



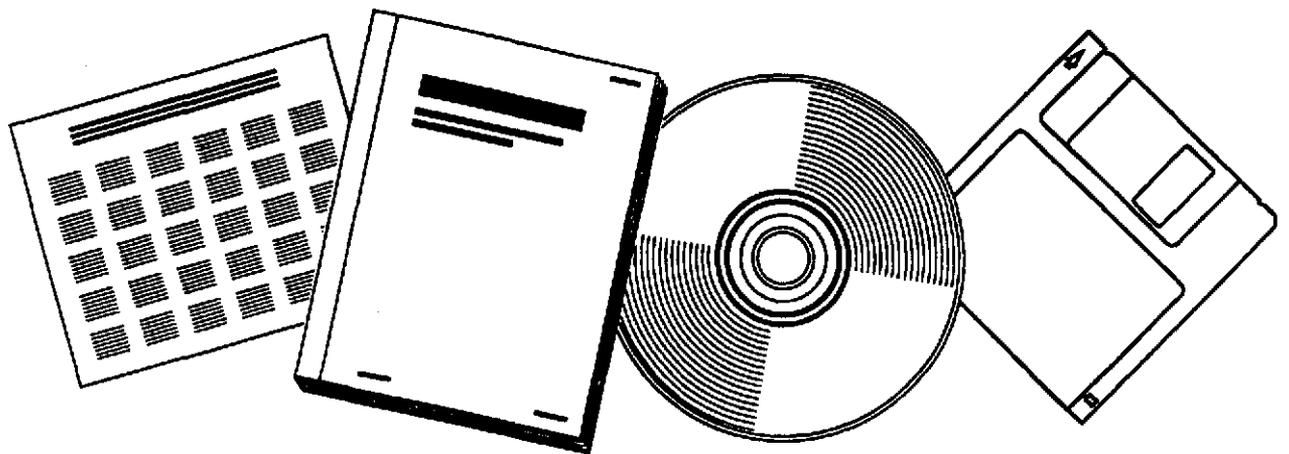
PB89-164685

NTIS[®]
Information is our business.

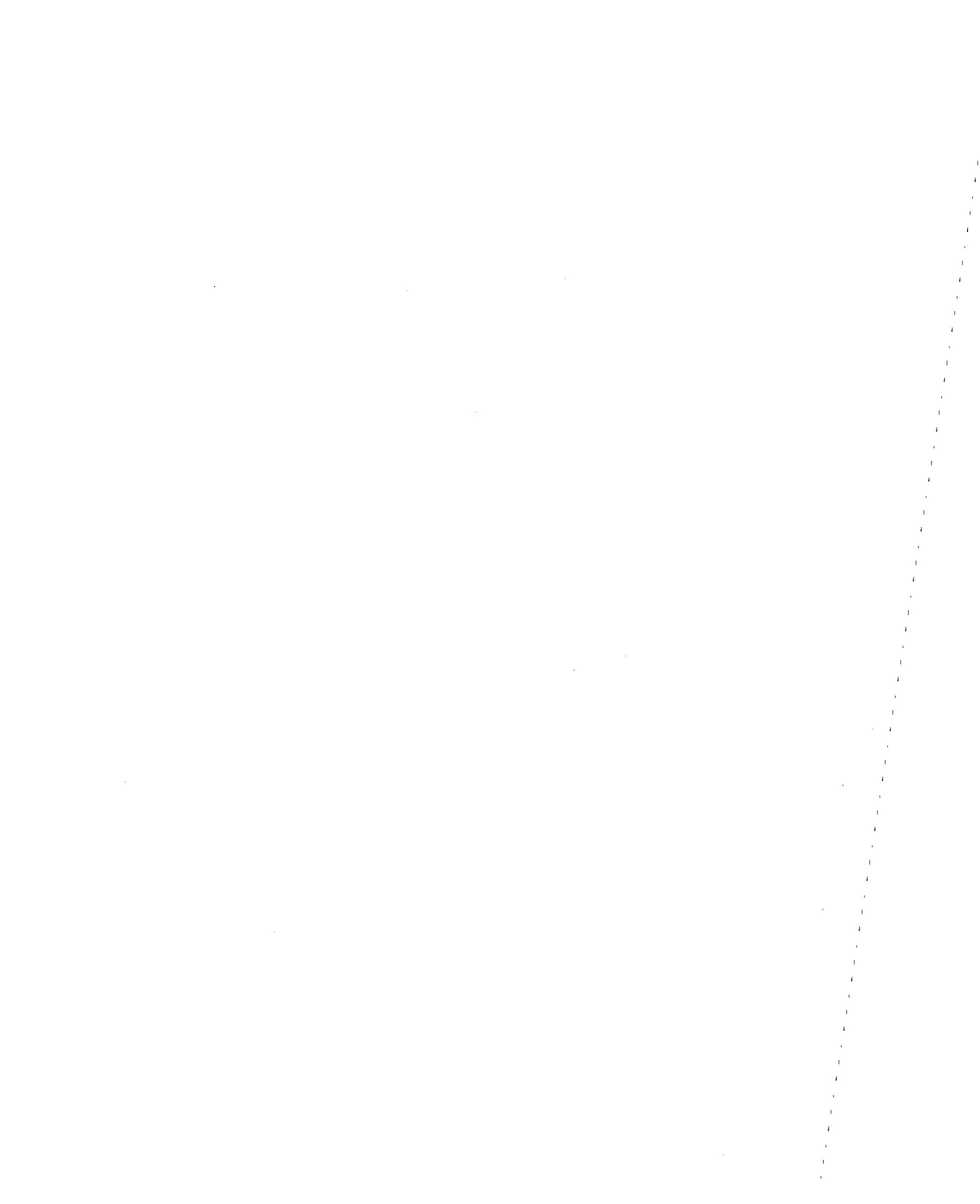
**INDUSTRIAL HYGIENE SURVEY REPORT CAIN
CHEMICAL, INC., BAYPORT PLANT PASADENA,
TEXAS, JUNE 1-2, 1988**

**U.S. NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
CINCINNATI, OH**

JUN 89



**U.S. DEPARTMENT OF COMMERCE
National Technical Information Service**



REPORT DOCUMENTATION PAGE	1. REPORT NO.	2.	3. PB89-164685	
4. Title and Subtitle Industrial Hygiene Survey Report of Cain Chemical, Inc., Petrochemicals Division, Bayport Plant, Pasadena, Texas, Report No. IWS-134-20-11			5. Report Date 89/01/11	
7. Author(s) Piacitelli, G., D. Votaw, and R. Krishnan			8. Performing Organization Rept. No. IWS-134-20-11	
9. Performing Organization Name and Address Division of Surveillance, Hazard Evaluations and Field Studies, NIOSH, U.S. Department of Health and Human Services, Cincinnati, Ohio			10. Project/Task/Work Unit No.	
12. Sponsoring Organization Name and Address			11. Contract (C) or Grant(G) No. (C) (G)	
15. Supplementary Notes			13. Type of Report & Period Covered	
16. Abstract (Limit: 200 words) A walk through survey was conducted at the Cain Chemical Company, Petrochemical Division (SIC-2869), Pasadena, Texas for the purpose of evaluating worker exposure to four ethylene glycol ethers: 2-methoxyethanol (109864) (2-ME), 2-methoxyethanol-acetate (2-MEA), 2-ethoxyethanol (110805) (2-EE), and 2-ethoxyethanol-acetate (2-EEA). The potential for inhalation and dermal exposures to the ethers existed at this site where the following activities were being conducted: loading of trucks or rail cars, decontamination of process equipment, and collection of quality control samples. Full shift exposures to 2-ME and 2-EE were very low. Measurable short term inhalation exposures during the collection of quality control samples ranged up to 1.22 parts per million (ppm) for 2-EEA and 2.45ppm for 2-ME. Near pumping equipment the airborne emissions reached 0.05ppm for 2-EEA and 0.44ppm for 2-ME. The authors recommend the installation of local exhaust ventilation at the quality control sampling location to reduce exposure levels. Also recommended is that impermeable coveralls be provided to workers involved in handling glycol ether liquids and that improved emission controls be instituted in the pumping equipment, specifically multiple seals.			14.	
17. Document Analysis a. Descriptors				
b. Identifiers/Open-Ended Terms NIOSH-Publication, NIOSH-Author, NIOSH-Survey, Field-Study, Region-6, IWS-134-20-11, Chemical-manufacturing-industry, Chemical-industry-workers, Skin-exposure, Occupational-exposure				
c. COSATI Field/Group			REPRODUCED BY U.S. DEPARTMENT OF COMMERCE NATIONAL TECHNICAL INFORMATION SERVICE SPRINGFIELD, VA. 22161	
18. Availability Statement			19. Security Class (This Report)	21. No. of Pages 27
			22. Security Class (This Page)	22. Price

