

1 RECOMMENDATIONS FOR STANDARDS

The National Institute for Occupational Safety and Health (NIOSH) recommends that worker exposure to ethylene glycol monomethyl ether (EGME), ethylene glycol monoethyl ether (EGEE), and their acetates, ethylene glycol monomethyl ether acetate (EGMEA) and ethylene glycol monoethyl ether acetate (EGEEA), be controlled in the workplace by complying with the recommendations presented in this Chapter. These recommendations are designed to protect the health and provide for the safety of workers for up to a 10-hr workshift and a 40-hr workweek over a working lifetime. Compliance with all sections of the recommended standard, including the recommended exposure limits (RELs), should prevent or greatly reduce the risk of adverse effects on exposed workers.

SECTION 1.1 RECOMMENDED EXPOSURE LIMITS FOR EGME, EGEE, AND THEIR ACETATES

1.1.1 Exposure

Exposure to EGME and EGMEA in the workplace shall be limited to 0.1 part per million parts of air (0.1 ppm, or 0.3 mg EGME/m³ and 0.5 mg EGMEA/m³) as a time-weighted average for up to 10 hr/day during a 40-hr workweek (10-hr TWA). Exposure to EGEE and EGEEA in the workplace shall be limited to 0.5 ppm (1.8 mg EGEE/m³ and 2.7 mg EGEEA/m³) as a 10-hr TWA. Exposure to these glycol ethers shall be reduced using state-of-the-art engineering controls and work practices.

Dermal contact shall be prohibited because EGME, EGEE, and their acetates are readily absorbed through the skin.

1.1.2 Sampling and Analysis

Workplace air samples shall be collected and analyzed for EGME, EGEE, and their acetates as described by Occupational Safety and Health Administration (OSHA) Method No. 79 [OSHA 1990] (discussed in Section 5.2 and Appendix A) or by any other methods with at least equal accuracy, precision, and sensitivity. The NIOSH Occupational Exposure Sampling Strategy Manual [Leidel et al. 1977] provides guidance for the number of samples to be collected and is discussed in Section 8.8.

SECTION 1.2 EXPOSURE MONITORING

Exposure monitoring shall be conducted as specified in Sections 1.2.1 and 1.2.2. Results of all exposure monitoring shall be recorded and maintained as specified in Section 1.9.

1.2.1 Industrial Hygiene Surveys

In work areas where airborne exposures to EGME, EGEE, or their acetates may occur, the employer shall conduct initial industrial hygiene surveys to determine the magnitude of exposure by using personal sampling techniques for an entire workshift. The employer shall keep records of these surveys. If the employer concludes that exposure concentrations for all glycol ethers are less than one-half the REL, the records must show the basis for this conclusion. Surveys shall be repeated at least annually and whenever any process change is likely to increase concentrations of airborne EGEE, EGME, EGEEA, and EGMEA. The employer shall also look for, evaluate, and record the potential for dermal exposure.

1.2.2 Personal Monitoring

If workers are exposed to any glycol ether at or above one-half the REL, a program of personal monitoring shall be instituted to identify and to measure or calculate the exposure of each worker (see Section 8.8). Source and area monitoring may be a useful supplement to personal monitoring. In all personal monitoring, samples representative of the TWA exposures to airborne glycol ethers shall be collected in the breathing zone of the worker. Procedures for sampling and analysis shall be in accordance with Section 1.1.2. For each determination of an occupational exposure concentration, a sufficient number of samples (as determined in Leidel et al. [1977]), shall be collected to characterize each worker's exposure during each workshift. Although not all workers must be monitored, a sufficient number of samples must be collected to characterize the exposure of all workers. Variations in work and production schedules as well as worker locations and job functions shall be considered when determining sampling locations, times, and frequencies.

If a worker is exposed to EGME, EGEE, or their acetates at concentrations below the REL but at or above one-half the REL, the exposure of that worker shall be monitored at least once every 6 months or more frequently, as indicated by a professional industrial hygienist. If a worker is exposed to one of these glycol ethers at concentrations exceeding the REL, the worker must wear a respirator until adequate engineering controls and/or work practices are instituted. Controls shall then be initiated, the worker shall be notified of the exposure and of the control measures being implemented, and the worker's exposure shall be evaluated at least once a week. Such monitoring shall continue until two consecutive determinations at least 1 week apart indicate that the worker's exposure no longer exceeds the REL. At that time, semiannual monitoring can be resumed; if concentrations of the glycol ethers are less than one-half the REL after two consecutive semiannual surveys, sampling can be conducted annually.

All episodes of skin contact shall be reported to a supervisor. These reports and the results of any investigation or corrective action are to be retained with other records.

1.2.3 Biological Monitoring

Measurement of two glycol ether metabolites—ethoxyacetic acid (EAA, the metabolite of EGEE and EGEEA) and methoxyacetic acid (MAA, the metabolite of EGME and EGMEA)—

may help characterize occupational exposure to EGEE, EGME, and their acetates when the potential exists for airborne concentrations at or above one-half the REL, or for dermal contact from accidental exposure or breakdown of chemical protective clothing (see Section 5). Guidelines for biological monitoring are presented in Appendix G.

SECTION 1.3 MEDICAL MONITORING

The employer shall provide the following information to the physician performing or responsible for the medical monitoring program:

- The requirements of the applicable standard
- An estimate of the worker's potential exposure to glycol ethers, including any available results from workplace sampling
- A description of the worker's duties as they relate to exposure
- A description of any protective equipment the worker may be required to use

1.3.1 General

- The employer shall institute a medical monitoring program for all workers who are exposed to airborne concentrations of EGEE, EGME, or their acetates at or above one-half the REL, or who have the potential for dermal exposure.
- If a worker has had a dermal exposure, the employer shall provide this information to the physician responsible for or performing the medical monitoring program.
- The employer shall ensure that all medical examinations and procedures are performed by or under the direction of a licensed physician.
- The employer shall provide the required medical monitoring at a reasonable time and place without loss of pay or other cost to the workers.
- The employer shall institute a biological monitoring program for all workers who are exposed to airborne concentrations of EGME, EGEE, or their acetates at or above one-half the REL, or who have the potential for dermal exposure. Guidelines for biological monitoring are presented in Appendix G.

