos.
(f) Reproductive toxins		Chemicals that adversely affect the reproductive capabilities including chromosomal damage (mutations) and effects on fetuses (teratogenesis).
	Signs and Symptoms	Birth defects; sterility.
	Chemicals	Lead; DBCP
(g) Cutaneous hazards		Chemicals that affect the dermal layer of the body.
	Signs and Symptoms	Defatting of the skin; rashes;irritation.
	Chemicals	Ketones; chlorinated compounds.
(h) Eye hazards		Chemicals that affect the eye or visual capacity.
	Signs and Symptoms	Conjunctivitis; corneal damage.
	Chemicals	Organic solvents; acids.

Target Organ Toxin A toxic substance that attacks a specific organ of the body. For example, overexposure to carbon tetrachloride can cause liver damage.

TCC Tag (Tagliabue) Closed_Cup. See Flashpoint.

TCL Toxic concentration low, the lowest concentration of a gas or vapor capable of producing a defined toxic effect in a specified test species over a specified time.

TDL Toxic dose low, lowest administered dose of a material capable of producing a defined toxic effect in a specified test species.

Temp Temperature.

Ter See Teratogen.

Teratogen A substance or agent, exposure to which by a pregnant female can result in malformations in the fetus.

Tfx Toxic effect(s).

TLV Threshold Limit Value is a term used by ACGIH to express the airborne concentration of material to which nearly all persons can be exposed day after day without adverse effects. ACGIH expresses TLVs in three ways:

TLV-TWA: The allowable Time-Weighted Average concentration for a normal 8-hour workday or 80-hour workweek.

TLV-STEL: The Short-Term Exposure Limit, or maximum concentration for a continuous 15-minute exposure period (maximum of four such periods per day, with at least 60 minutes between exposure periods, and provided the daily TLV-TWA is not exceeded).

TLV-C: The ceiling exposure limit—the concentration that should not be exceeded even instantaneously.

TOC Tag Open Cup. See Flashpoint.

Torr A unit of pressure, equal to 1/760 atmosphere.

Toxic A chemical falling within any of the following categories:

(a) A chemical that has a median lethal dose (LD_{50}) of more than 50 milligrams per kilogram but not more than 500 milligrams per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 grams each.

(b) A chemical that has a median lethal dose (LD_{50}) of more than 200 milligrams per kilogram but not more than 1,000 milligrams per kilogram of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between two and three kilograms each.

(c) A chemical that has a median lethal concentration (LC_{50}) in air of more than 200 parts per million but not more than 2,000 parts per million by volume of gas or vapor, or more than two milligrams per liter but not more than 20 milligrams per liter of mist, fume, or dust, when administered by continuous inhalation for one hour (or less if death occurs within 1 hour) to albino rats weighing between 200 and 300 grams each.

Toxic Substance Any substance that can cause acute or chronic injury to the human body, or which is suspected of being able to cause diseases or injury under some conditions.

Toxicity The sum of adverse effects resulting from exposure to a material, generally, by the mouth, skin, or respiratory tract.

Trade Name The trademark name or commercial trade name for a material or product.

Transplacental An agent that causes physical defects in the developing embryo.

TSCA Toxic Substances Control Act (Federal Environmental Legislation administered by EPA) regulates the manufacture, handling, and use of materials classified as "toxic substances."

TWA Time-Weighted Average exposure is the airborne concentration of a material to which a person is exposed, averaged over the total exposure time—generally the total workday (8 to 12 hours). Also see TLV.

UEL, or UFL Upper explosive limit or upper flammable limit of a vapor or gas; the highest concentration (highest percentage of the substance in air) that will produce a flash of fire when an ignition source (heat, arc, or flame) is present. At higher concentrations, the mixture is too "rich" to burn. Also see LEL.

ug Microgram, one-millionth of a gram.

Unstable Tending toward decomposition or other unwanted chemical change during normal handling or storage.

Unstable Reactive A chemical that, in the pure state, or as produced or transported, will vigorously polymerize, decompose, condense, or become self-reactive under conditions of shocks, pressure, or temperature.

USDA U.S. Department of Agriculture.

Vapor The gaseous form of a solid or liquid substance as it evaporates.

Vapor density The weight of a vapor or gas compared to the weight of an equal volume of air is an expression of the density of the vapor or gas. Materials lighter than air have vapor densities less than 1.0 (examples: acetylene, methane, hydrogen). Materials heavier than air (examples: propane, hydrogen sulfide, ethane, butane, chlorine, sulfur dioxide) have vapor densities greater than 1.0. All vapors and gases will mix with air, but the lighter materials will tend to rise and dissipate (unless confined). Heavier vapors and gases are likely to concentrate in low places—along or under floors, in sumps, sewers, and manholes, in trenches and ditches—where they may create fire or health hazards.