Industrial Hygiene Survey Report
of
Cain Chemical, Inc.
Petrochemicals Division
Bayport Plant
5757 Underwood Road
Pasadena, Texas 77507

Survey Conducted By:
Greg Piacitelli, C.I.H., NIOSH
David Votaw, NIOSH
E. Radha Krishnan, P.E., PEI
Kevin Landkrohn, OSHA

Dates of Survey:
June 1-2, 1988

Report Written by:
Greg Piacitelli, NIOSH
David Votaw, NIOSH
Radha Krishnan, PEI

Date of Report:
January 11, 1989

Report Number:
134.20.11

Industrial Hygiene Section
Industrywide Studies Branch
Division of Surveillance, Hazard Evaluations and Field Studies
National Institute for Occupational Safety and Health
Centers for Disease Control
Cincinnati, Ohio

DISCLAIMER

Mention of company or product name in this report does not constitute endorsement by the National Institute for Occupational Safety and Health (NIOSH).



ACKNOWLEDGEMENTS

This report was prepared in cooperation with PEI Associates, Inc. whose responsibilities were completed within the scope of work under Contract No. J-9-F-7-0055 for the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA), Washington, D.C. The OSHA participant during the site visit was Kevin Landkrohn, Industrial Hygienist (Office of Health Standards).

PURPOSE OF SURVEY: To evaluate worker exposures, personal protection equipment and engineering controls in work areas using any of four ethylene glycol ethers (2-ME, 2-MEA, 2-EE, 2-EEA) proposed for revised regulation by OSHA.

EMPLOYER REPRESENTATIVES CONTACTED: Gregory Krenek, C.I.H., Corporate Industrial Hygienist
Benjamin F. Breeding, Plant Manager
Marc A. Penansky, EO Derivatives Production Supervisor
Steven R. Ashby, C.S.P., Site Safety Engineer

EMPLOYEE REPRESENTATIVES CONTACTED: None (Non-union)

SIC CODE 2869 (Petrochemical manufacturer)

ABSTRACT

The National Institute for Occupational Safety and Health (NIOSH) is conducting an "Exposure Assessment of Industries Using Ethylene Glycol Ethers" in collaboration with PEI Associates, Inc. (PEI), Cincinnati, Ohio. This work is being conducted at the request of the Occupational Safety and Health Administration (OSHA) which is proposing to revise its current regulations for 2-methoxyethanol (2-ME), 2-ethoxyethanol (2-EE), and their respective acetates (2-MEA and 2-EEA).

The NIOSH study involves surveying several workplaces where these glycol ethers are manufactured or used as ingredients in process materials. Each survey involves collecting industrial hygiene samples and obtaining information concerning glycol ether usage, process operations, and engineering controls, past exposure levels, the potentially exposed workforce, and the corporate industrial hygiene and safety programs. This information is being compiled by PEI and reported to OSHA's Office of Regulatory Analysis for its assessment of the technical feasibility and economic impact of revising the exposure standards for the glycol ethers.

The specific results from a survey conducted at the Cain Chemical, Inc., Bayport Plant in Pasadena, TX are presented in this report. The potential for inhalation and dermal exposure to the ethylene glycol ethers exists at this plant primarily during the following activities: 1) loading of trucks or rail cars (during gauging and sampling), 2) decontamination of process equipment, and 3) collection of QC samples.

The monitoring results indicate that full-shift exposures to 2-ME and 2-EEA were very low at the Bayport Plant during our evaluation; all sample concentrations were well below the current OSHA and American Conference of Governmental Industrial Hygienists (ACGIH) exposure criteria. Measureable short-term inhalation exposures occurred during the collection of QC samples from the process stream (1.22 parts per million (ppm) 2-EEA and 2.45 ppm 2-ME); the potential for dermal exposure was highest during in this activity. Airborne emissions were found to be the highest near pumping equipment (0.50 ppm 2-EEA and 0.44 ppm 2-ME), however, little work activity was observed in these areas. Neither decontamination of process equipment nor loading of products occurred during our survey period therefore no exposure assessment could be made concerning these activities.

Efforts to further minimize exposures in at the Bayport Plant should focus on 1) installing local exhaust ventilation at QC sample collection stations in the process area; 2) providing impermeable coveralls to workers responsible for handling glycol ether liquids; and 3) improving emission controls (e.g. multiple seals) in the pumping equipment.

INTRODUCTION

Adverse central nervous system (encephalopathy) and hematotoxic (anemia, leukopenia) effects in workers exposed to 2-methoxyethanol (2-ME) were first noted in the late 1930s [Donley 1936; Parsons and Parsons 1938]. The hematotoxic effects of exposure to 2-ME and other ethylene glycol ethers were later confirmed in animal studies [Miller et al. 1983; Werner et al. 1943ab]. In the late 1970s, studies reported adverse reproductive effects, including testicular atrophy, infertility, fetotoxicity, and fetal malformations in laboratory animals exposed to different ethylene glycol ethers [Doe et al. 1983; Miller et al. 1982, 1984, Brown et al. 1984].

Occupational Safety and Health Administration (OSHA) permissible exposure limits (PELs) were established for eight glycol ethers (including 2-ME (25 parts per million or ppm), 2-methoxyethyl acetate or 2-MEA (25 ppm), 2-ethoxyethanol or 2-EE (200 ppm) and 2-ethoxyethyl acetate or 2-EEA (100 ppm) in 1981 based upon the 1968 American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs[®]). These TLVs[®] were based on the hematotoxic and neurotoxic effects and on exposure concentrations reported in the early case reports of human health effects. However, more recent information from experimental animal studies indicates that adverse reproductive effects may occur at exposure concentrations below the current OSHA PELs. Therefore, because of the increased concern about their potential to cause reproductive and embryotoxic effects, OSHA is currently developing a proposal to revise its regulation of these four glycol ethers.

Under contract to OSHA's Office of Regulatory Analysis (ORA), PEI Associates, Inc. (PEI) is assessing the technical feasibility and economic impact of revising the exposure standard for ethylene glycol ethers. This work involves compiling information concerning: glycol ether usage patterns, workplace exposures, control technology, and compliance costs. Data are being collected through both mail questionnaires and site visits.

The National Institute for Occupational Safety and Health (NIOSH) is assisting OSHA in its evaluation of workplace exposures by cooperatively conducting industrial hygiene surveys with PEI at approximately 11 different plants representing the major usage groups (e.g., industrial coatings, jet fuel additives, commercial printing, aircraft painting, automobile refinishing, maintenance painting, and electronics manufacture) of the four regulated glycol ethers. Each survey involves industrial hygiene sampling and collecting information concerning process operations and engineering controls, glycol ether usage patterns, the potentially exposed workforce, and exposure control methods.

This report presents the results of a site visit conducted at the Gain Chemical, Inc., Bayport Plant, a manufacturer of glycol ethers, during June 1-2, 1988.