1.3.2 Preplacement Medical Examinations

Preplacement medical examinations shall include at least the following:

- A comprehensive medical, work, and reproductive history that emphasizes identification of existing medical conditions (e.g., those affecting the reproductive, hematopoietic, and central nervous systems, skin, liver, and kidneys) and previous occupational exposure to chemical or physical agents

- A medical examination giving special attention to the reproductive, hematopoietic, and central nervous systems, skin, liver, and kidneys
- Routine urinary monitoring for MAA and EAA before job placement, which may be a useful adjunct to environmental monitoring because it indicates both airborne and dermal exposures
- A judgment of the worker's ability to use positive- and negative-pressure respirators

1.3.3 Periodic Medical Examinations

Periodic medical examinations shall be provided at least annually to all workers occupationally exposed to airborne concentrations of EGME, EGEE, and their acetates at or above one-half the REL, and to workers with the potential for dermal exposure. These examinations shall include at least the following:

- An update of medical and work histories
- A medical examination and tests as outlined above

1.3.4 Medical Consultation

Workers who have a dermal exposure or who are exposed to concentrations of EGME, EGEE, or their acetates above the REL should be given the opportunity to consult with a physician regarding possible adverse health effects, including reproductive and developmental effects. OSHA Form 200 shall be modified to include any reports of dermal exposure.

SECTION 1.4 LABELING AND POSTING

All labels and warning signs shall be printed both in English and the predominant language of workers who do not read English. Workers unable to read the labels and warning signs shall be informed verbally regarding the instructions printed on labels and signs in the hazardous work areas of the plant.

1.4.1 Labeling

Containers of EGME, EGMEA, EGEE, or EGEEA used or stored in the workplace shall carry a permanently attached label that is readily visible. The label shall identify the glycol ether and give information regarding its effects on human health and emergency procedures (see Figure 1-1).

1.4.2 Posting

Signs bearing information about the health effects of EGME, EGMEA, EGEE, or EGEEA shall be posted in readily visible positions in work areas and at entrances to work areas or

building enclosures where the potential exists for exposures at or above the REL or where skin exposures may occur (see Figure 1-2).

If respirators and personal protective clothing are needed during the manufacturing or handling of these glycol ethers or during the installation or implementation of required engineering controls, the following statement shall be added in large letters to the signs required in this section:

Respirators and protective clothing are required in this area.

In any area where emergency situations may arise, the required signs shall be supplemented with emergency first-aid procedures and the locations of emergency showers and eyewash fountains.

SECTION 1.5 PROTECTIVE CLOTHING AND EQUIPMENT

Engineering controls and good work practices shall be used to keep the airborne concentrations of EGME, EGEE, and their acetates below the REL and to prevent skin and eye contact. When protective clothing and equipment are needed, they shall be provided by the employer at no cost to the worker.

1.5.1 Eye and Face Protection

The employer shall provide chemical splash-proof safety goggles or face shields (20-cm minimum) with goggles and shall ensure that workers wear the protective equipment during any operation in which splashes of these glycol ethers are likely to occur. Devices for eye and face protection shall be selected, used, and maintained in accordance with 29 CFR* 1910.133 and 30 CFR 56.150004, and 57.150004.

1.5.2 Skin Protection

- Workers at risk of dermal exposure to these glycol ethers shall be provided with appropriate protective clothing such as gloves and disposable clothing. Information presented in Section 8.6.1 provides guidance in the selection of appropriate materials for gloves and clothing.
- Clothing contaminated with these glycol ethers shall be cleaned before reuse. Anyone who handles contaminated clothing or is responsible for its cleaning shall be informed of the hazards of these glycol ethers and the proper precautions for their safe handling and use.

* *Code of Federal Regulations.* See CFR in references.

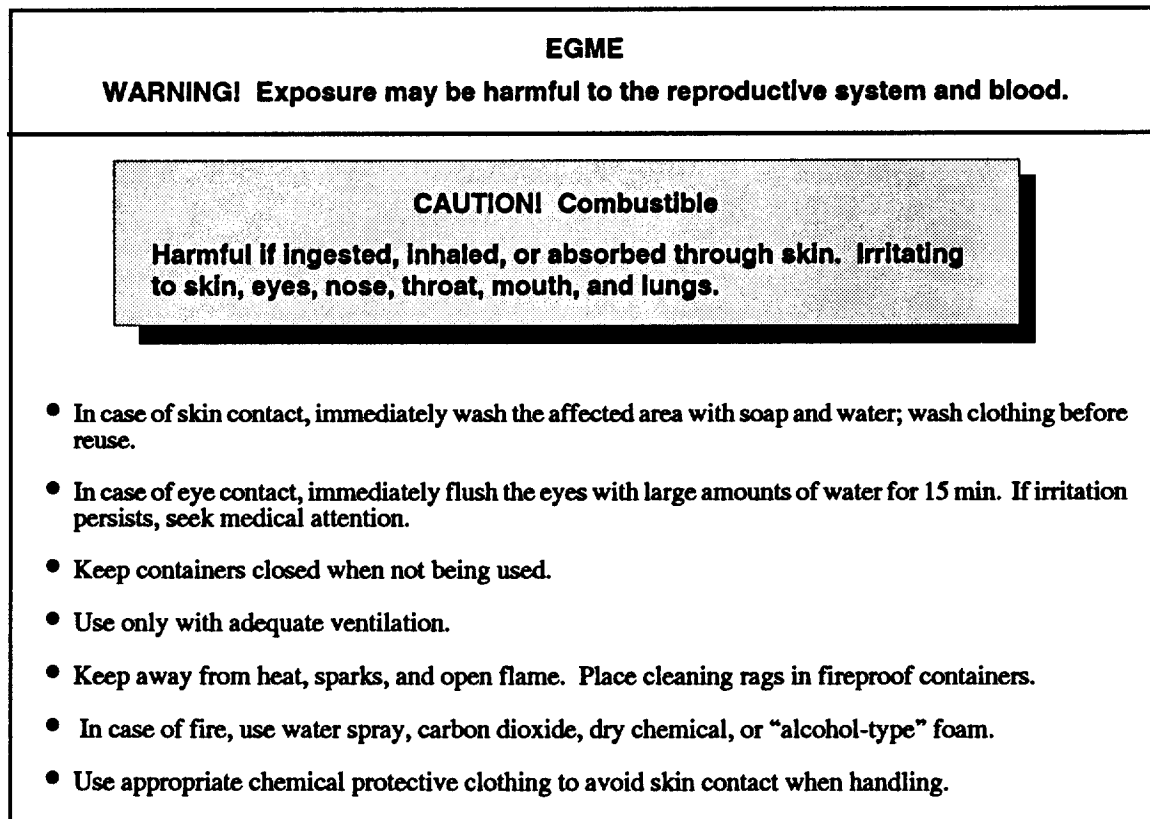


Figure 1-1. Example of a container label identifying the glycol ether and listing information about its effects of human health and emergency procedures.

