V. OCCUPATIONAL EXPOSURE LIMITS

The current U.S. standard (OSHA) for occupational exposure to ethylene oxide is 50 parts per million (ppm) parts of air, which corresponds approximately to 90 mg/cu m, as an 8 hour time-weighted average concentration, with no ceiling level stipulated. [29 CFR 1910.1000]. This standard was adopted from the standards established by the American National Standards Institute (ANSI). An identical exposure limit, the Threshold Limit Value (TLV), had been adopted by the American Conference of Governmental Industrial Hygienists (ACGIH, 1957).

The USSR has a standard of 0.5 ppm (1 mg/cu m), which was adopted in 1966 [Winell, 1975]. Occupational exposure standards of 50 ppm and 20 ppm (36 mg/cu m) are recommended by the Federal Republic of Germany and Sweden, respectively [ICF Conf., 1975].

Table 8 lists the federal standard and the ACGIH recommended TLV and short term exposure limits ("STEL") for ETO. The exposure limits for certain hydration and reaction products of ETO, i.e. ethylene chlorohydrin and ethylene glycol, are listed. Also shown for comparison are the exposure levels published by the Federal Republic of Germany, Sweden, and the USSR.

NIOSH recommends, based on the recent results of tests for mutagenesis, that exposure be controlled so that workers are not exposed to ETO at a concentration greater than 135 mg/cu m (75 ppm) determined during a 15-minute sampling period, as a ceiling occupational exposure limit and, in addition, with the provision that the TWA concentration limit of 90 mg/cu m (50 ppm) for a work-day not be exceeded. As additional information on the toxic effects of ETO becomes available, this recommended level for exposures of short duration may be altered. The adequacy of the current U.S. ETO standard, which was based on the data available at the time of promulgation, has not been addressed in this report. Further assessment of other ETO exposure situations, and of the adequacy of the ETO occupational exposure standard will be undertaken during the FY 80 development of the NIOSH Criteria Document on epoxides (including ETO). In the interim, NIOSH strongly recommends that the control strategies presented herein, or others considered to be more applicable to particular local situations, be implemented to assure maximum protection of the health of employees. Good work practices will help to assure their safety.

Table 8. Occupational Exposure Limits for ETO and Some Hydration and Reaction Products

Substance		TWA Values ppm (a)	TWA Values mg/cu m (b)	Tenative Values STEL** ppm	Tenative Values STEL** mg/cu m
Ethylene Oxide	U.S. Federal Std.	50	90		
	ACHIH TLV (Rec.)	50	90	75	135
	German (FRG) Std.	50	90		
	Swedish Std.	20	36		
	USSR level	0.5	1		
Ethylene Chlorohydrin	U.S. Federal Std.	5	16		
	ACGIH TLV (*), (C), skin, (Rec.)	1	3	1	3
	German (FRG) Std.	5	16		
Ethylene Glycol					
particulate	ACGIH TLV	---	10	---	20
vapor	ACGIH TLV	100	250	125	325

Notes and definitions:
For ETO: 1 ppm is approx. equal to 1.80 mg/cu m at 25 C, and 760 mm Hg, 1 mg/l is approx. equal to 556 ppm at 25 c. and 760 mm Hg.
(*) Indicates 1976 additions to the TLV listing.
(C) Threshold Limit Value - Ceiling. The concentration that should not be exceeded even instantaneously.
a) Parts of a vapor or gas per million parts of contaminated air, by vol. at 25 degrees C and 760 mm Hg press.
b) Approximate mg of substance per cu. m . of air.
Rec. = Recommendation.
** "STEL" - Short term exposure limit (recommended by the ACGIH as a "maximal concentration to which workers can be exposed for a period up to 15 minutes continously..." provided that no more than four excursions per day are permitted, with at least 60 minutes between exposure periods..."
TLV = Threshold Limit Value, as proposed by ACGIH.
TWA - Time Weighted Average over 8 hour work shift.
"Skin" notation refers to the potential contributors to the overall exposure by the cutaneous route (including mucous membranes and eye), either by airborne, or more particularly, by direct contact with the substance. Vehicles can alter skin absorption. This designation was intended by the TLV Committee to suggest appropriate measures for the prevention of cutaneous absorption so that the threshold limit is not invalidated.