BACKGROUND

Physical and Chemical Properties. The glycol ethers 2-methoxyethanol and 2-ethoxyethanol, and their respective acetates, are part of the family of ethylene glycol ethers; their chemical and physical properties are summarized in Table 1. The ethylene glycol ethers are manufactured by the reaction of ethylene oxide with the appropriate alcohol (e.g., ethanol, methanol); the glycol ethers are used to form acetates by their reaction with acetic acid. In general, glycol ethers and their acetates are colorless liquids with versatile solvent properties (e.g., miscible in water and most hydrocarbon solvents, low vapor pressure, slow evaporation rate) which make them useful in a wide variety of industrial applications.

Production, Use, and Exposure. The total U.S. production of the regulated ethylene glycol ethers and acetates in 1983 is listed in Table 2.

Ethylene glycol ethers and acetates have been used commercially for over 50 years, primarily as solvents in the manufacture of protective coatings such as paints, lacquers, metal coatings, baking enamels, phenolic varnishes, epoxy resin coatings, and stains [NIOSH 1983]. Ethylene glycol ethers and acetates are also used as solvents for printing inks, textile dyes and pigments, and leather finishes; as anti-icing additives in military jet fuels; and in the manufacture of printed circuit boards. Many of these uses require direct handling of the glycol ethers by workers during the formulation and/or evaporation stages, thus leading to the potential for occupational exposure via inhalation and/or skin absorption [Dugard et al. 1984]. Based on data obtained during the National Occupational Hazard Survey (NOHS) conducted by NIOSH during 1972-1974, an estimated 2.5 million men and women may be occupationally exposed to glycol ethers (NIOSH 1977). According to this survey, the numbers of workers potentially exposed to the regulated glycol ethers are presented in Table 3.

Toxicology. The effects of the short-chain ethylene glycol ethers (2-ME, 2-MEA, 2-EE, and 2-EFA) on reproduction and fetal development have been studied extensively in rats, rabbits, and mice. The results uniformly show developmental toxicity, including increased incidences of fetal malformations and resorptions. In general, the evidence suggests that the glycol ether acetates have the same toxicologic activity as their parent glycol ethers. Some studies have indicated that behavioral teratogenic effects may occur in the offspring of rats treated with 2-ME and 2-EE [Nelson and Brightwell 1984]. Testicular damage has also been caused in rats after acute exposures to 2-ME [Doe et al. 1983].

Changes in the blood and adverse effects on the bone marrow and thymus have been observed in rats, mice, and rabbits exposed to 2-ME. The effects of lowered red and white blood cell counts appear to be the result of bone marrow suppression. Recent studies [Miller et al. 1983a] have confirmed histologically the reported depressant effect of 2-ME on the bone marrow and thymus of rats and rabbits. Grant et al. [1985] have reported at least

TABLE 1

PHYSICAL AND CHEMICAL PROPERTIES OF FOUR ETHYLENE GLYCOL ETHERS

Property	2-ME	2-MEA	2-EE	2-EEA
IUPAC Chemical Name	2-methoxyethanol	2-methoxyethyl acetate	2-ethoxyethanol	2-ethoxyethyl acetate
CAS No.	109-86-4	110-49-6	110-80-5	111-15-9
RTECS No.	KL5775000	KL5950000	KK8050000	KK8225000
Empirical 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	132.1
Specific gravity	0.97	1.01	0.93	0.97
Density (lbs/gal)	8.04	8.37	7.75	8.10
Vapor pressure (mmHg) 25°C	9.7	2.0-3.7	5.7	2.8
20°C	6.0	2.0	4.0	2.0
Boiling point (°C)	124.5	145.0	135.0	156.0
Flash point (°F) open cup	115	140	120	138
1 ppm=mg/m ³ (25°C, 760mmHg)	3.11	4.83	3.69	5.41
1 mg/m ³ =ppm (25°C, 760mmHg)	0.32	0.21	0.27	0.19
Other identifiers:	methyl cellosolve ethylene glycol monomethyl ether Dowanol EM	methyl cellosolve acetate ethylene glycol monomethyl ether acetate	cellosolve ethylene glycol monoethyl ether Dowanol EE	cellosolve acetate ethylene glycol monoethyl ether acetate

Clayton and Clayton, 1982

TABLE 2

U.S. PRODUCTION OF FOUR ETHYLENE GLYCOL ETHERS

Compound	1983 Production (pounds)
2-ME	83,000,000
2-MEA	1,000,000
2-EE	187,000,000
2-EEA	153,000,000

SRI 1984

TABLE 3

ESTIMATE OF U.S. WORKERS POTENTIALLY EXPOSED TO ETHYLENE
GLYCOL ETHERS AND ACETATES

Compound	Number of Workers
2-ME	100,000
2-MEA	20,500
2-EE	407,000
2-EEA	321,000

NIOSH 1977

partial reversal of these effects in rats following short-term exposure to 2-ME. Limited information suggests that 2-EE, 2-EEA, and 2-MEA also produce adverse effects in the peripheral blood of rats [Werner et al. 1943b], mice [Nagano et al. 1979], and dogs [Werner et al. 1943a].

Methoxyacetic acid (MAA) has been isolated and identified in urine as the major metabolite of 2-ME in rats [Miller et al. 1983]. Although all of the glycol ethers are not metabolized via a single pathway, it has been suggested that the major metabolites of 2-ME and 2-EE, MAA and ethoxyacetic acid (EAA), respectively, act to cause the testicular [Miller, et al., 1982, 1984], developmental [Brown et al. 1984], and hematotoxic [Miller et al. 1982] effects observed in rats treated with 2-ME or 2-EE.

Neurologic and hematologic effects were observed in workers following inhalation and dermal exposure to 2-ME [Donley 1936; Greenburg et al. 1937; Zavan 1963; Ohi and Wegman 1978]. A cross-sectional study assessing fertility among men engaged in the production of 2-ME reported decreases in testicular size [Cook et al. 1982]. A cross-sectional evaluation of semen quality among men exposed to 2-EE found significantly lower sperm count per ejaculate [NIOSH 1986]. Painters exposed to both 2-EE and 2-ME had sperm abnormalities including reduced sperm counts, and abnormalities of both red and white blood cells [Welch and Schrader 1986].

APPLICABLE STANDARDS AND RECOMMENDED LIMITS

Based on toxicological data, NIOSH recommended in Current Intelligence Bulletin (CIB) No. 39 The Glycol Ethers, with Particular Reference to 2-Methoxyethanol and 2-Ethoxyethanol: Evidence of Adverse Reproductive Effects that 2-ME, 2-EE, and structurally-related glycol ethers be regarded in the workplace as having the potential to cause adverse reproductive effects in male and female workers. Also noted were embryotoxic effects, including teratogenesis, in the offspring of the exposed pregnant females [NIOSH 1983].

The NIOSH current recommended exposure limit (REL) for glycol ethers is therefore "reduction of workplace levels to the lowest extent possible." Since publication of CIB No. 39, additional data on the glycol ether compounds have become available (as summarized by the European Chemical Industry Ecology and Toxicology Center [ECETOC 1985]). These data are currently being evaluated by NIOSH during the development of a criteria document for the ethylene glycol ethers.

The current NIOSH RELs, OSHA PELs and ACGIH TLVs[®] established for the targeted glycol ethers are summarized in Table 4.