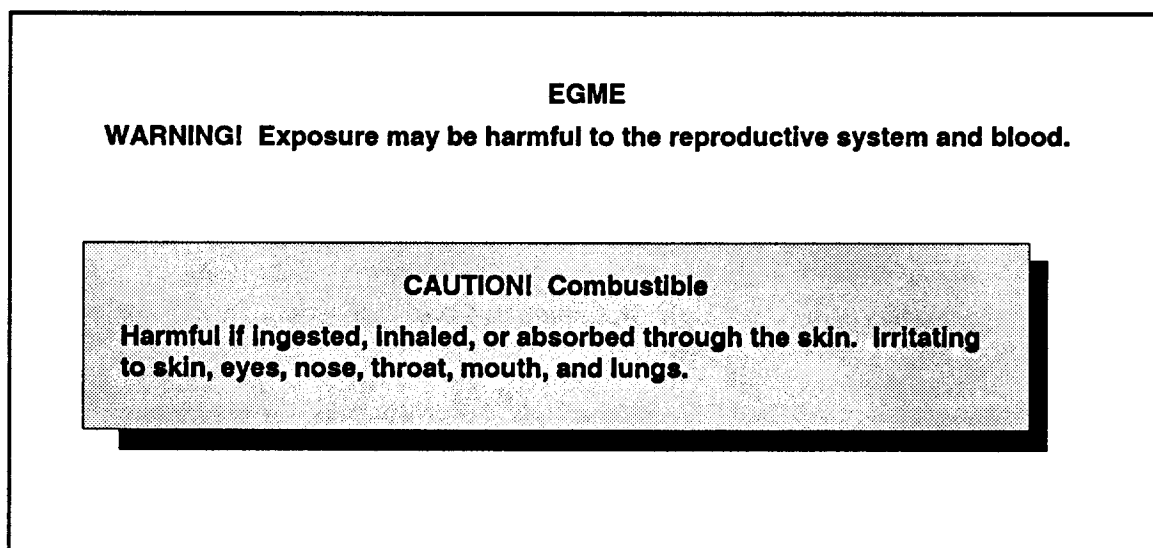


Figure 1-2. Example of a sign containing information about the health effects of a glycol ether.

- The employer shall ensure that all personal protective clothing and equipment is inspected regularly and maintained in a clean and satisfactory working condition.
- Protective clothing or gloves shall be evaluated on a routine basis to ensure that they are in good condition and no breakthrough has occurred.

1.5.3 Respiratory Protection

Engineering controls and good work practices shall be used to control respiratory exposure to airborne contaminants. The use of respirators is the least desirable method of controlling worker exposures and should not be used as the primary control method during routine operations. However, NIOSH recognizes that respirators may be required to provide protection in certain situations such as implementation of engineering controls, short-duration maintenance procedures, and emergencies. Respirator selection guides for protection against EGEE, EGME, and their acetates are presented in Tables 1-1 through 1-3.

- Respirators shall be provided by the employer when such equipment is necessary to protect the health of the worker. The worker shall use the provided respiratory protection in accordance with instructions and training received.
- The employer shall ensure that respirators are properly fitted and that workers are instructed at least annually in the proper use and testing for leakage of respirators assigned to them.
- Workers should not be assigned to tasks requiring the use of respirators unless it has been determined that they are physically able to perform the work and use the equipment. The respirator user's medical status should be reviewed at least annually or more frequently as recommended by the physician responsible for the physical examination. See Appendix H for additional information about the medical aspects of wearing respirators.
- The employer shall be responsible for establishing and maintaining a respiratory protection program as follows:^{*}
 1. Written standard operating procedures governing selection and use of respirators shall be established.
 2. The worker shall be instructed and trained in the proper use of respirators and their limitations.
 3. Where practicable, the respirators should be assigned to individual workers for their exclusive use.

^{*}The OSHA minimum requirements for a respiratory protection program for general industry may be found in 29 CFR 1910.134, and the minimum Mine Safety and Health Administration (MSHA) requirements for the mining industry may be found in 30 CFR 56.5005, 57.5005, 70.305, and 70.305-1.

Table 1-1.—NIOSH-recommended respiratory protection for workers exposed to EGME and EGMEA

Condition	Minimum respiratory protection*
1 ppm or less (10 × REL)	Any supplied-air respirator equipped with a half-mask [†]
2.5 ppm or less (25 × REL)	Any supplied-air respirator equipped with a hood or helmet and operated in a continuous-flow mode
5.0 ppm or less (50 × REL)	Any supplied-air respirator with a full facepiece, or Any self-contained breathing apparatus with a full facepiece
100 ppm or less (1,000 × REL)	Any supplied-air respirator equipped with a half-mask [†] and operated in a pressure-demand or other positive-pressure mode
200 ppm or less (2,000 × REL)	Any supplied-air respirator equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode
Greater than 200 ppm	Any self-contained breathing apparatus equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode, or Any supplied-air respirator equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive-pressure mode
Fire fighting	Any self-contained breathing apparatus equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode
Escape	Any air-purifying, [‡] full-facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister, or Any appropriate escape-type, self-contained breathing apparatus

* Only NIOSH/MSHA-approved equipment shall be used.

[†] If eye irritation occurs, a respirator equipped with full facepiece, helmet, or hood shall be used.

[‡] Air-purifying respirators are used for escape only because EGME and EGMEA do not have good odor-warning properties.