VI. HAZARDS, CONTROL MEASURES, MEDICAL SURVEILLANCE, AND RECORD KEEPING

A. Hazards and Precautions, Prevention, and Emergency Procedures

1. Fire, Explosion and Reactivity Data

Ethylene oxide is an extremely volatile, flammable liquid with a vapor that forms explosive mixtures with air over a wide range of concentrations (3-100% in air by volume, i.e. 30 thousand ppm and above). Because of its extreme flammability, the following safeguards should be taken in areas where ETO is used as a sterilant:

a. All ignition sources, including static electricity, should be controlled where ETO is in use.

b. Foam, carbon dioxide, or dry chemical fire extinguishers should be readily accessible (a solid stream of water will scatter and spread the fire). If a hose is provided for use against fire, it should be equipped with a fogging nozzle.

c. Where a fan is located in ductwork in which ETO is present in a concentration greater than 7,500 ppm (approximately 25% of the lower flammable limit), the fan blades and appropriate parts of the ventilation system should be made of a nonsparking material. The motor should be explosion-proof.

d. Automatic water spray systems should be provided to cool the sterilizing equipment in case of a nearby fire.

e. Low pressure steam or hot water should be used for heating ETO or mixtures in which ETO is used.

f. ETO not in immediate use in a sterilizing unit should be stored away from heat and strong oxidizers, strong acids, alkalies, anhydrous chlorides of iron, aluminum, or tin, iron oxide, and aluminum oxide.

2. Spill, Leak, and Disposal Procedures

If ETO is spilled or leaks, the following steps should be immediately taken:

a. Evacuate all but those persons necessary for clean-up activities.

b. Remove all ignition sources.

c. Ventilate the area of the spill or leak.

d. If in the gaseous form, stop the flow of gas. If the source of leak is a gas cylinder and the leak cannot be stopped in place, remove the leaking cylinder to a safe place in the open air and repair the leak or allow the cylinder to empty.

e. If in the liquid form, absorb small quantities on paper towels. Evaporate in a safe place (e.g., a fume hood).

ETO should not be allowed to enter a confined space, such as a sewer, because of its toxicity and the possibility of an explosion. Further, in the clean-up of leaks or spills and maintenance or repair operations on contaminated systems or equipment, authorized personnel should be required to wear respirators and other protective clothing (including gloves). (see Section B.2.)

3. Sanitation Practices

Appropriate sanitation practices should be instituted in ETO work areas and should include the following:

a. Clothing which becomes wet with liquid ETO should be removed as soon as possible and placed in sealed containers for storage until it can be discarded (into a decontamination furnace) or decontaiminated for reuse by laundering, steaming, or comparably effective treatment. If laundering is to be performed by a commercial establishment, the manager of that establishment should be informed by the employer at the ETO work area of the hazards of exposure to ETO either in or on contaminated clothing or vaporized into the air, and of the precautions to be taken.

b. Persons involved with handling and/or treatment of ETO-contaminated clothing should be informed of the hazard and should take appropriate precautions.

c. Employees whose skin becomes contaminated with ETO should immediately wash or shower to remove any ETO from the skin.

d. Employees who handle ETO should wash their hands thoroughly before eating, smoking, or using toilet facilities.

B. Recommendations for Control of Hazardous Exposure Situations

1. Posting of Signs

Entrances to areas where ETO is used as a sterilant should be posted with signs indicating:

DANGER:
AUTHORIZED PERSONNEL ONLY
ETHYLENE OXIDE AREA
EXTREMELY FLAMMABLE GAS
MAY BE HARMFUL IF INHALED

Emphasis in any sign should be placed on the possible danger and the restricted nature of the area.