TABLE 4
APPLICABLE STANDARDS AND RECOMMENDED LIMITS

Compound	Exposure Limit ^a (ppm)		
	NIOSH REL	OSHA PEL	ACGIH TLV [®]
2-ME	*	25 ^s	5 ^s
2-MEA	*	25 ^s	5 ^s
2-EE	*	200 ^s	5 ^s
2-EEA	*	100 ^s	5 ^s

CFR 1984; ACGIH 1987

^a 8-hour time-weighted-average (TWA₈)

^s Skin notation

* Reduce exposure to lowest feasible level

HISTORY AND DESCRIPTION OF THE PLANT

Cain Chemical, Inc. is a petrochemical manufacturer (SIC Code 2869) and a wholly-owned subsidiary of Occidental Petroleum. Cain Chemical produces approximately 60 chemicals at seven different plant locations in the United States; the Bayport Plant in Pasadena, Texas makes 42 of these chemicals. The process equipment which is used to manufacture ethylene oxide (EO), EO derivatives (which include 2-ME and 2-EE), and acetates (including 2-EEA) was built by ICI Americas, Inc. in 1981 and sold to Cain Chemical, Inc. in July 1987. The Bayport Plant remains the newest ethylene oxide (EO) derivatives facility in the United States.

The Bayport Plant produces ethylene oxide (from ethylene and oxygen), glycols, EO derivatives, and acetates. The EO derivatives include methyl ethylene glycol ethers (e.g., 2-ME), ethyl ethylene glycol ethers (e.g., 2-EE), butyl ethylene glycol ethers (e.g., 2-BE) and ethanolamines. Ethylene glycol ether acetates (e.g., 2-EEA, 2-BEA) are produced in a batch mode from the ethyl and

butyl ethylene glycol ethers. Figure 1 presents a block diagram of the different products manufactured at the Bayport Plant. The plant process equipment (which is located outdoors) is constructed on separate concrete "pads" (e.g., EOD pad, storage pad, glycol refining pad), which makes it easier to isolate and clean areas.

The facility's nameplate capacities for 2-ME, 2-EE, and 2-EEA are 12, 40, and 35 million pounds per year, respectively. Production rates at the time of the survey for 2-ME, 2-EE, and 2-EEA were 167, 80, and 69 percent of their respective capacities.

The major markets for 2-ME include domestic consumption as a jet fuel additive and production of printed circuit boards. Over 90 percent of the 2-EE produced and 60 to 75 percent of the 2-EEA produced are exported to destinations such as South America, Africa, Europe, Japan, and Pakistan. The primary domestic market for 2-EE and 2-EEA is the coatings industry.

PROCESS DESCRIPTION

Production. Cain Chemical manufactures the four types of EO derivatives (methyl glycol ethers, ethyl glycol ethers, butyl glycol ethers, and ethanolamines) in separate continuous production campaigns; approximately 40 percent of the campaigns are devoted to methyl and ethyl glycol ethers. Each campaign is of two to three weeks duration; sixteen campaigns are conducted per year on a quarterly schedule. It takes approximately two days to switch from one campaign to another since the same equipment is utilized for each campaign (with different temperature, pressure, feed stock, reaction rates, etc.). The equipment essentially consists of S-shaped reactors followed by two sets of distillation columns; ethylene oxide is fed to the reactors via pipeline. Figure 2 presents a simplified block diagram of the production process for methyl, ethyl, and butyl ethylene glycol ethers.

There are two 2-ME and two 2-EE storage tanks on site; storage capacity of the 2-ME and 2-EE tanks are 560,000 gallons and 780,000 gallons respectively. There are also two batch tanks for intermediate storage of the products.

The acetates campaigns are conducted in a separate set of equipment in a batch operation. Approximately 53,000 pounds of 2-EEA are produced per batch. No 2-MEA is produced at the Bayport Plant. There is one 2-EEA storage tank of 330,000 gallon capacity at the Bayport Plant.

The methyl EO derivatives continuous campaign and the 2-EEA batch campaign were being conducted at the time of the survey.

Quality Control (QC). The Bayport Plant has an on-site laboratory for performing analyses on QC samples collected from the process stream. The laboratory is functionally organized into three groups performing different types of analyses. Tests performed in the Group I area included distillation, water analysis (both performed under laboratory hoods), pH, color, and total

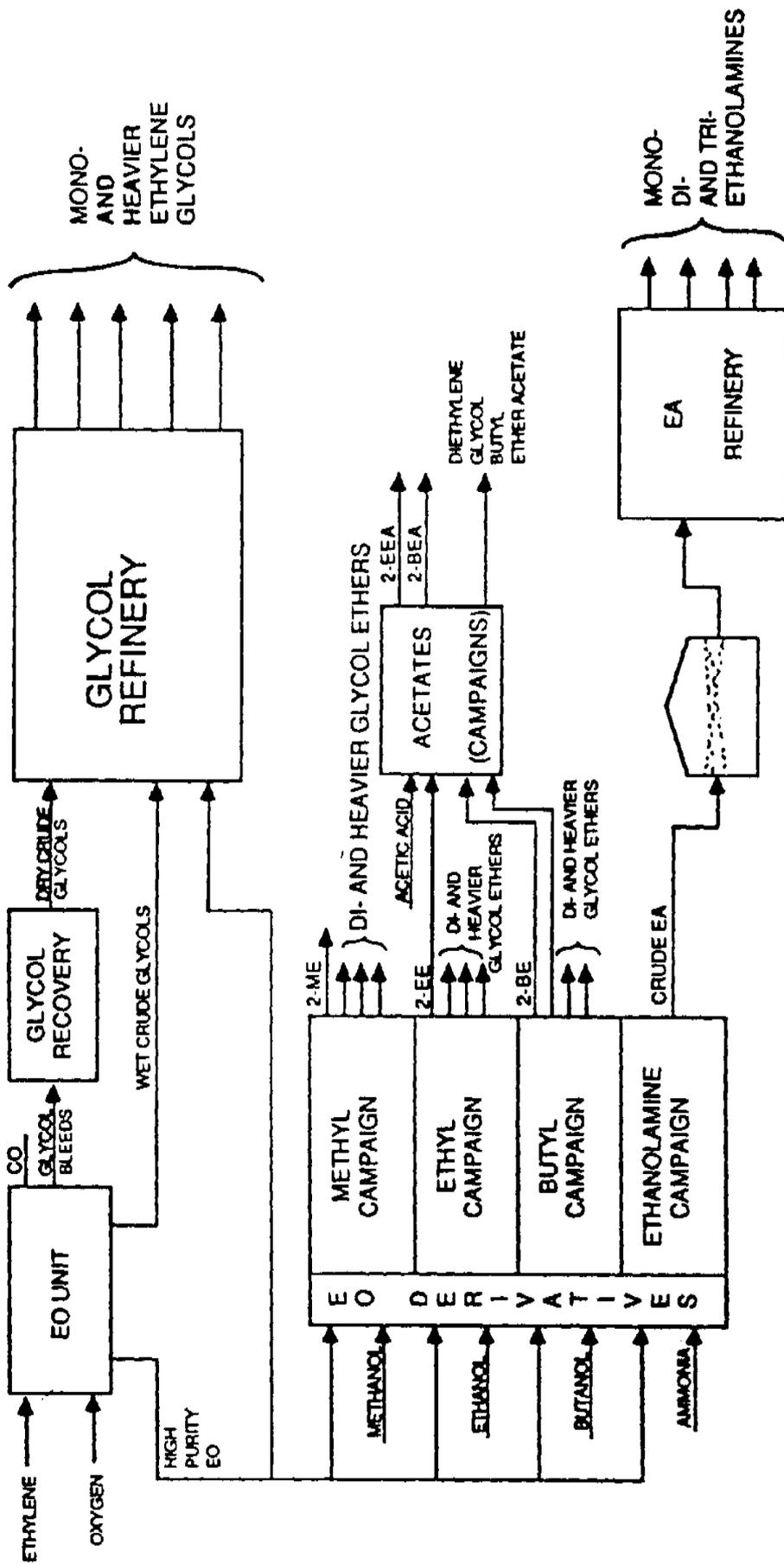


Figure 1. Block diagram of products manufactured at the Cain Chemical plant, Pasadena, Texas.

