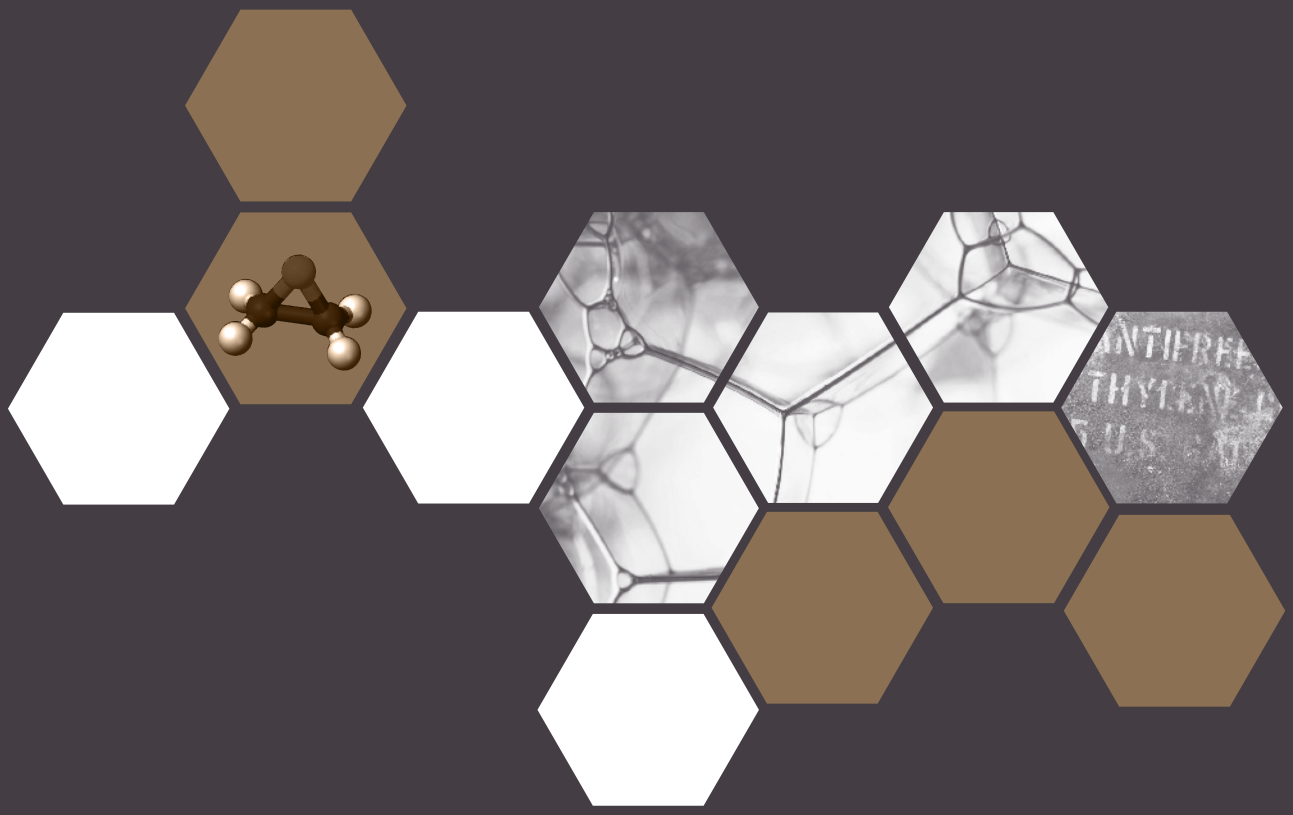
ethyleneoxide

third edition



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To the Reader

Manual Preparation

As members and affiliated companies of the American Chemistry Council, we support efforts to improve the industry's responsible management of chemicals. To assist in this effort, the American Chemistry Council's Ethylene Oxide/Ethylene Glycols Panel supported the creation and publication of this manual. The Panel is comprised of the following companies:

Balchem Corporation/ARC Specialty Products

BASF Corporation

Bayer Material Science LLC

Celanese Ltd.

Champion Technologies

Croda, Inc.