2. Protective Clothing and Respirators

a. Sustained or intermittent skin contact with liquid ETO may produce dermatitis at the site of contact. However, due to the extreme penetrating ability of ETO, and the consequent ineffectiveness of many types of clothing materials to prevent skin contact, the use of any conventional "impervious" clothing is not suggested. There are, however, certain special types of protective clothing which are effective when working with ETO. For example, one of the large ETO manufacturers provides its workers with knitted gloves which have been coated with certain polymers, including polyvinylchloride. In addition, conscientious adherence to appropriate sanitation practices should eliminate most hazards of skin contact with ETO.

b. If ETO splashes into the eye, severe irritation may result. For this reason it is suggested that rubber framed goggles, equipped with approved impact resistant glass or plastic lenses, be worn whenever there is danger of the material coming in contact with the eyes (i.e., in operations which involve transport of bulk containers of ETO from the storage room to the sterilizer unit for installation). Eye wash fountains within easy access from the immediate work area are recommended; they should be so situated that additional contact of the eyes with ETO in vapor form during washing is unlikely.

c. It is suggested that respirators be readily accessible in the event of an emergency situation resulting from an accidental spill or leak of ETO, and for use during subsequent clean-up and disposal procedures. A self-contained breathing apparatus with a full facepiece operated in a pressure-demand or other positive pressure mode is suggested for this purpose.

Respirators (respiratory protective devices) should be those approved under the provisions of 30 CFR 11.

3. Engineering and Other Control Technology

A number of control problems were discovered during the field surveys conducted at several medical facilities which use ETO in sterilizing operations. These problems were addressed in Section III of this report, along with some recommendations for their amelioration. Those, and the following general recommendations should be followed in all medical facilities which use ETO as a sterilant. All equipment should be operated in accordance with manufacturers' recommendations.

a. Sterilization operations involving ETO should be isolated from all non-ETO work areas.

b. ETO work areas, except for outdoor systems, should be maintained under negative pressure, with respect to non-ETO work areas. This may be accomplished by continuous local exhaust ventilation so that air movement is always from non-ETO work areas to ETO work areas. Where a fan is used to affect such air movement, the fan blades and other appropriate parts of the ventilation system should be made of a nonsparking material. Local exhaust pickups should be located at areas where the possibilities for leaks are the greatest (i.e., in close proximity to sterilizing units and aerators). Exhaust air should not be discharged into any work area or into the general environment without decontamination. This may be accomplished using a calalytic converter, or by discharging exhaust air directly to the fire box of a decontamination furnace, with subsequent discharge of this air to the general environment. Sterilizing units and aerators should be closed systems. Elimination of residual ETO from both systems should be accomplished only by ventilation ducts leading directly from the sterilizers and aerators to the decontamination apparatus described above.

c. All equipment (e.g., sterilizing units, gas tanks, and aerators) should be periodically checked for leaky valves, fittings, and gaskets, and for any other malfunctioning parts. Equipment manufacturers' recommendations regarding preventive maintenance should be observed. Further, periodic measurements should be made which demonstrate the

effectiveness of the local exhaust system (e.g., air velocity or static pressure).

d. Tanks of ETO in storage areas should be securely fastened in place and out of the path of traffic.

4. Training in Proper Operational Procedures

Employees operating sterilizer equipment should have received instruction in all parameters of sterilization and aeration procedures. Such training should strictly adhere to equipment manufacturers' installation, operating, routine care, and preventive maintenance instructions. Responsible supervision should be provided.

C. Medical Surveillance, Record Keeping, and Informing Employees of the Hazard

1. Medical Surveillance

Medical surveillance, as described in this section, should be made available to all persons subject to occupational exposure to ETO.

a. Preplacement medical examinations should include at least:

(1) comprehensive medical and work histories with special emphasis directed to symptoms related to eyes, blood, lungs, liver, kidneys, nervous system, and skin.

(2) a comprehensive physical examination, with particular emphasis given to pulmonary, neurologic, hepatic, renal, and ophthalmologic systems, and the skin.

(3) a complete blood count to include at least a white cell count, a differential count, hemoglobin, and hematocrit.