Table 1-2.—NIOSH-recommended respiratory protection for workers exposed to EGEE

Condition	Minimum respiratory protection *
5 ppm or less (10 × REL)	Any supplied-air respirator equipped with a half-mask [†]
12.5 ppm or less (25 × REL)	Any supplied-air respirator equipped with a hood or helmet and operated in a continuous-flow mode
25 ppm or less (50 × REL)	Any supplied-air respirator with a full facepiece, or Any self-contained breathing apparatus with a full facepiece
500 ppm or less (1,000 × REL)	Any supplied-air respirator equipped with a half-mask [†] and operated in a pressure-demand or other positive-pressure mode
1,000 ppm or less (2,000 × REL)	Any supplied-air respirator equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode
Greater than 1,000 ppm	Any self-contained breathing apparatus equipped with a full facepiece operated in a pressure-demand or other positive-pressure mode, or Any supplied-air respirator equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive-pressure mode
Fire fighting	Any self-contained breathing apparatus with a full facepiece and operated in a pressure-demand or other positive-pressure mode
Escape	Any air-purifying, [‡] full-facepiece respirator (gas mask) with a chin-style or front- or back-mounted organic vapor canister, or Any appropriate escape-type, self-contained breathing apparatus

* Only NIOSH/MSHA-approved equipment shall be used.

[†] If eye irritation occurs, a respirator equipped with full facepiece, helmet, or hood shall be used.

[‡] Air-purifying respirators are used for escape only because EGEE does not have good odor-warning properties.

Table 1-3.—NIOSH-recommended respiratory protection for workers exposed to EGEEA

Condition	Minimum respiratory protection *
5.0 ppm or less (10 × REL)	Any air-purifying respirator [†] equipped with organic vapor cartridges, [‡] or Any supplied-air respirator equipped with a half-mask [‡]
12.5 ppm or less (25 × REL)	Any supplied-air respirator operated in a continuous flow mode, [‡] or Any powered, air-purifying respirator [†] equipped with a loose-fitting hood or helmet and an organic vapor cartridge or canister
25 ppm or less (50 × REL)	Any powered, air-purifying respirator [†] equipped with a tight-fitting facepiece and organic vapor cartridges, or Any air-purifying, full-facepiece respirator [†] equipped with organic vapor cartridges or canisters, or Any supplied-air respirator with a full facepiece, or Any self-contained breathing apparatus with a full facepiece
500 ppm or less (1,000 × REL)	Any supplied-air respirator equipped with a half-mask [‡] and operated in a pressure-demand or other positive-pressure mode
1,000 ppm or less (2,000 × REL)	Any supplied-air respirator equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode
Greater than 1,000 ppm	Any self-contained breathing apparatus equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode, or Any supplied-air respirator equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive-pressure mode
Fire fighting	Any self-contained breathing apparatus equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode
Escape	Any air-purifying, full-facepiece respirator [†] (gas mask) with a chin-style or front- or back-mounted organic vapor canister, or Any appropriate escape-type, self-contained breathing apparatus

*Only NIOSH/MSHA-approved equipment shall be used.

[†]Air-purifying respirators should be used with EGEEA (which has good odor-warning properties) only when the other glycol ethers (which have poor odor-warning properties) are not present in the workplace.

[‡]If eye irritation occurs, a respirator equipped with a full facepiece, helmet, or hood shall be used.

4. Respirators shall be regularly cleaned and disinfected.
5. Respirators shall be stored in a convenient, clean, and sanitary location.
6. Respirators used routinely shall be inspected during cleaning. Worn or deteriorated parts shall be replaced. Respirators for emergency use (e.g., self-contained devices) shall be thoroughly inspected at least once a month and after each use.
7. The respiratory protection program shall be regularly evaluated by the employer to determine its continued effectiveness.
8. Additional information about the selection, maintenance, and use of respirators can be found in the *NIOSH Respirator Decision Logic* [NIOSH 1987b] and the *NIOSH Guide to Industrial Respiratory Protection* [NIOSH 1987a].

SECTION 1.6 INFORMING WORKERS ABOUT THE HAZARDS OF GLYCOL ETHERS

1.6.1 Hazard Communication

If workers have the potential for dermal exposure or are assigned to areas where airborne exposures to EGME, EGEE, EGMEA, and EGEEA are one-half or more of the REL, they shall be kept informed of the hazards, relevant signs and symptoms of toxicity, and proper conditions and precautions for the safe use and handling of these glycol ethers. Workers shall be made aware of possible reproductive, developmental, and hematologic effects of exposure to these glycol ethers.

The employer shall notify the worker when exposure exceeds the REL in the work area to which he is assigned.

1.6.2 Training

The employer shall institute a continuing education program conducted by persons qualified by experience or training in occupational safety and health. The program shall ensure that all workers exposed to EGME, EGEE, or their acetates have current knowledge of glycol ether hazards, proper maintenance, cleanup methods, and proper use of protective clothing and equipment, including respirators. The instructional program shall include oral and written descriptions of the environmental and medical monitoring programs and of their advantages to the worker. The employer shall maintain a written plan of these training and monitoring programs. In addition, employers shall follow the OSHA regulations in 29 CFR 1910.1200, Hazard Communication.

Workers shall also be instructed about their responsibilities for following proper work practices and sanitation procedures to help protect their health and provide for their safety and that of their fellow workers.

All workers in areas where exposure to EGME, EGEE, or their acetates may occur during spills or emergencies shall be trained in proper emergency and evacuation procedures.

1.6.3 File of Written Hazard Communication

Required information shall be recorded on the material safety data sheet (see example in Appendix D) or on a similar OSHA form that describes the relevant toxic, physical, and chemical properties of the glycol ethers and mixtures of glycol ethers that are used or otherwise handled in the workplace. This information shall be kept on file and shall be readily available to workers for examination and copying.

SECTION 1.7 ENGINEERING CONTROLS AND WORK PRACTICES

1.7.1 Engineering Controls

Engineering controls shall be used as needed to maintain exposure to airborne glycol ethers within the limits prescribed in Chapter 1.

1.7.1.1 Local Exhaust Ventilation

Local exhaust ventilation may be effective when used alone or in combination with process enclosure. When a local exhaust ventilation system is used, it shall be designed and operated to prevent accumulation or recirculation of airborne glycol ethers in the workplace. Exhaust ventilation systems discharging to outside air shall conform with applicable local, State, and Federal air pollution regulations and shall not constitute a hazard to workers or to the general population. Before maintenance work on control equipment begins, the generation of airborne glycol ethers shall be eliminated to the greatest extent feasible.

1.7.1.2 Maintaining Design Airflow

Enclosures, exhaust hoods, and ductwork shall be kept in good repair to maintain designed airflows. Measurements such as capture velocity, duct velocity, or static pressure shall be made at least semiannually, and preferably monthly, to demonstrate the effectiveness (quantitatively, the ability of the control system to maintain exposures below the REL) of the mechanical ventilation system. NIOSH recommends the use of continuous airflow indicators such as water or oil manometers marked to indicate acceptable airflow. A record shall be kept showing design airflow and the results of all airflow measurements. Measurements of the effectiveness of the system in controlling exposures shall also be made as soon as possible after any change in production, process, or control devices that may increase airborne concentrations of EGME, EGEE, and their acetates.