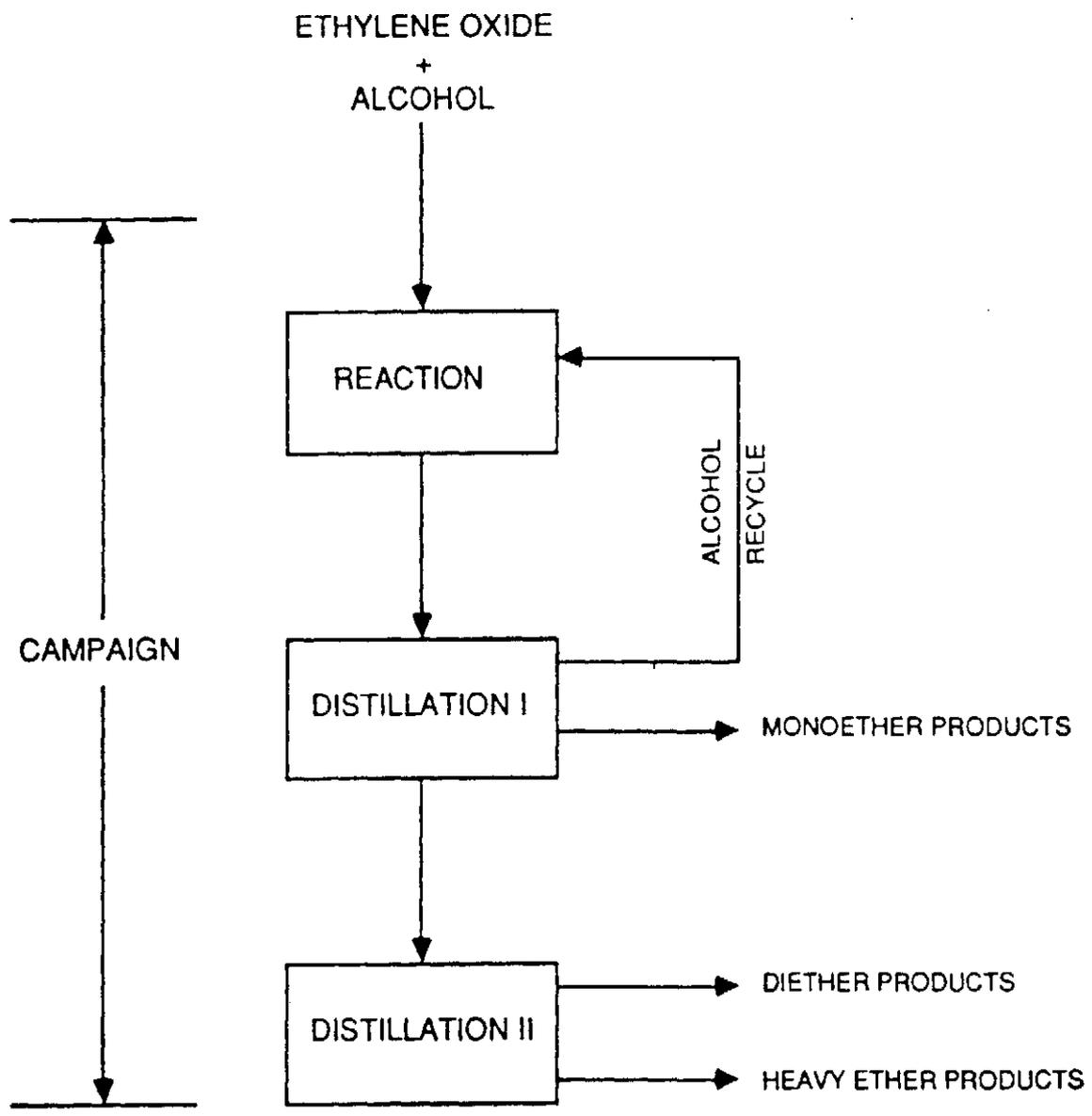


Figure 2. Simplified block diagram of production process for methyl, ethyl and butyl production campaigns at Cain Chemical, Pasadena, Texas.

organic carbon. Specific gravity tests are performed in the Group II area. Gas chromatograph (GC) analyses are performed in the Group III area; weighing and dilution of the sample prior to GC analysis is performed under a hood. A total of approximately 20 QC samples per shift are received for analysis from an EO derivatives campaign and an acetate campaign.

Loading Operations. All glycol ether and acetate products are shipped to customers by rail or truck. There are a total of five truck loading stations at the plant, one of which is used exclusively for glycol ethers and another for acetates. It takes approximately 40 minutes to load a truck and about 10 trucks are loaded per shift. On average, 8000 trucks are loaded annually at the Cain Chemical Bayport Plant.

Two types of techniques are used for monitoring the filling operation: metering devices (for 2-EEA), and manual dipstick measurement (for 2-ME and 2-EE). The latter technique is required for 2-ME and 2-EE because separate hoses are needed to prevent cross-contamination between the two products. QC samples are taken from the trucks by either lowering a sampling container into a hatch at the top of the truck or opening a valve at the bottom of the truck.

Approximately 2500 rail cars (each of 23,000 gallons capacity) are loaded per year at the Bayport Plant. It takes 2 to 2.5 hours to load a rail car with most rail loading occurring on the night shift. Monitoring techniques for filling operations are similar to that for trucks. QC samples are collected from hatches at the top of the rail cars.

DESCRIPTION OF ENGINEERING CONTROLS

Large open-air chemical process operations such as those at the Cain Chemical facility incorporate a number of engineering controls designed to prevent the release of intermediate chemicals and products into the environment. Many of these controls are an integral part of the process equipment, whereas others have been added for a specific purpose. Some controls are designed to reduce worker exposures, whereas others are intended to abate environmental releases. Frequently, the environmental controls also function indirectly to reduce the level of toxic contaminants in the workplace air.

Process Operations. Because glycol ethers (and acetates) are manufactured in a closed reactor system, emissions are inherently confined to some extent. Additionally, the reactors at the EO Derivatives facility are equipped with trip systems (which monitor process conditions such as feed rate and temperature) to maintain the integrity of the process. Process vent scrubbers are used on the first column in the distillation phase; chilled water condensers are used on both distillation columns to prevent the release of lighter materials. Six of the 25 pumps that handle the ethylene glycol ethers (in the storage and process areas) are equipped with dual mechanical seals; the other pumps have either single mechanical seals or packing which are less effective in preventing the direct release of material into the environment. The EO Derivatives plant has a closed drain system that serves to control exposures during the purging of the system prior to campaign changes. The plant also has a fixed point hydrocarbon monitoring system that monitors hydrocarbon concentrations at 56 locations within the plant.

Quality Control (QC) Operations. Sample coolers (chilled water condensers used to lower the temperature of the liquid and therefore minimize gaseous phase emissions) have been installed at the locations where QC samples are collected. Analyses on the QC samples are performed in a laboratory with fresh-air ventilation. There are two laboratory hoods in the Group I area, four in the Group II area, and one in the Group III area; all hoods are rated Class A (approved for handling flammable compounds with face velocities greater than 100 linear feet per minute.)

Cain Chemical personnel indicated that these controls and monitors were part of the original plant design, and estimated the cost of the controls to be over a million dollars; retrofitting of such controls would have been considerably more expensive.

PERSONAL PROTECTIVE EQUIPMENT

Cain Chemical requires all process workers to wear company-laundered uniforms, hard hats, steel-toed shoes and safety glasses; shower facilities are also made available. Technicians in the process and loading areas wear neoprene gloves when performing certain activities (e.g., QC sampling, tank truck gauging). Laboratory technicians generally wear disposable latex gloves when performing QC analyses; nitrile gloves are also available in the laboratory. Full-face air-line respirators and acid suits are available in the plant area for unusual circumstances or emergencies.