(4) In addition to the medical examination, employees should be counseled by the physician to ensure that each employee is aware that ETO has been shown to induce mutations in experimental animals. The relevancy of these findings in animals to male or female employees has not yet been determined. The findings do indicate, however, that employers and employees should do everything possible to minimize exposure to ETO. If a physician becomes aware of any adverse effects on the reproductive system, any cancers in individuals who have been exposed to ETO, or any abnormal offspring born to parents either or both of whom have been exposed to ETO, the information should be forwarded to the Director, NIOSH, as promptly as possible.

b. Periodic examinations should be made available on an annual basis, and more frequently if indicated by professional medical judgment based on such factors as emergencies and the pre-existing health status of the employee. These examinations should include at least:

(1) interim medical and work histories.

(2) a physical examination as described above for the preplacement examination.

2. Record Keeping and Availability of Records

The employer should keep accurate records on the following:

a. All measurements taken to determine employee exposure to ETO, including:

(1) Dates of measurement
(2) Operations being monitored
(3) Sampling and analytical method used
(4) Numbers, durations, and results of samples taken
(5) Names and airborne exposure concentrations of employees in monitored areas

b. Measurements demonstrating the effectiveness of mechanical ventilation (e.g., air velocity, static pressure, or air volume exchanged), including:

(1) Dates of measurements
(2) Types of measurements taken
(3) Results of measurements

c. Employee medical surveillance, including:

(1) Full name of employee
(2) All information obtained from medical examinations which is pertinent to ETO exposure
(3) Any complaints by the employee relatable to exposure to ETO
(4) Any treatments for exposure to ETO, and the results of that treatment

All of the aforementioned records should be updated at least annually. The employee's medical examination and surveillance records should be made available upon request to designated medical representatives of the Assistant Secretary of Labor for Occupational Safety and Health (OSHA), and the Director of the National Institute for Occupational Safety and Health (NIOSH). Records of environmental and occupational monitoring should be made available upon request to authorized representatives of OSHA and NIOSH. All employees or former employees should have access to the exposure measurement records which indicate their own exposure to ETO. An employee's medical records should be available upon written request to a physician designated by the employee or former employee. Records of all examinations should be held for at least 30 years following the termination of employment.

3. Informing Employees of the Hazard

Each employee, prior to being permitted to work in an ETO sterilizing area, should receive instruction and training on:

a. The nature of the hazards and toxicity of ETO (including those hazards described above), including recognition of the signs and symptoms of acute exposure, and the importance of reporting these immediately to designated health and supervisory personnel.

b. The specific nature of the operation involving ETO which could result in exposure.

c. The purpose for, and operation of, respirator equipment.

d. The purpose for, and application of, decontamination practices.

e. The purpose for, and significance of, emergency practices and procedures, and the employees' specific role in such activities.

f. The purpose for, and nature of, medical examinations, including advantages to the employee of participating in the medical surveillance program.

VII. SAMPLING AND ANALYTICAL METHODS

A. Airborne-ETO Monitoring Techniques and Equipment.

A number of techniques are available for the reliable analytical determination of low concentrations of ETO in air. These include: (1) hydration of ETO (collected in a bubbler) to ethylene glycol followed by oxidation to formaldehyde, which is determined colorimetrically by its reaction with sodium chromotropate (Bolton et al, 1964), and (2) adsorption of the ETO on charcoal, followed by desorption with carbon disulfide, and gas chromatographic determination of the ETO (NIOSH method described in a later section). In addition, instrumentation is available for the direct quantitative determination of the concentration of ETO in air. These direct reading instrumental methods include: a) thermal conductivity detection, b) gas chromatography, c) hydrogen flame-ionization detection, and (d) infrared spectrophotometry.

Other methods (as well as modifications of the above methods), and specific techniques have been described for the determination of airborne ETO concentration. These include: spectrophotometry (Pozzoli et al, 1968), colorimetry (Adler, 1965; Critchfield and Johnson, 1957; Gage, 1957), and volumetric methods (Gunther, 1965; Hollingsworth and Waling, 1955; Lubatti, 1944; and Swan, 1954). Gas chromatography of air residues from fumigated materials has been used for foodstuffs, pharmaceuticals, and surgical equipment (Adler, 1965; Ben-Yehoshua and Krinsky, 1968; Berck, 1965; Brown, 1970; Buquet and Manchon, 1970; Heuser and Scudamore, 1968, 1969; Kulkarni et al, 1968; Manchon and Buquet, 1970). ETO can be determined in cigarette smoke by gas chromatography or mass spectrometry after conversion to ethylene chlorohydrin (Binder and Lindner, 1972; Muramatsu et al, 1968), and in mixtures of lower olefin oxides and aldehydes by gas chromatography (Kaliberdo and Vaabel, 1967). The limits of detection of ETO by spectrophotometry and gas chromatography in these materials are generally of the order of 1 mg/kg.