1.7.1.3 Forced-draft Ventilation

Forced-draft ventilation systems shall be equipped with remote manual controls and should be designed to shut off automatically in the event of a fire.

1.7.2 General Work Practices

- Operating instructions for all equipment shall be developed and posted where EGME, EGEE, and their acetates are handled or used.
- Transportation, use, and disposal of these glycol ethers shall comply with all applicable local, State, and Federal regulations.
- These glycol ethers shall be stored in tightly closed containers and in well-ventilated areas.
- Containers shall be moved only with the proper equipment and shall be secured to prevent loss of control or dropping during transport.
- Storage facilities shall be designed to prevent contamination of workroom air and to contain spills completely within surrounding dikes.
- Ventilation switches and emergency respiratory equipment shall be located outside storage areas in readily accessible locations.
- Process valves and pumps shall be readily accessible and shall not be located in pits or congested areas.
- Glycol ether containers and systems shall be handled and opened with care. Approved protective clothing and equipment as specified in Section 1.5 shall be worn by workers who open, connect, and disconnect glycol ether containers and systems. Adequate ventilation shall be provided to minimize exposures of such workers to airborne glycol ethers.
- Glycol ether storage equipment and systems shall be inspected daily for signs of leakage. All equipment, including valves, fittings, and connections, shall be checked for leaks immediately after glycol ethers are introduced therein.
- When a leak is found, it shall be repaired promptly. Work shall resume normally only after necessary repair or replacement has been completed and the area has been well ventilated.

1.7.3 Confined or Enclosed Spaces

- A permit system shall be used to control entry into confined or enclosed spaces holding containers of glycol ethers (e.g., tanks, pits, tank cars, and process vessels) where egress is limited. Permits shall be signed by an authorized representative of the employer and shall certify that preparation of the confined space, precautionary measures, and personal protective equipment are adequate and that precautions have been taken to ensure that prescribed procedures will be followed.
- Confined spaces that hold containers of EGME, EGEE, and their acetates shall be thoroughly ventilated, inspected, and tested for oxygen deficiency and for airborne concentrations of these glycol ethers. Every effort shall be made to prevent the

inadvertent release of hazardous amounts of these glycol ethers into confined spaces in which work is in progress. Glycol ether supply lines shall be disconnected or blocked off before such work begins.

- No worker shall enter a confined space holding containers of glycol ethers without an entry large enough to admit a worker wearing a safety harness, lifeline, and appropriate personal protective equipment as specified in Section 1.5.
- Confined spaces shall be ventilated while work is in progress to keep the concentration of glycol ethers below the RELs, to keep the concentration of other contaminants below toxic or dangerous levels, and to prevent oxygen deficiency.
- If the concentrations of these glycol ethers in the confined space exceed the RELs, respiratory protective equipment is required for entry.
- Anyone entering a confined space shall be observed from the outside by another properly trained and protected worker. An additional supplied-air or self-contained breathing apparatus with safety harness and lifeline shall be located outside the confined space for emergency use. The person entering the confined space shall maintain continuous communication with the standby worker.

1.7.4 Emergency Procedures

Emergency plans and procedures shall be developed for all work areas where there is a potential for exposure to EGME, EGEE, and their acetates. These plans and procedures shall include those specified below and any others considered appropriate for a specific operation or process. Workers shall be instructed in the effective implementation of these plans and procedures.

- The following steps shall be taken in the event of a leak or spill of these glycol ethers:
 - All nonessential personnel shall be evacuated from the leak or spill area.
 - Persons not wearing the appropriate protective equipment and clothing shall be restricted from the leak or spill area until cleanup has been completed.
 - All ignition sources shall be removed.
 - The area where the leak or spill occurs shall be adequately ventilated to prevent the accumulation of vapor.
 - EGME, EGEE, EGMEA and EGEEA shall be contained and absorbed with vermiculite, sand, paper towels, or equivalent materials.
 - Small quantities of absorbed material shall be placed under a fume hood and sufficient time shall be allowed for the liquid to evaporate and for the vapors to clear the ductwork in the hood.

- Large quantities of absorbed material shall be burned in a suitable combustion chamber.
- Absorbed materials shall be disposed of as hazardous waste.
- The spill area shall be cleaned with water.
- Only personnel trained in the emergency procedures and protected against the attendant glycol ether hazards shall clean up spills and control and repair leaks.
- Personnel entering the spill or leak area shall be furnished with appropriate personal protective clothing and equipment. Other personnel shall be prohibited from entering the area.
- Safety showers, eyewash fountains, and washroom facilities shall be provided, maintained in working condition, and made readily accessible to workers in all areas where skin or eye contact with EGME, EGEE, EGMEA, or EGEEA is likely. If one of these glycol ethers is splashed or spilled on a worker, contaminated clothing shall be removed promptly, and the skin shall be washed thoroughly with soap and water. Eyes splashed by these glycol ethers shall be irrigated immediately with a copious flow of water for 15 min. If irritation persists, the worker should seek medical attention.

1.7.5 Storage

EGME, EGEE, and their acetates shall be stored in cool, well-ventilated areas and kept away from acids, bases, and oxidizing agents.

1.7.6 Waste Disposal

All waste material shall be securely packaged in double bags, labeled, and incinerated. The incinerator residue shall be disposed of in a manner consistent with Federal (EPA), State, and local regulations, or it shall be disposed of in a licensed hazardous waste landfill.

1.8 SANITATION AND HYGIENE

1.8.1 Food, Cosmetics, and Tobacco

The following shall be prohibited in areas where EGME, EGEE, EGMEA, or EGEEA is produced or used: the storage, preparation, dispensing, or consumption of food or beverages; the storage or application of cosmetics; and the storage or use of all tobacco products.

1.8.2 Handwashing

The employer shall provide handwashing facilities and encourage workers to use them before eating, smoking, using the toilet, or leaving the worksite.