Vapor pressure The pressure exerted by a saturated vapor above its own liquid in a closed container. When quality control tests are performed on products, the test temperature is usually 100°F, and the vapor pressure is expressed as pounds per square inch (psig or psia), but vapor pressures reported as MSDS's are in millimeters of mercury (mmHg) at 68°F (20°C), unless stated overwise. Three facts are important to remember:

1. Vapor pressure of a substance at 100°F will always be higher than the vapor pressure of the substance at 68°F (20°C).
2. Vapor pressures reported on MSDS's in mmHg are usually very low pressures; 760 mmHg is equivalent to 14.7 pounds per square inch.
3. The lower the boiling point of a substance, the higher its vapor pressure.

Ventilation See General Exhaust, Local Exhaust, and Mechanical Exhaust.

Vermiculite An expanded mica (hydrated magnesium-aluminum-iron silicate) used as sorbent for spill control and cleanup.

Viscosity The tendency of a fluid to resist internal flow without regard to its density.

Volatility A measure of how quickly a substance forms a vapor at ordinary temperatures.

Water Disposal Methods Proper disposal methods for contaminated material, recovered liquids or solids, and their containers.

Water-Reactive A chemical that reacts with water to release a gas that is either flammable or presents a health hazard.

Work Area A room or defined space in a workplace where hazardous chemicals are produced or used, and where employees are present.

Workplace An establishment at one geographical location containing one or more work areas.

Zinc Fume Fever A condition brought on by inhalation of zinc oxide fume characterized by flulike symptoms with a metallic taste in the mouth, coughing, weakness, fatigue, muscular pain, and nausea, followed by fever and chills. The onset of symptoms occurs four to twelve hours after exposure.

APPENDIX G

Partial List of National Fire Protection Association — American National Standards Institute — — Underwriters Laboratory Standards Applicable to Chemical Engineering —

ELECTRICAL CODES
National Electrical Code, ANSI/NFPA 70-1984
National Electrical Safety Code, ANSI C2-1984

GROUNDS AND GROUNDING
Ground-Fault Circuit Interrupters, ANSI/UL 943-1985
Safety Standard for Grounding and Bonding Equipment, ANSI/UL 467-1984

BOILER-FURNACES
Fuel Oil-Fired Multiple Burner Boiler-Furnaces, Explosion Prevention, ANSI/NFPA 85D-1984
Gas-Fired Multiple Burner Boiler-Furnaces, Explosion Prevention, ANSI/NFPA 85B-1984
Pulverized Coal-Fired Multiple Burner Boiler-Furnaces, Explosion Prevention, ANSI/NFPA 85E-1985

CONTROL EQUIPMENT (ANSI/UL)
Control Equipment for Use with Flammable Liquid Dispensing Devices, Safety Standard for, ANSI/UL 1238-1984

EXHAUST SYSTEMS
Blower and Exhaust Systems, ANSI/NFPA 91-1983

EXPLOSIONS
Explosion Prevention Systems, ANSI/NFPA 69-1978
Explosion Venting, ANSI/NFPA 68-1978

FIRE PROTECTION
Identification of Fire Hazards of Materials, ANSI/NFPA 704-1985
Life Safety Code, ANSI/NFPA 101-1985
Uniform Coding for Fire Protection, ANSI/NFPA 901-1981

FLAME ARRESTERS
Flame Arresters for Use on Vents of Storage Tanks for Petroleum Oil and Gasoline, ANSI/UL 525-1984

FLAMMABLE LIQUIDS
Flammable and Combustible Liquids Code, ANSI/NFPA 30-1984

FLAMMABLE VAPORS AND DUSTS
Group Classification of Flammable and Combustible Vapors and Combustible Dusts, ANSI/NFPA 497M-1983

GAS, NATURAL
Production, Storage and Handling of Liquified Natural Gas, ANSI/NFPA 59A-1985

GASES, LIQUEFIED PETROLEUM
Storage and Handling of Liquefied Petroleum Gases, ANSI/NFPA 58-1983

MATERIALS HANDLING--CANS
Metal Safety Cans, ANSI/UL 30-1984

OXIDIZING MATERIALS
Storage of Gaseous Oxidizing Materials, ANSI/NFPA 43C-1980
Storage of Liquid and Solid Oxidizing Materials, ANSI/NFPA 43A-1980

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