A LABORATORY SAFETY PROGRAM AT DELAWARE

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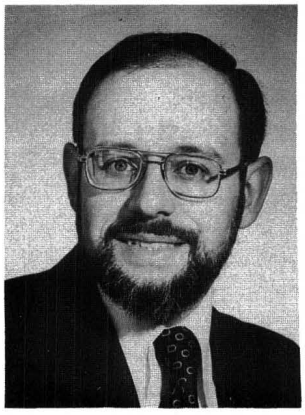

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UNDERGRADUATE AND graduate students in chemical engineering are generally poorly trained in laboratory safety and housekeeping. Organized safety efforts are usually initiated only after a serious accident or after a potentially serious near-miss occurs. Fortunately, no serious accident has occurred in the department of chemical engineering at the University of Delaware. However, several years ago we realized that the state of our laboratories with regard to safety was poor. Problems included large quantities of compressed gas (including hydrogen) in our building, a lack of safety and rescue equipment, a lack of alarm systems, insufficient training of personnel, and a general ignorance of safe laboratory procedures and housekeeping.

THE BEGINNING

As a result of a special concern about compressed gas handling, in February of 1979, Harry Dorsman, an industrial safety expert with the E. I. du Pont de Nemours Company, was invited to evaluate our safety needs in this area. He was accompanied on his laboratory inspection tour by several chemical engineering faculty and by the department laboratory coordinator; this group became the nucleus of the present day departmental safety committee. Although the inspection and report focused on compressed gas safety, Mr. Dorsman also noted a vast number of problems with laboratory housekeeping, solvent storage, inadequate personal protective equipment, electrical safety, fume hood use, and a lack of emergency preparedness. As a result of this examination, it was clear that safety awareness should become a high priority in all our laboratories, and that all faculty, students and staff should be committed to laboratory safety.

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The compressed gas summary and the laboratory inspection notes were issued by the department chairman as the first safety report. A follow-up inspection occurred later, and a second safety report, prefaced by a statement from the chairman requiring all laboratory personnel to upgrade noncompliance areas, was issued. As will be discussed shortly, safety inspections and reports now occur on a regular basis. Also, experiments, and even whole laboratories, have been shut down for various periods of time by the safety coordinator and the department chairman because of seri-

ous safety problems or repeated noncompliance.

The departmental Safety Committee now includes faculty, graduate students and staff. Membership rotates yearly in order to involve many different people. The Safety Committee organizes safety training programs, establishes departmental safety rules, evaluates university policy, recommends safety equipment purchases and, three times a year, conducts safety audits followed by a written report. The department also maintains a safety reference library which is useful in preparing process hazard reviews described below, and in checking laboratory toxicity and chemical reactivity hazards. A number of key references appear in Table 1. Several of these publications provide guidelines for performing laboratory safety inspections, checklists of common safety hazards, and ratings of the potential severity of such hazards.

The departmental safety inspections include all laboratories and support service areas including a solvent storage building, a remote compressed gas storage building, a gas cylinder loading dock and storage, machine shop, storeroom, undergraduate laboratories and classrooms, and offices. Ideally, the users and faculty of each laboratory should be present when an inspection is being made. All safety hazards are explained in detail. At the time of inspection, a commitment from the users to resolve all safety hazards is the best assurance that corrective action will be taken. Also, previous reports are used during each inspection to identify unresolved safety problems. The inspection report with a summary memo is given to the department chairman, who distributes copies to the departmental community. These reports identify specific problems and sometimes specify a time limit for the correction of safety flaws or poor housekeeping. Inspection teams recheck problem laboratories as needed, and sometimes recommend strict action to the department chairman.

TABLE 1
Key References in Departmental Safety Library

L. Bretherick, *Handbook of Reactive Chemical Hazards,* 3rd Ed., Butterworths, 1985.

Compressed Gas Association, Handbook of Compressed Gases, Van Nostrand Reinhold Co., 1981, 2nd Ed.

Hoffman, J. M. & D. C. Master, (ed), "Chemical Process Hazard Review," ACS Symposium Series 274, American Chemical Society, 1985.

Marc J. LeFevre, *First Aid Manual for Chemical Accidents,* Academic Press, 1980.

National Research Council, Committee on Hazardous Substance in the Laboratory, "Prudent Practices for Handling Hazardous Chemicals in Laboratories," National Academy Press, Washington, D.C., 1981.

N. Irving Sax, *Dangerous Properties of Industrial Materials,* 6th Ed., Van Nostrand Reinhold Co., 1984.

Norman V. Steere (ed), *R & D Laboratory Safety Manual,* National Safety Council, Chicago, IL.

George Whitmyre (ed), "Laboratory Safety Manual," University of Delaware, Chemical Engineering Department, Newark, DE, 19716.

To emphasize the importance of safe laboratory operating procedure, at the beginning of each academic year a mandatory safety orientation program is given for all new graduate students, staff, postdoctoral fellows and visiting scholars.