1.8.3 Laundering

- Protective clothing, equipment, and tools shall be cleaned periodically.
- The employer shall provide for the cleaning, laundering, or disposal of contaminated work clothing and equipment.
- Any person who cleans or launders this work clothing or equipment must be informed by the employer that it may be contaminated with EGME, EGEE, EGMEA, or EGEEA—chemicals that may cause adverse reproductive, developmental, hematologic (blood), and central nervous system (CNS) effects.

1.8.4 Cleanup of Work Area

The work area shall be cleaned at the end of each shift (or more frequently if needed) using vacuum pickup. Collected wastes shall be placed in sealed containers with labels that indicate the contents. Cleanup and disposal shall be conducted in a manner that prevents worker contact with wastes and complies with all applicable Federal, State, and local regulations.

1.8.5 Showering and Changing Facilities

Workers shall be provided with quick-drench shower facilities and with facilities for showering and changing clothes at the end of each workshift.

1.9 RECORDKEEPING

1.9.1 Exposure Monitoring

The employer shall establish and maintain an accurate record of all exposure measurements required in Section 1.2. These records shall include the name of the worker being monitored, social security number, duties performed and job locations, dates and times of measurements, sampling and analytical methods used, type of personal protection used (if any), and number, duration, and results of samples taken.

1.9.2 Medical Monitoring

The employer shall establish and maintain an accurate record for each worker subject to the medical monitoring specified in Section 1.3. Pertinent medical records (i.e., the physician's written statement, the results of medical examinations and tests, medical complaints, reports of skin exposure, etc.) shall be retained in the medical files of all workers subject to airborne concentrations of EGME, EGEE, EGMEA, or EGEEA in the workplace at or above one-half the REL. Copies of applicable environmental monitoring data shall also be included in the worker's medical file.

1.9.3 Record Retention

In accordance with the requirements of 29 CFR 1910.20(d) (Preservation of Records), the employer shall retain the records described in Sections 1.2, 1.3, and 1.6 for at least the following periods:

- 30 years for exposure monitoring records, and
- the duration of employment plus 30 years for medical surveillance records

1.9.4 Availability of Records

- In accordance with 29 CFR 1910.20 (Access to Employee Exposure and Medical Records), the employer shall allow examination and copying of exposure monitoring records by the subject worker, the former worker, or anyone having the specific written consent of the subject or former worker.
- Any medical records required by this recommended standard shall be provided upon request for examination and copying to the subject worker, the former worker, or anyone having the specific written consent of the subject or former worker.

1.9.5 Transfer of Records

If the employer ceases to do business and no successor is available to receive and retain the records for the prescribed period, the employer shall notify the Director of NIOSH at least 3 months before record disposal and transmit them to the Director if instructed to do so [29 CFR 1910.1028].

2 INTRODUCTION

2.1 PURPOSE

This document presents the criteria and recommended standards necessary to prevent health impairment from exposure to ethylene glycol monomethyl ether (EGME), ethylene glycol monomethyl ether acetate (EGMEA), ethylene glycol monoethyl ether (EGEE), and ethylene glycol monoethyl ether acetate (EGEEA). The document was developed in accordance with Section 20(a)(3) of the Occupational Safety and Health (OSH) Act of 1970. In this Act, the National Institute for Occupational Safety and Health (NIOSH) is charged with developing criteria for toxic materials and harmful physical agents, and describing exposure concentrations at which no worker will suffer impaired health or functional capacities or diminished life expectancy as a result of work experience. This document also responds to Section 2.2(c)(1) of the OSH Act, which authorizes NIOSH to develop and establish recommended occupational safety and health standards.

NIOSH has formalized a system for developing criteria on which to base standards for ensuring the health and safety of workers exposed to hazardous chemical and physical agents. Simple compliance with these standards is not the only goal. The criteria and recommended standards are intended to help management and labor develop better engineering controls and more healthful work practices.

Recommended standards for EGEE, EGME, EGEEA, and EGMEA apply only to workplace exposures arising from the processing, manufacturing, handling, and use of these glycol ethers. The recommendations are not designed for the population at large, and any extrapolation beyond the occupational environment may not be warranted. The recommended standards are intended to protect workers from the acute and chronic effects of EGEE, EGME, EGEEA, and EGMEA. Exposure concentrations are measurable by techniques that are valid, reproducible, and available to industry and government agencies.

2.2 SCOPE

The information in this document assessed the hazards associated with occupational exposure to EGEE, EGME, EGEEA, and EGMEA. Chapter 1 presents the recommended standards and describes their requirements. Chapter 3 gives information about the chemical and physical properties of EGEE, EGME, EGEEA, and EGMEA, production methods, uses, and the extent of worker exposure. Chapter 4 discusses and summarizes the effects of exposure to these glycol ethers on humans and animals. Subsequent chapters describe environmental sampling and analytical methods, medical monitoring, biological monitor-

ing, existing occupational health standards, and a correlation of exposure and effect. In addition, methods for worker protection are discussed, including suggested work practices, engineering controls, personal protective clothing and equipment, and exposure monitoring and recordkeeping.

3 PROPERTIES, PRODUCTION, AND POTENTIAL FOR EXPOSURE

3.1 CHEMICAL AND PHYSICAL PROPERTIES

EGME, EGMEA, EGEE, and EGEEA are part of a family of ethylene glycol monoalkyl ethers represented by the general formula $R_1OCH_2CH_2OR_2$ where R_1 represents the alkyl moiety and R_2 either H or acetate. In this document, unless otherwise specified, the term "glycol ethers" will refer to EGME, EGEE, and their acetates.

EGME (ethylene glycol monomethyl ether), also known as methyl Cellosolve[®], 2-methoxyethanol (2-ME), or Jeffersol EM[®] [NIOSH 1987c], is an organic compound with the chemical formula $CH_3OCH_2CH_2OH$. It is a colorless liquid with a mild, nonresidual odor; the odor threshold is 2.3 ppm [Amoore and Hautala 1983]. EGME is miscible with water and many organic solvents.

EGMEA (ethylene glycol monomethyl ether acetate), also known as methyl Cellosolve[®] acetate or 2-methoxyethyl acetate (2-MEA), is the acetate ester of EGME with the chemical formula $CH_3OCH_2CH_2OCOCH_3$ and is prepared by esterifying EGME with acetic acid. It is a colorless liquid with a mild, ether-like odor; no data are available on the odor threshold of EGMEA. It is miscible in water and with many organic solvents.