The Dow Chemical Company

Eastman Chemical Company

Honeywell

Shell Chemical LP

The development of this manual was led by the Panel's Ethylene Oxide Safety Task Group (EOSTG), a group comprised of producers and users of ethylene oxide. The EOSTG functions to generate, collect, evaluate and share information to support product stewardship with regard to ethylene oxide. The EOSTG formed a manual work group, chaired by Keith Vogel of Lyondell Chemical Company, to lead the development of this document. The following work group members provided significant contributions:

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Ralph Gingell	Shell Chemical LP
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7.0 Personnel Exposure

7.1 Introduction

This Chapter provides an overview of issues related to personnel exposure to EO including selection of personal protective equipment for use in EO service. This Chapter focuses on the requirements of the OSHA EO standard published in the Federal Register on June 22, 1984, and amended on April 6, 1988. The regulation, 29 CFR 1910.1047, should be consulted for specific requirements.

7.2 OSHA Standard for Ethylene Oxide

Coverage

The OSHA regulation applies to any worker who may be exposed to EO. Operations associated with the production, use, transportation, storage, loading or unloading of EO are covered under this regulatory standard. The only exception to this coverage is the processing, use, or handling of products containing EO where objective, reasonably reliable data demonstrates that the product is not capable of releasing EO in airborne concentrations at or above the action level under expected conditions of processing, use, or handling. Records of the objective data must be maintained if the exemption is used.

Exposure Limits

OSHA's Permissible Exposure Limits, or PELs, are the following:

- 1 ppm in air as an 8-hour time weighted average (TWA) concentration
- 5 ppm in air as a 15-minute time weighted average (TWA) concentration - excursion limit (EL)

There is also an action level (AL) at 0.5 ppm as an 8-hour TWA, which triggers certain compliance activities such as exposure monitoring, medical surveillance, and training. The excursion limit is 5 ppm.

7.3 Other Exposure Standards/ Recommendations for Ethylene Oxide

Immediately Dangerous to Life and Health

The National Institute for Occupational Safety and Health (NIOSH) has quantified exposures to approximately 400 toxic chemicals that could be "Immediately Dangerous to Life and Health" (IDLH). The IDLH exposure value for EO is 800 ppm. The official definition of IDLH is given in 30 CFR 11.3. The IDLH concentration represents an estimate of the maximum concentration of a substance in air from which healthy workers can escape without loss of life or irreversible health effects under conditions of a maximum 30-minute exposure time.

Emergency Response Planning Guidelines

The American Industrial Hygiene Association (AIHA) has recommended Emergency Response Planning Guidelines (ERPGs) for a number of substances. For EO, AIHA has recommended an ERPG-3 of 500 ppm, which is "the maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing life threatening health effects."[1]

The ERPG-2 of 50 ppm for EO is "the maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair an individual's ability to take protective action." [1]

There is no specified ERPG-1 for EO, the "maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing more than mild, transient adverse health effects or without perceiving a clearly defined objectionable odor."

Acute Exposure Guideline Levels

Acute Exposure Guideline Levels (AEGL) for EO were proposed by a National Academy of Sciences committee in September 2006, as set out in Table 7.1 below.

Table 7.1 AEGL Values for Ethylene Oxide

Classification	10 minute	30 minute	1 hour	4 hour	8 hour	Endpoint
AEGL-1 (Nondisabling)	No values derived					
AEGL-2 (Disabling)	80 ppm (144 mg/m^3)	80 (144)	45 (81)	14 (25)	7.9 (14)	Developmental toxicity and neurotoxicity
AEGL-3 (Lethal)	360 ppm (648 mg/m^3)	360 (648)	200 (360)	63 (113)	35 (63)	Lethality

AEGL-1 is the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic, non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.

AEGL-2 is the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects, or an impaired ability to escape.

AEGL-3 is the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

Data were available for deriving AEGL-2 and -3 values. Values for AEGL-1 were not derived because the odor threshold and concentrations causing mild sensory irritation would be above the AEGL-2 levels causing “disabling effects.” [2]

Exposure Monitoring

Initial monitoring is required to determine airborne concentrations of EO to which employees are exposed. If concentrations are above the OSHA action level of 0.5 ppm, periodic monitoring is also required. Additional monitoring may be required if there are changes in process, production, control equipment, personnel, or work practices that may result in new or additional exposures. The OSHA regulation requires employees to be notified of any monitoring results within 15 days of receipt of the results.