The method used for the analysis of the ETO samples obtained in the NIOSH field study involved adsorption on charcoal, and gas chromatographic determination following desorption with carbon disulfide. The method, known as NIOSH Analytical Method #S286, is outlined below, and is described in detail in the reference.

B. Principle of the NIOSH Standard Method.

A known volume of air is drawn through a series of two charcoal tubes to trap the ETO vapor present. The two-tube sampling arrangement is necessary to prevent sample migration (and loss) upon storage, and to insure that the front tube is not overloaded during sampling.

The charcoal in each tube is transferred to a 5-ml screw-capped sample container, and the ETO is desorbed with carbon disulfide. An aliquot of the desorbed sample is injected into a gas chromatograph, following which the area of the resulting peak is determined and compared with areas obtained from the injection of "standards" (i.e., known concentrations of ETO).

C. Range of Sensitivity of the Method.

The method was validated over the range of ETO concentrations of 40-176 mg/cu m at a temperature of 26 C and atmospheric pressure of 761 mm Hg, using a 5-liter sample. Under the conditions of recommended sample size (5 liters), the probable useful concentration range of this method is 20-270 mg/cu m at a detector sensitivity that gives nearly full scale deflection of the strip chart recorder for a 1.4-mg ETO sample. This method is capable of measuring much smaller amounts if the desorption efficiency is adequate. Desorption efficiency must be determined over the range used.

The upper limit of the range of the method is dependent on the adsorptive capacity of the front charcoal tube. This capacity varies with the ETO concentration and with the presence of other substances in the sampled air.

The charcoal tube series consists of two separate large tubes; the first tube contains 40 mg of charcoal and the second tube (used as the backup tube) contains 200 mg of charcoal. The charcoal is held in place by glass wool plugs at the tube ends. If a particular atmosphere is suspected of containing a large amount of ETO, an air sample of smaller volume should be taken.

D. Interference.

When the amount of moisture in the air is so great that condensation actually occurs in the tube, organic vapors will not be trapped efficiently; consequently, the breakthrough threshold is decreased.

Any compound which has the same retention time on the chromatography column as ETO under the conditions described in this method has a potential for interfering with the estimation of ETO. A change in the separation conditions, such as column packing or temperature, will generally circumvent the interference problem.

E. Precision and Accuracy.

The coefficient of variation for this method in the range 41-176 mg/cu m is 0.103. This value corresponds to a 9.3 mg/cu m standard deviation at the 90 mg/cu m (present federal standard) level.

Advantages and disadvantages of the method, as well as other aspects of the recommended sampling and analytical method, are described in detail in the reference. (NIOSH, 1977)

APPENDIX

List of Additional Equipment Used in the NIOSH Field Study:

1) Velometer, Alnor Jr. Model 8100. Alnor Instrument Co. 7301 N. Caldwell Avenue, Niles, Illinois, 60648. Ranges: 0-200 fpm on low scale, and 0-800 fpm on high scale.
2) TLV "Sniffer", Portable Gas Detection and Alarm System, Bacharach Instrument Co., Mountain View, California.
3) Century Organic Vapor Analyzer, Model OVA-128, (and portable direct reading gas chromatograph). Century System Corporation, Arkansas City, Kansas. Also, Rustrak portable strip chart recorder (Gulton Industries Inc.).
4) Personal Sampling Pumps, Bendix Model 44, battery operated, Calibrated at a flow rate of 200 cc/min. (Note: Recent experience with the analytical test method indicates that a flow rate of 150-170 cc/min produces best results.)

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