DESCRIPTION OF THE WORKFORCE

The Bayport Plant operates two 12-hour shifts per day, 365 days per year. There are a total of 105 Cain Chemical employees and 65 contract maintenance employees at the Bayport Plant; a total of 50 Cain Chemical employees (including nine supervisory/technical personnel) and 47 contract maintenance employees may be exposed to ethylene glycol ethers. Cain Chemical employees with a potential for exposure to the ethylene glycol ethers can be grouped into the following job classifications:

Process Technician - This job category includes the Ethylene Oxide Derivatives Technician (EODT), Glycol Refinery Technician, Acetates Technician (AT), and the Panel Board Operator. There are a total of four process technicians per shift; each technician is trained in all four jobs. With the exception of the Panel Board Operator, who remains indoors throughout the shift, the process technicians spend approximately 50 percent of their time outdoors. Their duties include checking for leaks, monitoring pumps, collecting QC samples (generally once every four hours), and decontaminating process equipment prior to maintenance and repair and during campaign changes (decontamination of equipment is usually performed only on the night shift).

Service Technician (ST) - The primary duties of service technicians include loading of rail cars and trucks, and sampling product shipments. There are three Service Technicians per shift and these workers spend most of their time outdoors. There is some potential for dermal exposure when collecting QC samples from rail cars and trucks, and when gauging trucks and rail cars

during loading of 2-ME and 2-EE; this exposure potential is minimized by the use of neoprene gloves by the technicians during such operations.

Laboratory Technician (LT) - The laboratory technicians conduct analyses on QC samples in the laboratory. There are a total of three laboratory technicians per shift, one each in Group I, Group II and Group III areas.

Shift Supervisor (EODSS) - The shift supervisor may be present in any of the process areas; there is one shift supervisor per shift.

Table 5 provides a breakdown (by job title, gender, and age) of the number of workers at the Bayport Plant who may be exposed to the glycol ethers.

TABLE 5
NUMBER OF WORKERS POTENTIALLY EXPOSED TO
ETHYLENE GLYCOL ETHERS AT
CAIN CHEMICAL BAYPORT PLANT

Job Title	Number of Workers Exposed			
	Males		Females	
	All	< age 45	All	< age 45
Process Technician (EODT & AT)	11	11	1	1
Service Technician (ST)	11	11	1	1
Lab Technician (LT)	5	4	7	7
EOD Shift Supervisor EODSS)	5	4	0	0
Other Supervisor/Technical	7	6	2	2
Contractor (Maintenance) (MTSE)	47	47	0	0

Cain Chemical plant personnel identified the following activities as having the greatest potential for high short-term exposures:

- Loading of trucks or rail cars (performed by STs).
- Decontamination of equipment during campaign changes.
- QC sampling (EODTs and ATs).

MEDICAL AND INDUSTRIAL HYGIENE PROGRAMS

Exposure monitoring for 2-ME, 2-EE and 2-EEA is conducted on a quarterly schedule throughout the year. Cain Chemical presently uses 3M Gas Badges for collecting personal samples; sample analyses are performed by a private laboratory (NATLSO, Long Grove, IL). The annual cost for exposure monitoring was estimated by Cain Chemical personnel to be about \$35 per worker. Time-weighted-average exposure data for samples collected during 1982-87 are summarized in Tables 6 and 7.

TABLE 6

EXPOSURES TO ETHYLENE GLYCOL ETHERS
 CAIN CHEMICAL INC., BAYPORT PLANT (1982-87)
 (Company Data Summarized by Year)

YEAR	CONCENTRATION (ppm)								
	2-ME			2-EE			2-EFA		
	n	mean	(SD)	n	mean	(SD)	n	mean	(SD)
1982	29	0.44	(0.80)	12	2.31	(2.33)	4	2.55	(2.36)
1983	3	0.11	(0.06)	4	0.69	(0.89)	5	1.60	(1.47)
1984	0	-	-	0	-	-	0	-	-
1985	7	0.26	(0.47)	7	0.05	(0.07)	0	-	-
1986	1	0.69	-	3	0.01	(0.01)	4	0.04	(0.02)
1987	11	0.05	(0.02)	2	0.40	(0.50)	8	0.08	(0.04)
1982-87	51	0.29	(0.64)	28	1.13	(1.86)	21	0.91	(1.53)

TABLE 7

EXPOSURES TO ETHYLENE GLYCOL ETHERS
 CAIN CHEMICAL INC., BAYPORT PLANT (1982-87)
 (Company Data Summarized by Job Title)

JOB TITLE	CONCENTRATION (ppm)								
	2-ME			2-EE			2-EFA		
	n	mean	(SD)	n	mean	(SD)	n	mean	(SD)
Process Tech (EODT & AT)	12	0.17	(0.19)	8	1.99	(2.29)	9	1.04	(1.26)
Service Technician (ST)	7	0.38	(0.46)	3	0.08	(0.11)	5	0.09	(0.05)
Laboratory Technician (LT)	16	0.38	(1.10)	9	0.61	(1.76)	5	0.72	(1.39)
Shift Supervisor (EODSS)	7	0.21	(0.12)	2	2.77	(3.44)	2	2.81	(3.95)
Contractor-Maintenance (MTSE)	9	0.29	(0.18)	6	0.75	(0.63)	0	-	-

Medical monitoring at the Bayport Plant consists of pre-employment and annual medical examinations (inc. blood chemistry, physical evaluation and x-rays). The annual cost for these examinations was estimated to be \$115 per worker.

SAMPLING STRATEGY AND METHODS

A one-shift sampling survey was conducted at the Cain Chemical Bayport Plant to measure the extent of exposures associated with the manufacture of 2-ME and 2-EEA. Both personal and area long-term (5- to 8-hour) and short-term (3- to 15-minute) samples were collected. Long-term samples evaluated full-shift exposures, whereas short-term samples measured peak exposures of relatively short duration.

OSHA Method 53 was used for sampling and analysis of all NIOSH samples [OSHA 1985]. Airborne samples were collected on charcoal, desorbed with methylene chloride/methanol and analyzed by gas chromatography using flame ionization detection (GC/FID). A brief description of the sampling and analytical procedures follows:

Long-term samples were taken with Gilian Model LFS-113DC portable low-flow air sampling pumps calibrated at a flow rate between 0.1-0.2 liters per minute (Lpm). Targeted sample volumes were generally between 30-70 liters.

Short-term samples were collected with SKC Model 224 sampling pumps calibrated at approximately 1.0 Lpm; sample volumes were nominally 15 liters.

All samples were collected on SKC No. 226-01 coconut charcoal tubes (100 mg primary/50 mg backup sections) connected to sampling pumps with tygon tubing. Personal samples were attached near the breathing zone of the worker while area samples were positioned in the immediate vicinity of typical work stations. Samples were refrigerated between sample collection and analysis. Sample analyses were performed by DataChem (Salt Lake City, UT). Charcoal tube samples were desorbed with 95/5 (v/v) methylene chloride/methanol and analyzed using a Hewlett-Packard Model 5890A gas chromatograph equipped with a flame ionization detector.

Table 8 presents the analytical limit of detection (LOD) and limit of quantitation (LOQ) for each of the two ethylene glycol ethers sampled at the Bayport Plant. The LOD is that level at which an instrument response can confidently be attributed (95% probability) to the presence of the compound being measured; the LOQ indicates the point at which an indicated response is within acceptable confidence limits. Table 8 also shows the equivalent LOD and LOQ concentrations for an 8-hr TWA sample collected at 0.2 Lpm and a 15-minute short-term sample collected at 1.0 Lpm.

TABLE 8

LIMIT OF DETECTION (LOD) AND LIMIT OF QUANTITATION (LOQ)
FOR 2-ME and 2-EEA

Specific Glycol ether	Analytical Limits (mg/sample)		Sampling Limits (ppm/sample)			
	LOD	LOQ	TWAB ^a		Peak ^b	
			LOD	LOQ	LOD	LOQ
2-EEA	0.01	0.03	0.02	0.06	0.12	0.37
2-ME	0.01	0.03	0.03	0.10	0.21	0.64

^a 8-hour time-weighted average sample collected at 0.2 Lpm.