Regulated Areas

Regulated areas must be established wherever occupational exposure may exceed the PELs. Those areas must be marked and access limited to authorized persons. Warning signs must be posted around regulated areas stating:

Figure 7.1 OSHA Warning for EO Regulated Areas

Methods of Compliance

Where the TWA or excursion limit is exceeded, the employer must establish and implement a written program to reduce employee exposure to or below the TWA and to or below the excursion limit by means of engineering and work practice controls, as required by paragraph (f)(1) of Section 1910.1047, and by the use of respiratory protection where required or permitted under this Section.

The compliance program must include a schedule for periodic leak detection surveys and a written plan for emergency situations as specified in paragraph (h)(i) of the OSHA regulation.

OSHA recognizes that engineering controls are generally not feasible for certain activities, including loading and unloading of railcars, vessel cleaning, and maintenance and repair activities. In cases where engineering controls are not feasible to prevent exposure above either of the PELs, NIOSH-approved respirators must be worn. See the Respiratory Protection discussion in Section 7.5 below for more information on respirator selection.

Medical Surveillance Program

The employer must provide annual medical surveillance for employees who are or may be exposed to EO at or above the Action Limit, without regard to the use of respirators, for at least 30 days during the year. Specific requirements for surveillance and medical record retention are included in the OSHA standard [3].

Training

Information and training must be provided to any personnel who are potentially exposed to EO at or above the action limit or excursion limit. Topics for training are specified in the OSHA standard.

Product Exemptions

Products made from EO or containing EO are exempt from the standard if objective data shows they will not release EO at or above the action level during normal handling or use.

Written Emergency Plan

An emergency plan must be developed for each workplace where there is a possibility of an emergency. The employer must have a means of promptly alerting affected employees of an emergency occurrence.

Recordkeeping

The standard contains requirements for retention of medical and exposure records. Other provisions of the standard also contain recordkeeping requirements.

7.4 Measuring Exposure

A number of methods are available for monitoring exposure to EO. Many of these involve the use of charcoal tubes and sampling pumps, followed by analysis of the samples by gas chromatography. There are also indicator tube systems specific to EO that do not require subsequent analysis, with detection limits in the low ppm range. Portable electrochemical EO detector/alarms and passive badge-type monitors for EO exposure are also available.

Appendix D of the OSHA EO standard describes available methods of sampling and analysis. The employer has the obligation of selecting a monitoring method which meets the accuracy and precision requirements of the standard under the employer's field conditions.

7.5 Personal Protective Equipment

Ethylene Oxide Exposure

When there is potential for exposure to EO vapors or liquid, it is important to use the proper protective equipment. EO can be trapped against the skin and can cause severe chemical blistering and burns, which take a long time to heal. When released, EO liquid will quickly change to vapor. If protective clothing with open sleeves and legs is worn, this vapor can readily get underneath the clothing and result in burns. EO can also penetrate protective clothing seams, so it is important to consider suit construction as well.

Even dilute EO solutions can result in severe chemical burns if the skin remains exposed to the solution. Figure 7.2 shows a chemical burn resulting from 90 minutes of exposure to a dilute EO-water mixture absorbed into leather shoes.

Figure 7.2 Chemical Burn Resulting from Low Concentration of EO in Water

Eye Protection

Splashes of EO into the eye can cause severe eye irritation with corneal injury. The OSHA EO standard recommends wearing goggles at all times in those areas where there is a risk of splashes from liquid EO. Face shields (visors) provide additional protection when performing any activity in which there is a risk of splashes from liquid EO.

In the non-mandatory Appendix A of the standard, OSHA recommends that contact lenses not be worn where EO exposure potential exists. Where contact with EO can occur, consider the use of contact lenses carefully in the context of overall personal protective equipment policies and practices.

Protective Clothing

There are many important factors to consider when selecting appropriate personal protective equipment. These can be broadly grouped into two categories: material chemical resistance and material physical properties.

- Material chemical resistance: ideally, the chosen material(s) resists permeation, degradation, and penetration by the respective chemicals.
  - Permeation breakthrough time is the most important factor used to assess material chemical compatibility. The rate of permeation is a function of several factors such as chemical concentration, material thickness, humidity, temperature, and pressure.
  - Degradation involves physical changes in a material resulting from chemical exposure, use, or ambient conditions (such as sunlight). The most common observations of material degradation are discoloration, swelling, loss of physical strength, or deterioration.
  - Penetration is the movement of chemicals through zippers, seams, or imperfections in a protective clothing material.
- Physical properties: other factors to consider include evaluating the material for its
  - Strength, such that it can withstand the physical tasks at hand
  - Resistance to tears, punctures, cuts, and abrasions
  - Durability in light of repeated contamination and decontamination
  - Flexibility/pliability to allow users to perform needed tasks
  - Heat/cold resistance, such that the material maintains its protective integrity and flexibility under hot and cold extremes
  - Flame resistance/ability to self extinguish where a fire hazard may be present (such as in the event of a flash fire). For EO service, consider whether a flash oversuit or an EO resistant suit incorporating flash protection may be appropriate.
  - Seam quality, such that that garment seams in the clothing are constructed to provide the same physical integrity as the garment material