EGEE (ethylene glycol monoethyl ether), also known as Cellosolve[®], 2-ethoxyethanol (2-EE), or Jeffersol EE[®] [NIOSH 1987c], is an organic compound with the chemical formula $C_2H_5OCH_2CH_2OH$. It is a colorless liquid with a sweetish odor; the odor threshold is 2.7 ppm [Amoore and Hautala 1983]. EGEE is miscible with water and many organic solvents.

EGEEA (ethylene glycol monoethyl ether acetate), the acetate ester of EGEE, is also known as Cellosolve[®] acetate, 2-ethoxyethyl acetate (2-EEA), and has the chemical formula $C_2H_5OCH_2CH_2OCOCH_3$. It is a colorless liquid with a mild, nonresidual odor; the odor threshold is 0.056 ppm [Amoore and Hautala 1983]. EGEEA has a low solubility in water, but is miscible with many organic solvents.

Other chemical and physical properties are listed in Table 3-1.

3.2 PRODUCTION METHODS AND USES

The ethylene glycol monoalkyl ethers EGME and EGEE are usually produced by a reaction of ethylene oxide with methyl or ethyl alcohol, but may also be made by the direct alkylation

Table 3-1.—Chemical and physical properties of EGME, EGMEA, EGEE, and their acetates*

Property	EGME	EGMEA	EGEE	EGEEA
RTECS [†] number	KL5775000	KL5950000	KK8050000	KK8225000
CAS [‡] number	109-86-4	110-49-6	110-80-5	111-15-9
Molecular formula	C ₃ H ₈ O ₂	C ₅ H ₁₀ O ₃	C ₄ H ₁₀ O ₂	C ₆ H ₁₂ O ₃
Molecular weight	76.1	118.1	90.1	132.2
Specific gravity 25°/4°C	0.962	1.007	0.926	0.975
Evaporation rate (butyl acetate = 1.00)	0.62	0.30	0.41	0.2
Boiling point (°C)	124.2	144.5	135.0	156.3
Freezing point (°C)	-85	-65.1	-100	-61.7
Vapor pressure (mm Hg 25°C)	9.7	2.0-3.7	5.75	2.8
Refractive index	1.400	1.402	1.406	1.406
Flash point (°C), closed cup	39	49	43	52
Autoignition temperature (°C)	285	392	235	379
Flammability limits (vol. % in air)	1.8-14.0	1.5-12.3	1.70-15.6	1.7
Water solubility (% by weight)	Miscible	Miscible	Miscible	23
Vapor density (air = 1)	2.6	4.1	3.1	4.6
ppm in saturated air (25°C)	12,800	2,600-4,900	7,600	3,700
mg/m ³ at 25°C, 760 mm Hg = 1 ppm	3.11	4.83	3.69	5.41
ppm at 25°C, 760 mm Hg = 1 mg/m ³	0.32	0.21	0.27	0.19

*Adapted from Rowe and Wolf [1982], UCC [1983], NFPA [1987].

[†]Registry of Toxic Effects of Chemical Substances [NIOSH 1987c].

[‡]Chemical Abstract Services.

of ethylene glycol with an alkylating agent such as dimethyl or diethyl sulfate [Rowe and Wolf 1982]. Temperature, pressure, reactant molar ratios, and catalysts are selected to give the product mix desired. Ethylene glycol monoalkyl ethers are not formed as pure compounds, but must be separated from the diethers of diethylene glycol, triethylene glycol, and the higher glycols. Ethylene glycol monoalkyl ether acetates are prepared by esterifying the particular glycol ether with acetic acid, acetic acid anhydride, or acetic acid chloride.

Glycol ethers and their acetates are widely distributed and have been used commercially for more than 50 years. Table 3-2 presents production figures for these glycol ethers. The most important single use of EGME is as a jet fuel deicer [Meridian Research, Inc. 1987]. Because military jets lack the inline deicers found on commercial jets, all JP-4 jet fuel contains 0.1% to 0.2% EGME as a deicing agent. JP-5, a new jet fuel, uses 0.15% diethylene glycol monomethyl ether (DEGME) in place of EGME as a deicer [Meridian Research, Inc. 1987]. EGME is also used in the manufacture of printed circuit boards, as an intermediate in the manufacture of plasticizers, in inks and coatings, and in photography and dyeing applications. EGMEA is a low production chemical that is used as an intermediate for plasticizers and also in specialty solvent applications. Approximately 50% of EGEE produced is utilized as a chemical intermediate for EGEEA production; it is also used as a solvent for surface coatings (especially those based on epoxy resins) and as a solvent in cleaning and printing ink formulations. EGEEA is used as a solvent in coating applications for automobiles, coils, machinery and equipment, and metal furniture and appliances.

3.3 PROCESS AND WORKER JOB DESCRIPTIONS

The usefulness of glycol ethers and their acetate derivatives can be attributed to their physical properties, particularly their miscibility or high solubility in water and other organic solvents, and their low vapor pressures. These properties allow them to serve a number of functions in a variety of products. The following information was obtained during surveys conducted in various industries to determine occupational exposures to glycol ethers [Cal OSHA 1983; Meridian Research, Inc. 1987].

3.3.1 Paints and Coatings

Although frequently comprising less than 10% of the final product, glycol ethers serve a variety of important functions in paints and coatings. One function is as a solvent to keep

Table 3-2.—U.S. production of EGME, EGEE, and their acetates*

Compound	Production (lb)
EGME	79,849,000
EGMEA	1,000,000
EGEE	121,808,000
EGEEA	84,028,000

*Sources: TSCAPP [1977], Industrial Economics, Inc. [1985], and USITC [1986].

the various paint components in solution. Latex coatings contain glycol ethers or their acetate derivatives to enhance the coalescing properties of the product when applied. By slowing the evaporation rate, glycol ethers reduce moisture condensation or "blush." They also improve the penetration and bonding qualities of paints and coatings. Specialty products, such as aircraft or electrostatic paints, may contain 18% to 35% glycol ethers [Cal OSHA 1983].

The manufacture of paints and coatings is a batch process. Components are added manually or through a closed piping system to the mixing tank. Because glycol ethers generally constitute a small percentage of the total formulation, they are often added manually. After mixing, the product is packaged according to customer specifications. Maximum exposures occur during weighing, mixing, and filling operations. During the compounding and mixing of a batch, exposures to the glycol ethers are low, mainly due to low vapor pressures and short exposure times. If ventilation is required to control other more volatile components, glycol ether exposures will be coincidentally reduced. During filling operations, exposures depend on whether the process is manual or automated and vary with the size of the containers [Cal OSHA 1983].