^b 15-minute short-term sample collected at 1.0 Lpm.

Cain Chemical simultaneously collected full-shift personal samples on the 11 employees monitored by NIOSH during the survey. These samples were taken using 3M^{*} No. 3500 passive gas badges and analyzed by gas chromatography (LOD = 0.0014 mg per sample). Cain Chemical did not collect any area or short-term samples).

MONITORING RESULTS

A total of 21 field samples were collected and analyzed for 2-ME and 2-EEA. Only eight field samples indicated the presence of any of the ethylene glycol ethers; two area samples indicated the presence of both 2-ME and 2-EEA. Individual sample results are reported in Table 9 as time-weighted averages (TWAs) over the respective sampling duration. Of the 10 detectable results, six were between the limit of detection (LOD) and the limit of quantitation (LOQ).

Long-term Sampling. A total of 18 long-term samples (11 personal and 7 area) were collected during the monitored workshift. Table 9 shows that the sample results of the 11 full-shift personal samples ranged from nondetected to 0.15 ppm for 2-ME, and nondetected to 0.04 ppm for 2-EEA. In comparison, Cain Chemical's duplicate monitoring showed nondetectable results on all samples, with the exception of a measured concentration of 0.42 ppm 2-EEA for the Acetates Process Technician (AT). (This Cain sample was collected side-by-side to NIOSH sample CA-25 which indicated 0.04 ppm 2-EEA). Table 9 shows that the maximum full-shift area concentrations measured by NIOSH during the study were 0.44 ppm 2-ME and 0.50 ppm 2-EEA in the vicinity of a distillation column reflux pump and an acetate transfer pump, respectively.

Short-term Sampling. Three samples were collected to evaluate short-term (peak) exposures; results are shown in Table 9. The two short-term samples obtained during the collection of QC samples for 2-ME and 2-EEA showed levels of 2.45 ppm 2-ME and 1.22 ppm 2-EEA, respectively. These samples were

TABLE 9

SAMPLING RESULTS FOR 2-METHOXYETHANOL (2-ME) AND 2-ETHOXYETHYL ACETATE (2-EEA)
 CAIN CHEMICAL, INC., BAYPORT PLANT, PASADENA, TEXAS
 JUNE 2, 1988

Sample ID	Job/area	Time Start-Stop	Flow (cc/min)	Duration (min)	Air volume, (L)	Concentration (ppm) ^a	
						2-ME	2-EEA
CA-27	Process Tech (EODT)	0654-1423	199.3	449	89.5	0.07 ^b	<0.02 ^c
CA-25	Process Tech (AT)	0701-1423	103.3	442	45.7	<0.07 ^c	0.04 ^b
CA-15	Process Tech (EODT)	0654-1424	97.1	450	43.7	0.15 ^b	<0.04 ^c
CA-13	Area: 2-ME reflux pump	0847-1437	207.5	350	72.6	0.44	0.36
CA-3	Area: 2-EEA transfer pump	0831-1436	100.8	365	36.8	0.17 ^b	0.50
CA-30	2-EEA QC collection ^d	1154-1157	1010.0	3	3.0	<1.06 ^c	1.22 ^b
CA-8	2-ME QC collection ^d	1126-1141	1050.0	15	15.8	2.45	<0.12 ^c
CA-20	Process Tech (Panel Op)	0713-1426	196.0	433	84.9	<0.04 ^c	<0.02 ^c
CA-4	Area: Panel Board Room	0711-1427	202.1	436	88.1	<0.04 ^c	<0.02 ^c
CA-10	Area: Break Room	0703-1430	197.8	447	88.4	<0.04 ^c	<0.02 ^c
CA-21	Area: QC laboratory	0805-1449	198.6	404	80.2	<0.04 ^c	<0.02 ^c
CA-5	Area: QC laboratory	0807-1447	203.5	400	81.4	<0.04 ^c	<0.02 ^c
CA-6	Lab Technician (Group 1)	0809-1447	97.9	398	39.0	<0.08 ^c	<0.05 ^c
CA-2	Lab Technician (Group 2)	0814-1448	97.7	394	38.5	<0.08 ^c	<0.05 ^c
CA-14	Lab Technician (Group 3)	0819-1458	98.5	399	39.3	<0.08 ^c	<0.05 ^c
CA-31	Lab analysis (Group 1) ^d	0811-0826	1050.0	15	15.8	<0.20 ^c	<0.12 ^c
CA-32	Service Technician	0736-1414	105.8	398	42.1	<0.08 ^c	<0.04 ^c
CA-11	Area: 2-EEA Truck Loading	0740-1426	104.1	406	42.3	<0.08 ^c	0.13 ^b
CA-17	Service Technician	0737-1016	102.3	159 ^e	16.3	<0.20 ^c	0.11 ^c
CA-12	Service Technician	0725-1421	111.8	416	46.5	<0.07 ^c	0.04 ^c
CA-7	Shift Supervisor	0650-1415	199.2	445	88.6	<0.04 ^c	0.02 ^c

^a Samples were not time-weighted to 8-hour concentrations.

^b Laboratory analysis of analyte was below limit of quantitation.

^c Laboratory analysis of analyte was below limit of detection.

^d Short-term samples.

^e Sample pump was turned off during the shift.

collected side-by-side with the long-term sample CA-25 worn by an Acetates Process Technician (AT). The short-term sample obtained during laboratory analyses (by a Group I Laboratory Technician) did not show any detectable concentrations of 2-ME or 2-EEA.

DISCUSSION

Results clearly indicate that exposures to the regulated ethylene glycol ethers and acetates were quite low at the Cain Chemical Bayport Plant during the survey period. Sixty-two per cent of the field samples had non-detectable results; only workers in the process area had any detectable exposures to either 2-ME or 2-EEA.

The most significant inhalation exposures occurred during the collection of QC samples for 2-ME and 2-EEA. This is generally an infrequent (1-2 times per shift) and brief (5-10 minutes) activity performed by a process technician. Also, though not measured, the potential for dermal exposures from accidental spills/splashing of the liquid samples existed in this area. Although some skin protection was afforded by neoprene gloves worn during sample collection, the workers wore only permeable cotton coveralls; no respirators were worn in this outdoor area.

Relatively high concentrations of 2-ME and 2-EEA were measured near respective reflux and transfer pumps in the process area. While little or no worker activity was observed in these locations, the potential does exist for exposures to occur. Efforts could therefore be taken to control the release of emissions from these pumps.

Neither decontamination of process equipment nor loading of products occurred during our survey period therefore no exposure assessment can be made concerning these activities.

SUBSTITUTES

Cain Chemical indicated that they have noticed a trend in the consumer industry to substitute ethylene glycol monobutyl ether (2-BE) for 2-EE in many usage areas, as evidenced by the greater demand for 2-BE. Cain Chemical reported that their production of 2-BE has been increasing over the past few years, and that their current production rate for 2-BE was higher than that for either 2-EE or 2-ME. Cain Chemical mentioned that 2-BE is also cheaper than 2-EE and more readily available. The annual operating costs and equipment costs for producing 2-BE vis-a-vis 2-EE are comparable because the same equipment is used to manufacture both ethers. Cain Chemical, however, indicated that the trade-off is affected by the markets for the co-products of the di- and heavier glycol ethers which are also produced during these campaigns. The major usage area for the heavier ether products is in brake fluids. Cain Chemical has not identified any substitutes for 2-ME in its different applications.

With respect to the acetates, Cain Chemical indicated that ethylene glycol monobutyl ether acetate (2-BEA) is more expensive than 2-EEA, and that there has not been a significant trend in industry to substitute 2-BEA for 2-EEA. Cain Chemical also mentioned that, although the same equipment is used to produce both 2-EEA and 2-BEA, operating costs for producing 2-BEA would be higher because the production of a 2-BEA batch takes longer than a 2-EEA batch.