Many protective clothing materials in common use are permeable to or attacked by EO. Clothing contaminated by EO must either be discarded or decontaminated before reuse. Clothing must be discarded if it has been degraded or has absorbed EO. It is also important to note that EO and aqueous mixtures permeate leather, including leather boots (see Figure 7.2 above). Accordingly, leatherwear contaminated with liquid EO must be discarded because decontamination is not practical.

Materials proposed for use in protective equipment that are not known to be EO-resistant should first be tested to establish their suitability. Test data may be generated from a number of sources, such as materials manufacturers, equipment manufacturers, EO producers or users, researchers, contract laboratories, or others. Published, peer-reviewed data is also available to help evaluate the suitability of the material for EO use.

When evaluating test data, be aware that data may be of varying quality or reliability. Whether the data is well-documented or published, derived from multiple sources, has been subject to repeated testing, has been generated from an independent testing agency, and is recent or updated are all factors to consider. If an ASTM test method is available, there may be data obtained from tests performed in accordance with standard ASTM

methods. Note that qualitative ratings of"poor," "good," or "excellent" give little to no indication of how a material may perform against various chemicals and with regard to the specific needs of EO service.

EO permeation data for clothing, glove, and boot materials are presented in Tables 7.3, 7.4, and 7.5 below.

Respiratory Protection

If the presence of EO in excess of exposure limits is expected or detected, OSHA regulations dictate that respiratory protection consisting of a NIOSH-approved respirator must be used. The OSHA EO standard, 29 CFR 1910.1047, provides minimum standards for respiratory protection for airborne EO (Table 7.2).

Table 7.2 OSHA Minimum Standards for Respiratory Protection for Airborne Ethylene Oxide

Airborne EO Concentration or Condition of Use	Minimum Required Respirator Type
Less than or equal to 50 ppm	Full facepiece with EO-approved canister, front or back mounted
Less than or equal to 2,000 ppm	(A) Positive-pressure supplied air equipped with full facepiece, hood or helmet, or (B) Continuous-flow supplied air (positive pressure) equipped with hood, helmet or suit
Above 2,000 ppm or unknown (such as in emergencies)	(A) Positive-pressure self contained breathing apparatus (SCBA), or (B) Positive-pressure full facepiece supplied air respirator equipped with an auxiliary positive-pressure self-contained breathing apparatus
Firefighting	Positive-pressure self-contained breathing apparatus (SCBA), equipped with full face-piece
Escape	Any respirator described above

IMPORTANT NOTE for Tables 7.3, 7.4, and 7.5: Data and characterizations of performance are provided as reported by materials manufacturer, from published literature or government sources, or from other databases. Data entered as "EOIC 1990 Data" is from materials permeation testing sponsored by the Ethylene Oxide Industry Council (now the Ethylene Oxide/Ethylene Glycols Panel) and published by Stull, Pinette, and Green (1990). The data displayed is for information purposes only; the data displayed does not constitute an endorsement or recommendation of any particular material of construction or PPE manufacturer. Note that some materials have been tested more than once by more than one party, as indicated by multiple results. Manufacturers may change materials selection or formulation at any time which may change breakthrough times and other performance characteristics of the PPE. Before making any PPE selection, contact the supplier for specific product information, suitability for use in EO service, and current information on test data regarding the manufacturer's products. "NS" means not specified in test data. PPE names and/or descriptions may be trademarked by the manufacturer.