TABLE 2
Contents of Safety Manual

Chapter 1	General Safety Principles and Regulations.
Chapter 2	Assembly and Use of Apparatus.
Chapter 3	Handling and Storage of Chemicals and Solvents.
Chapter 4	Compressed Gases and Gas Regulators; Regulator Inspection; Hydrogen Shed Entry Procedures.
Chapter 5	Safety in the Machine Shop.
Appendix 1	Eye Protection.
Appendix 2	Solvent Disposal Stations; Broken Glass Containers.
Appendix 3	References.
Appendix 4	Certification form, to be signed by individual and included in personnel file, that the Department Safety Manual has been read and understood.

The Safety Committee also reviews proposed changes in university safety policy and develops the departmental safety policy which, after approval by the faculty, is incorporated into the departmental safety manual. This safety manual, which is updated each year, provides the basic structure for the safe operations of our laboratories. This manual, the contents of which are shown in Table 2, contains basic university and department policies, and other safety information. All laboratory users must attest in writing that they have read and understood this manual, as well as had all their safety questions answered. Additional accountability is mandated by the State of Delaware's "right-to-know" law which requires "generic" toxicity training to be supplemented by a *documented* safety discussion of specific laboratory operations, hazards and control details between each graduate student and his advisor.

SPECIFIC SAFETY ACTIONS TAKEN

Our initial safety actions resulted from recommendations in the original safety report, and involved both procedural and structural changes. The first and im-

mediate action was to emphasize the importance of adequate eye protection by requiring all laboratory users and visitors to wear industrial safety glasses with side shields. This minimum level of eye protection is upgraded when, for example, a splash hazard requires chemical splash goggles or a face shield. An eye protection policy is a good starting point for any safety program because of its importance and because compliance can be easily checked and enforced. Further, it is a constant reminder that a safety policy is in force. Also, depending on the materials being used, neoprene gloves or other special safety equipment may be required as a result of a safety hazard review, which is discussed later.

Next, a remote gas storage building for flammable and toxic gases was built and a distribution network of ¼″ stainless steel, all-welded tubing with electronically controlled shut-off solenoids was installed. Our loading dock was enlarged and equipped with a firewall, roof, lighting, clearly marked gas storage bays and a gas cylinder cart ramp.

These two items represented the largest expenditures in our safety program. Most of the costs were borne by the administration of the University of Delaware; a recognition of the institutional importance of laboratory safety.

Also, custom computer inventory software was developed which, together with a user tag and serial number tracking system, provides us with on-line inventory control. Thus, the location of all hazardous gases is known at all times. (Incidentally, this program also prints a list of delinquent cylinders by user group or location, which has been helpful in reducing cylinder charges.)

Routine safety training was regularly scheduled and now continues, and volunteer emergency action personnel in the department (at any time approximately twenty faculty, staff and graduate students) are trained in cardiopulmonary resuscitation, industrial first-aid, and the use of 30-minute air-packs. Emergency eyewash stations have been installed throughout our laboratories and freon warning horns have been attached to all safety showers. Carbon monoxide and hydrogen detectors have been installed in all laboratories in which these gases are used, and in the remote gas storage facility. These detectors display a local audio-visual warning in the event of a leak. When 25% of the lower explosive limit of hydrogen (1% in air) or half the STEL of CO (200 ppm) is exceeded, the alarm state is reached. This activates the building evacuation alarm, notifies the county fire board, and, by electronically controlled solenoids mentioned earlier, stops all gas flow into the building from the remote gas storage facility.

HAZARD EVALUATION AND TRAINING—CONTINUING ACTIVITIES

To emphasize the importance of safe laboratory operating procedure, at the beginning of each academic year a mandatory safety orientation program is given for all new graduate students, staff, postdoctoral fellows and visiting scholars. Topics in this intensive two-day six-hour course, shown in Table 3, include "right-to-know" training, departmental safety philosophy and practice, toxicology, use of fume hoods, use of personal protective equipment, waste disposal, safety procedures when using electricity and compressed gases, emergency action, first aid, fire safety including hands-on fire extinguisher training, and emergency medical assistance. We emphasize,

TABLE 3
Graduate Student and Staff Laboratory Safety Program
(All lectures given by departmental staff except those noted by * which are given by Safety Division of the university.)

Day 1	• General Safety Procedures
	• Your Right-to-Know Chemical Hazards
	• General Laboratory Safety
	• Handling Chemicals*
	• Personal Protective Equipment
	• Using the Laboratory Fume Hood*
	• Hazardous Waste*
Day 2	• Glassware Safety Videotape
	• Compressed Gas Safety
	• Electrical Safety
	• Industrial Safety and First Aid*
	• Fire Safety and Fire Extinguisher Training*

during this safety course, that a graduate is more likely to find employment if he has an unblemished safety record, including documented safety training. Further, students are encouraged to consider job safety programs and employee safety involvement of potential future employers.

Also, junior and senior undergraduate students in the department receive a safety orientation lecture, including philosophy and practice, and "right-to-know" training at their first laboratory class meetings. The contents of this lecture are given in Table 4. During the year, individual safety orientation is provided, and specialized courses are given in the operation of self-contained breathing apparatus, cardiopulmonary resuscitation (CPR), cryogenic safety, use of x-ray equipment, industrial first aid, and machine shop safety.