A variety of industries use paints and coatings, but as previously noted, these products usually contain a small percentage of glycol ethers (i.e., less than 10%). Lacquer containing less than 1% glycol ethers is used to coat wood products. However, electrostatic paints used in a spraying process for metal parts may contain 20% to 30% glycol ethers. Glycol ethers are also used in the manufacture of coated fabrics. These fabrics pass through a dip pan to pick up the coating and then rise through a ventilated drying tower [Cal OSHA 1983].

The use of EGEE and EGME in protective coatings declined by more than 80% and 50%, respectively, between 1980 and 1984. Reformulation has virtually eliminated the use of EGEE, EGME, EGEEA, and EGMEA in consumer paints [Meridian Research, Inc. 1987].

3.3.2 Inks

Printing inks and solutions are formulated in batch-type operations and hence exposures are similar to those found in the manufacture of paints and coatings. Glycol ethers modify the drying rate, viscosity, fluidity, and penetrative ability of inks. Flexographic inks, such as alcohol-dilutable inks, acrylic inks, and water-based inks, contain glycol ethers in low concentrations, usually 5% to 10%. Ballpoint and marker inks may contain as much as 40% glycol ethers. Glycol ethers are also found in printing chemicals (e.g., "fountain solutions").

Printing press operators can receive exposure to glycol ethers through inhalation as well as skin contact because of their intimate contact with printing materials and machinery. Glycol ethers are used in several phases of printing and silkscreening operations. A few ounces used as a retarding agent may be added directly to the ink tray or pan, which is often left uncovered. Press and plate cleaning solvents may also contain glycol ethers. The most extensive dermal contact occurs when trays and other parts of the press are cleaned [Cal OSHA 1983].

In recent years, ink companies have reformulated away from glycol ethers. The use of EGEE in printing inks declined by 60% between 1977 and 1984 [Meridian Research, Inc. 1987].

3.3.3 Cleaners and Cleaning Solvents

Cleaning agents that contain glycol ethers are spot removers, carburetor cleaners, metal cleaners, and glass cleaners. In these products, glycol ethers function as surface active agents, enhancing the penetration of the product, clarifying the appearance, and in glass cleaners, increasing the viscosity. The percentage of glycol ethers in these products is less than 5% [Cal OSHA 1983].

3.4 NUMBER OF WORKERS POTENTIALLY EXPOSED

Based on information from the National Occupational Exposure Survey (NOES) [NIOSH 1983c], the estimated number of workers potentially exposed to glycol ethers in the workplace during the period 1981 to 1983 is as shown in Table 3-3. Among industries labeled by the 4-digit Standard Industrial Code (SIC), 34 were identified as having workers potentially exposed to EGEE, 26 to EGEEA, 24 to EGME, and 10 to EGMEA. NOES identified 102 occupations in which workers were potentially exposed to EGEE, 99 to EGEEA, 80 to EGME, and 27 to EGMEA. Table 3-4 presents the six industries and six occupations with the most workers potentially exposed to EGEE, EGME, and their acetates.

Appendix C presents representative information about the occurrence of airborne EGEE, EGME, and their acetates in the workplace.

Table 3-3.—Estimated number of U.S. workers potentially exposed to EGME, EGEE, and their acetates*

Compound	Number of workers
EGME	130,608
EGMEA	9,892
EGEE	247,691
EGEEA	244,639

*Source: NIOSH [1983c].

Table 3-4.—Six industries and six occupations with the most workers potentially exposed to EGEE, EGME, and their acetates*

Compound and industry	Workers exposed		Compound and occupation	Workers exposed	
	Number	% of total		Number	% of total
EGEE:†			EGEE:†		
Health services	40,893	16.5	Janitors and cleaners	40,086	16.2
Business services	26,476	10.7	Printing machine operators	19,321	7.8
Printing and publishing	23,634	9.5	Assemblers	15,747	6.4
Instruments and related products	19,419	7.8	Miscellaneous machine operators, N.E.C.	11,513	4.6
Rubber and miscellaneous plastic products	16,781	6.8	Registered nurses	10,988	4.4
Chemicals and allied products	14,251	5.8	Engineers, N.E.C.	8,805	3.6
EGEEA:‡			EGEEA:‡		
Printing and publishing	37,431	15.3	Painting and paint spraying machine operator	27,924	11.4
Transportation equipment	30,256	12.4	Printing machine operators	23,191	9.5
Transportation by air	16,143	6.6	Assemblers	17,412	7.1
Special trade contractors	11,934	4.9	Laborers, except construction	9,823	4.1
Electric and electronic equipment	11,892	4.8	Machine operators, not specified	9,783	4.0
Machinery, except electrical	11,702	4.7	Hand packers and packagers	9,190	3.8
EGME:§			EGME:§		
Chemicals and allied products	29,014	22.2	Assemblers	21,844	16.7
Business services	22,537	17.3	Janitors and cleaners	20,379	15.9
Printing and publishing	16,619	12.7	Printing machine operators	10,874	8.3
Machinery, except electrical	11,047	8.5	Machinists	7,325	5.6
Fabricated metal products	10,697	8.2	Typesetters and compositors	5,416	4.1
Paper and allied products	6,934	5.3	Chemists, except biochemists	5,267	4.0

(Continued)

See footnotes at end of table.

Table 3-4 (Continued).—Six industries and six occupations with the most workers potentially exposed to EGEE, EGME, and their acetates

Compound and industry	Workers exposed		Compound and occupation	Workers exposed	
	Number	% of total		Number	% of total
EGMEA:**			EGMEA:**		
Fabricated metal products	3,142	31.8	Assemblers	2,775	28.1
Electric and electronic equipment	1,743	17.6	Janitors and cleaners	1,160	11.7
Miscellaneous manufacturing industries	1,605	16.2	Packaging and filling machine operators	783	7.9
Chemicals and allied products	1,276	12.9	Metal plating machine operators	638	6.4
Machinery, except electrical	938	9.5	Miscellaneous machine operators, N.E.C.	592	6.0
Rubber and miscellaneous plastics products	465	4.7	Hand engraving and printing	526	5.3

* Source: NIOSH [1983b].

† Total workers exposed to EGEE = 247,691.

‡ Total workers exposed to EGEEA = 244,639.

§ Total workers exposed to EGME = 130,608.

** Total workers exposed to EGMEA = 9,892.