Table 7.3 Ethylene Oxide Permeation Data for Clothing

MATERIALS - PROTECTIVE CLOTHING
Permeation Breakthrough Time: >480 minutes
(See Important Note for Tables 7.3, 7.4, and 7.5, above)

Material (Manufacturer)	Gas/Liquid	Breakthrough Time (Minutes)			Additional Comments
		EOIC 1990 Data[1]	Materials/PPE Manufacturer Data[2]	Gov't Data	
Barricade® (DuPont®)	Gas	>480			No longer manufactured
	Liquid	>480			No longer manufactured
Challenge 5100®(ChemFab®)	Gas		>950		
Chemrel Max® (Chemron UK)	NS	>480			The personal protective suit is now manufactured by Draeger.
CPF-3® (Kappler/ DuPont®)	Gas	>480	>480		
	Liquid (11°C, 0°C)		>480		
CPF-4® (Kappler/ DuPont®)	Gas	>480	305		
	Liquid (11°C, 0°C)		>480		
Responder® (Kappler/DuPont®)	Gas	>480	>480		
Responder®/Blue Max (LifeGuard/MSA)	Gas	>480			

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Table 7.3 Ethylene Oxide Permeation Data for Clothing *(continued from page 73)*

Material (Manufacturer)	Gas/Liquid	Breakthrough Time (Minutes)			Additional Comments
		EOIC 1990 Data	Materials/PPE Manufacturer Data	Gov't Data	
Responder CSM® (Kappler/DuPont®)	Gas		>480		
Responder Plus® (Kappler/DuPont®)	Gas	>480			
Trellchem® HPS (Trelleborg)				>480	www.cdc.gov/niosh/ncpc/ecpc.html In supplement to NIOSH Guide to Chemicals.
Tychem® 9400 (DuPont®)	Gas	>480			No longer manufactured
	Liquid	>480			No longer manufactured
Tychem® 10,000 (DuPont®)	Gas	>480			No longer manufactured
	Liquid	>480			No longer manufactured
Tychem® BR and Tychem® LV (DuPont®)	Gas		>480		
	Liquid (0°C)		>480		
Tychem® Reflector (Kappler /DuPont®)	Gas		>480		
	Liquid		>480		
Tychem® Responder (Kappler/DuPont®)	Gas		>480		
Tychem® TK (DuPont®)	Gas		>480		
	Liquid (0°C)		>480		
	Mixture: 10% EO in HCFC 124		>480		

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Table 7.3 Ethylene Oxide Permeation Data for Clothing *(continued from page 74)*

MATERIALS – PROTECTIVE CLOTHING
Permeation Breakthrough Time: 60 - <480 minutes
(See Important Note for Tables 7.3, 7.4, and 7.5, above)

Material (Manufacturer)	Gas/Liquid	Breakthrough Time (Minutes)			Additional Comments
		EOIC 1990 Data	Materials/PPE Manufacturer Data	Gov't Data	
4H®			>240		Forsberg, K et al. Quick selection guide to chemical protective clothing. 3rd edition. Van Nostrand Reinhold 1997.
Butyl rubber			>240		Forsberg, K et al. Quick selection guide to chemical protective clothing. 3rd edition. Van Nostrand Reinhold 1997.
Cloropel™ – Blue CPE (ILC Dover)	NS	2) 118, 375	Rated by manufacturer as excellent (Little or no effect)		ILC Dover Chemical Compatibility Chart.
CPE® (Kappler/ DuPont®)	Gas	80			
MSA BETEX Butyl/ Neoprene	NS	165			No longer manufactured
PE/EVAL (4H®-Safety 4 Company and SilverShield®-Siebe North Company)			>240		www.cdc.gov/niosh/ ncpc/ecpc.html
Responder Plus® (Kappler/DuPont®)	Liquid	>180			
TeamMaster – Umex (Draeger)	NS		>60 to 120		
TeamMaster Pro –Himex® (Draeger)	NS		>60 to 120		
Tychem® F (DuPont®)	Gas		65		
Tychem®Responder (Kappler/DuPont®)	Liquid (11° C, 0°C)	>180	>180		
Tychem® TK (DuPont®)	Liquid (-70°C)		>180		

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Table 7.3 Ethylene Oxide Permeation Data for Clothing *(continued from page 75)*

Material (Manufacturer)	Gas/Liquid	Breakthrough Time (Minutes)			Additional Comments
		EOIC 1990 Data	Materials/PPE Manufacturer Data	Gov't Data	
Ultra-Pro Commander (Mar-Mac Manufacturing Inc®)	Gas	>180			Ultro Pro was replaced with TK500 series, now manufactured by DuPont.
WorkMaster – Umex (Draeger)	NS		>60 to 120		
WorkMaster – Himex ® (Draeger)	NS		>60 to 120		