Continual reminders of the importance of laboratory safety, as well as new safety information, is pro-

vided by safety bulletin boards on each floor of our building. Also, we maintain a safety equipment display, and signs on the entrance doors to laboratory blocks remind both departmental staff and visitors that eye protection is required. Other safety posters and placards also help to maintain a state of safety awareness in our laboratories. Finally, lists of emergency action personnel (*i.e.*, those trained in CPR and first aid) are posted by emergency telephones on each floor, as well as being distributed to all faculty and staff.

Also of great importance is the fact that all new experimental equipment must undergo a hazard review, which is modeled after industrial hazard evaluation systems. A hazard checksheet, designed to review new equipment plans and procedures as well as providing an itemized list of mechanical, electrical, chemical, compressed gas, and emergency safety factors, is used. Another worksheet, the failure mode effect list, is used to determine how "worst case" component failures effect other components. As a result of this program, safety is built into all new equipment. Also, information on the users, their university and home telephone numbers, and shutdown procedures are posted on each major piece of equipment in our laboratories.

CONCLUSION

From our experience it is clear that the most vital aspect of an ongoing safety program is the commitment and complete support of the faculty. Also, the Safety Committee Chairman and the faculty need to continually push forward in improving laboratory operating procedures, upgrading safety programs, and both inspiring and demanding a serious safety attitude and awareness among all personnel. This is best accomplished by setting an example and by requiring the immediate correction of any and all safety flaws which are found. All (especially the safety committee) need to become proficient in recognizing potential safety flaws before they become serious problems. Also, departmental safety rules need to be applied realistically and, most importantly, firmly and uniformly.

Laboratory safety is in everyone's best interest. This must be realized by all those who enter laboratories. The rewards of avoiding serious accidents and/or injuries are immeasurable and greatly outweigh the minor inconveniences of a safety program.

(Note: A copy of the Safety Manual of the Department of Chemical Engineering at the University of Delaware and the Hazard Review Checksheet are available on request from the authors.) □

TABLE 4
Undergraduate Safety Orientation Program

1. **Rationale for learning safe work habits in the laboratory.**
2. **Right-to-Know Law. (Access to hazardous chemical information, work place chemical list, labelling information, right to report Right-to-Know violations without retribution.)**
3. **Protective equipment.**
4. **Review of special protection and handling requirements for hazardous materials in each laboratory experiment.**
5. **Review of non-chemical hazards in each experiment.**
6. **First Aid and Emergency Procedures. (First aid, fires, spills and broken glass, use of location of first aid kits, emergency showers, eyewashers and emergency exits. Calling for help.)**

ChE books received

Chemistry and Biochemistry of the Amino Acids, Edited by G. C. Barrett; Chapman & Hall, 29 West 35th St., New York 10001; 684 pages, $99 (1985)

Recent Advances in the Engineering Analysis of Chemically Reacting Systems, Edited by L. K. Doraiswamy; Halsted Press, John Wiley & Sons, NY 10158; 611 pages, $49.95 (1984)

Lubricants and Related Products, Dieter Klamann; Verlay Chemie International, Deerfield Beach, FL 33441-1705; 489 pages, $43.60 (1984)

Enzyme Chemistry, Impact and Applications, Edited by Colin J. Suckling; Chapman & Hall, 29 West 35th St., New York, NY 10001; 255 pages, $36.00 (1984)

Chemistry of Pyrotechnics: Basic Principles and Theory, John A. Conkling; Marcel Dekker, 270 Madison Ave., New York, NY 10016; 190 pages, $49.75 (1985)

Organic Reactions, Vol. 34, Edited by A. S. Kende, et al; John Wiley & Sons, Inc., Somerset, NJ 08873; 412 pages, $49.95 (1985)

Nitric Acid and Fertilizer Nitrates, Edited by Cornelius Keleti; Marcel Dekker, 270 Madison Ave., New York, NY 10016; 378 pages, $95.00 (1985)

Sixth Symposium on Biotechnology for Fuels and Chemicals, Charles D. Scott, Editor; John Wiley & Sons, Inc., Somerset, NJ 08873; 697 pages, $74.95 (1985)

The Organic Chem Lab Survival Manual: A Students' Guide to Techniques, James W. Zubrick; John Wiley & Sons, Inc., Somerset, NJ 08873; 244 pages (1985)

Flame and Combustion, Second edition, J. A. Barnard and J. N. Bradley: Chapman & Hall, 29 W. 35th St., New York, NY 10001; 308 pages, $55 cloth, $27 paper (1985)

Chemistry of Hydrocarbon Combustion, D. J. Hucknall; Chapman & Hall, 29 West 35th St., New York, NY 10001; 415 pages, $85.00 (1985)

Surface Coatings, Vol. 2—Paints and Their Applications, Oil and Colour Chemists' Assn. of Australia; Chapman & Hall, 29 W. 35th St., New York, NY 10001; 899 pages, $65.00 (1985)