MATERIALS – PROTECTIVE CLOTHING
Permeation Breakthrough Time: Immediate - <60 minutes

(See Important Note for Tables 7.3, 7.4, and 7.5, above)

Material (Manufacturer)	Gas/Liquid	Breakthrough Time (Minutes)			Additional Comments
		EOIC 1990 Data	Materials/PPE Manufacturer Data	Gov't Data	
Butyl rubber (LifeGuard)	Gas	44-52			
Challenge® 5200 (ChemFab)	NS	27-35			
CPF® –2 (Kappler / DuPont®)	Gas		Immediate		
Fairprene® Neoprene	NS	51,158			No permeation data available from the materials manufacturer.
N-44 Neoprene (Pioneer-acquired by MAPA® Professional)	NS	31			
Natural rubber			<60		Forsberg, K et al. Quick selection guide to chemical protective clothing. 3rd edition. Van Nostrand Reinhold 1997.
Neoprene (DuPont®)			<60		Forsberg, K et al. Quick selection guide to chemical protective clothing. 3rd edition. Van Nostrand Reinhold 1997.

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Table 7.3 Ethylene Oxide Permeation Data for Clothing *(continued from page 76)*

Material (Manufacturer)	Gas/Liquid	Breakthrough Time (Minutes)			Additional Comments
		EOIC 1990 Data	Materials/PPE Manufacturer Data	Gov't Data	
Nitrile rubber			<60		Forsberg, K et al. Quick selection guide to chemical protective clothing. 3rd edition. Van Nostrand Reinhold 1997.
Polyethylene			<60		Forsberg, K et al. Quick selection guide to chemical protective clothing. 3rd edition. Van Nostrand Reinhold 1997.
Polyurethane (ILC Dover)	1) NS 2) NS	2) 29, 65	1) Not recommended by materials manufacturer for EO use (severe effect)		ILC Dover Chemical Compatibility Chart.
Polyvinyl chloride			<60		Forsberg, K et al. Quick selection guide to chemical protective clothing. 3rd edition. Van Nostrand Reinhold 1997.
Saranex™ (Dow Chemical Company)			<60		Forsberg, K et al. Quick selection guide to chemical protective clothing. 3rd edition. Van Nostrand Reinhold 1997.
Saranex™ NS			6		
Tychem® 7500 (DuPont®)	Gas	53 minutes	75		
Tychem ®QC (DuPont®)	Gas/Vapor		Immediate (less than 10 minutes)		
Tychem® SL (DuPont®)	Gas/Vapor	Immediate	Immediate		
Tyvek®-Polyethylene coated (DuPont®)	NS	Immediate (<1)			
Viton® (DuPont® Dow Elastomers®)			<60		Forsberg, K et al. Quick selection guide to chemical protective clothing. 3rd edition. Van Nostrand Reinhold 1997.

Table 7.4 Ethylene Oxide Permeation Data for Gloves

MATERIALS - PROTECTIVE GLOVES
Permeation Breakthrough Time: > 480 minutes

(See Important Note for Tables 7.3, 7.4, and 7.5, above)

Material (Manufacturer)	Gas/Liquid	Breakthrough Time (Minutes)			Additional Comments
		EOIC 1990 Data	Materials/PPE Manufacturer Data	Gov't Data	
Butyl Rubber (North® Safety Products)	Gas	>480			
Silvershield®(North® Safety Products)	NS/Gas	>480	>480		

MATERIALS – PROTECTIVE GLOVES
Permeation Breakthrough Time: 60 - < 480 minutes

(See Important Note for Tables 7.3, 7.4, and 7.5, above)

Material (Manufacturer)	Gas/Liquid	Breakthrough Time (Minutes)			Additional Comments
		EOIC 1990 Data	Materials/PPE Manufacturer Data	Gov't Data	
4H® (Ansell Occupational Healthcare®)	Gas	>240			No longer manufactured
878 Butyl® (Best®)	Gas	189	189		
A-15 Nitrile (Pioneer – acquired by MAPA® Professional)	NS	195, >315			
Butyl Chemical Protective – Styles CP-7, CP7F, CP-14, CP-14R, CP-25, IB-35 (Guardian Manufacturing®)	NS		173		
Barrier (Ansell Occupational Healthcare®)	Gas		234		
Silver Shield®/4H® (North® Safety Products)	NS - 21°C		>240		
Tychem® TK (DuPont®)	Gas		>180		

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Table 7.4 Ethylene Oxide Permeation Data for Gloves *(continued from page 78)*

MATERIALS – PROTECTIVE GLOVES
Permeation Breakthrough Time: Immediate - < 60 minutes
(See Important Note for Tables 7.3, 7.4, and 7.5, above)

Material (Manufacturer)	Gas/Liquid	Breakthrough Time (Minutes)			Additional Comments
		EOIC 1990 Data	Materials/PPE Manufacturer Data	Gov't Data	
65NFW Natural Rubber (Best®)	Gas	1			
6780 Neoprene (Best®)	Gas	21	21		
890 Viton® (Best®)	Gas	48	48		
CHEM-PLY™/N-440 neoprene (MAPA® Professional)	NS		45		
Composition 29-865 neoprene, 37-145 nitrile (Ansell Occupational Healthcare®)					Not tested by manufacturer for use in EO service.
Hustler™ 725R PVC (Best®)	Gas	1	1		
N-44 Neoprene (Pioneer-acquired by MAPA® Professional)	NS	31			
Natural Rubber Surgical (Dayton®)	NS	3, 5			
Neoprene Chemical Protective (Guardian Manufacturing®)			40		
Neoprene Ultraflex 32 (Best®)	Gas		Degradation rating over time -operations use; excellent at 5 min, 30 min, 60 min, 240 min). Permeation data: 7 minutes, (heavy exposure) Not tested in limited exposure.		

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Table 7.4 Ethylene Oxide Permeation Data for Gloves *(continued from page 79)*

Material (Manufacturer)	Gas/Liquid	Breakthrough Time (Minutes)			Additional Comments
		EOIC 1990 Data	Materials/PPE Manufacturer Data	Gov't Data	
Nitrile (Ansell Occupational Healthcare®)	(1) Gas; (2) Gas Splash	(1) minimal splash protection for routine tasks; (2) 60-84 minutes; (3) <4 to 4	(4) Not tested by vendor for use with EO		
Nitri-Solve® 727 Nitrile (Best®)	Gas	17	17		
Nitty Gritty® 65NFW (Best®)	Gas		1 minute		
PVC Model G3112 (North® Safety Products)	Gas	4-8			Not tested by manufacturer for use in EO service.
Stansolv® A-14 nitrile (MAPA® Professional)	NS		32 (non-normalized breakthrough)		
Stansolv® AK-22 (MAPA® Professional)			No test data available from vendor		
Stanzoil®/Milled Neoprene (Pioneer-acquired by MAPA® Professional)	Gas	28-38			
Ultraflex 22R Nitrile (Best®)	Gas	12	12		

Table 7.5 Ethylene Oxide Permeation Data for Boots

MATERIALS – PROTECTIVE BOOTS

(See Important Note for Tables 7.3, 7.4, and 7.5, above)

Material (Manufacturer)	Gas/ Liquid	Breakthrough Time (Minutes)			Additional Comments
		Materials Manufacturer Data	Boots Vendor Data	Gov't Data	
Rubber Bunker Boots, vulcanized, hand-crafted ozone resistant (FireTech™- a division of LaCrosse® Safety and Industrial)					Manufacturer notes it meets NFPA 1971 Standard on Protective Ensemble for Structural Fire Fighting, 2000 Edition.
Firewalker (Ranger™- Total Fire Group™)					According to manufacturer there is no EO permeation data available for the fabric that is used as a liner.
Hazmax™ (OnGuard Industries)	NS		180 minutes		Tested to meeting the NFPA 1991, 2005 Edition Boot Requirements
Steel Toe Neoprene Chemical Resistant Boots (Tingley Rubber Corporation)					Manufacturer notes "Chemical Resistance: Animal fats and blood, oils, certain acids, alcohols, alkalies, and certain solvents."
Neoprene (Tingley Rubber Corporation)					Manufacturer notes "Chemical Resistance: Fats, certain acids, hydrocarbons, caustics, and other chemicals."
HazProof® (Tingley Rubber Corporation)	NS		Actual breakthrough time: >60 minutes; Normalized breakthrough time: >60 minutes		
Triple Dipped Neoprene (Servus Fire)					Manufacturer notes NFPA 1971 (2000 edition) certified.

[1] *Gathered from American Chemistry Council, Ethylene Oxide Industry Council sponsored research by Stull, Pinette, and Green (1990).*

[2] *Collected from the Material manufacturer or PPE manufacturer.*