Note: OSHA does not currently regulate exposures to 2-BE or its acetate because of insufficient information concerning their toxicity. NIOSH recommends that caution be exercised to reduce worker exposures to structurally related glycol ethers until adequate testing demonstrate their safety [NIOSH 1983].

CONCLUSIONS AND RECOMMENDATIONS

The Cain Chemical Bayport Plant is a modern glycol ether manufacturing facility with sophisticated controls that serve to minimize environmental releases and occupational exposures. The manufacturing process occurs in a closed system located outdoors.

The potential for inhalation and dermal exposure to the ethylene glycol ethers exists primarily during the following activities: 1) loading of trucks or rail cars (during gauging and sampling), 2) decontamination of process equipment, and 3) collection of QC samples.

The monitoring results indicate that full-shift exposures to 2-ME and 2-EEA were very low at the Bayport Plant during our evaluation. The highest long-term concentration measured, 0.50 ppm 2-EEA for an area sample, is well below the 100 ppm OSHA PEL and the 5 ppm ACGIH TLV exposure criteria. Measureable short-term inhalation exposures occurred during the collection of QC samples from the process stream; the potential for dermal exposure was highest during in this activity. Airborne emissions were found to be the highest near pumping equipment, however, little work activity was observed in these areas. Neither decontamination of process equipment nor loading of products occurred during our survey period therefore no exposure assessment could be made concerning these activities.

Efforts to further minimize exposures in at the Bayport Plant should focus on 1) installing local exhaust ventilation and/or improving performance of sample coolers at QC sample collection stations in the process area; 2) providing impermeable coveralls to workers responsible for handling glycol ether liquids; and 3) improving emission controls (e.g., multiple seals) in the pumping equipment.

REFERENCES

- ACGIH. 1987. TLVs[®] threshold limit values and biological exposure indices for 1987-88. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.
- Brown NA, Holt D, Webb M. 1984. The teratogenicity of methoxyacetic acid in the rat. *Toxicol Lett* 22:93-100.
- CFR. 1984. Code of Federal Regulations, U.S. Dept of Labor, Occupational Safety and Health Administration. 29 CFR 1910.1000.
- Clayton GD, Clayton FE. 1982 *Patty's Industrial Hygiene and Toxicology*. John Wiley and Sons, Inc.
- Cook RR, Bodner KM, Kolesar RC, et al. 1982. A cross-sectional study of ethylene glycol monomethyl ether process employees. *Arch Environ Health* 37(6):346-51.
- Doe JE, Samuels DM, Tinston DJ, Wickramaratne GAD. 1983. Comparative aspects of the reproductive toxicology by inhalation in rats of ethylene glycol monomethyl ether and propylene glycol monomethyl ether. *Toxicol Appl Pharmacol* 69:43-7.
- Donley DE. 1936. Toxic encephalopathy and volatile solvents in industry. Report of a case. *J. Ind Hyg Toxicol* 18:571-7.
- Dugard PH, Walker M, Mawdsley SJ, Scott RC. 1984. Absorption of some glycol ethers through human skin in vitro. *Environ Health Perspect* 57:193-7.
- ECETOC. 1985. Technical report no. 17. The toxicology of glycol ethers and its relevance to man: an updating of ECETOC Technical Report #4. Brussels, Belgium.
- Grant D, Sulsh S, Jones HB, Gangolli SD, Butler WH. 1985. Acute toxicity and recovery in the hematopoietic system of rats after treatment with ethylene glycol monomethyl and monobutyl ethers. *Toxicol Appl Pharmacol* 77:187-200.
- Greenburg L, Mayers MR, Goldwater LJ, Burke WJ, Moskowitz S. 1937. Health hazards in the manufacture of "fused collars." 1. Exposure to ethylene glycol monomethyl ether. *J Ind Hyg Toxicol* 20(2):134-47.
- Miller RR, Carreon RE, Young JT, McKenna MJ. 1982. Toxicity of methoxyacetic acid in rats. *Fund Appl Toxicol* 2:158-60.
- Miller RR, Ayres JA, Yount JT, McKenna MJ. 1983. Ethylene glycol monomethyl ether. I. Subchronic vapor inhalation study with rats and rabbits. *Fund Appl Toxicol* 3:49-54.

Miller RR, Hermann EA, Young JT, Landry TD, Calhoun LL. 1984. Ethylene glycol monomethyl ether and propylene glycol monomethyl ether: metabolism, disposition, and subchronic inhalation toxicity studies. Environ Health Perspect 57:29-35.

Nagano K, Nakayama E, Koyano M, Oobayashi H, Adachi H, Yamada T. 1979. Mouse testicular atrophy induced by ethylene glycol monoalkyl ethers. Jpn J Ind Health 21:29-35.

Nelson BK, Brightwell WS. 1984. Behavioral teratology of ethylene glycol monomethyl and monoethyl ethers. Environ Health Perspect 57:43-6.

NIOSH. 1977. National occupational hazard survey, 1972-74. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 78-114.

NIOSH. 1983. Current intelligence bulletin 39. The glycol ethers with particular reference to 2-methoxyethanol and 2-ethoxyethanol: Evidence of adverse reproductive effects. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Services, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 83-112.

NIOSH. 1986. Ratcliffe J, Clapp D, Schrader SM, Turner Tw, Oser J, Tanaka S, Hornung R, Halperin W. Health hazard evaluation--determination report no. 84-415-1688, Precision Castparts Corporation, Portland, Oregon. Cincinnati: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health.

Ohi G, Wegman D. 1978. Transcutaneous ethylene glycol monomethyl ether poisoning in the work setting. J Occup Med 20(10):675-6.

OSHA. 1985. OSHA Analytical Methods Manual. Occupational Safety and Health Administration Laboratory, Salt Lake City, UT (available through ACGIH, Cincinnati, OH, ISBN: 0-936712-66-x).

Parsons CE, Parsons MM. 1938. Toxic encephalopathy and granulopenic anemia due to volatile solvents in industry: report of two cases. J Ind Hyg Toxicol 20(2):124-33.

SRI. 1984. Chemical Economics Handbook, Stanford Research Institute International, Menlo Park, CA.

Welch LS and Schrader S. Semen abnormalities stud of painters exposed to glycol ethers--draft report [Unpublished report submitted to the National Institute for Occupational Safety and Health by the George Washington University Medical Center, Washington, D.C., April 1986].

Werner HW, Mitchell JL, Miller JW, von Oettingen WF. 1943a. Effects of repeated exposure of dogs to monoalkyl ethylene glycol ether vapors. J Ind Hyg Toxicol 25:409-14.

Werner HW, Nawrocki CZ, Mitchell JL, Miller JW, von Oettingen WF. 1943b. Effects of repeated exposures of rats to vapors of monoalkyl ethylene glycol ether vapors. J Ind Hyg Toxicol 25:374-9.

Zavon MR. 1963. Methyl cellosolve intoxication. Amer Ind Hyg Assoc J 24(1):36-41.

NTIS does not permit return of items for credit or refund. A replacement will be provided if an error is made in filling your order, if the item was received in damaged condition, or if the item is defective.

Reproduced by NTIS
National Technical Information Service
U.S. Department of Commerce
Springfield, VA 22161

This report was printed specifically for your order from our collection of more than 2 million technical reports.

For economy and efficiency, NTIS does not maintain stock of its vast collection of technical reports. Rather, most documents are printed for each order. Your copy is the best possible reproduction available from our master archive. If you have any questions concerning this document or any order you placed with NTIS, please call our Customer Services Department at (703)487-4660.

Always think of NTIS when you want:

- Access to the technical, scientific, and engineering results generated by the ongoing multibillion dollar R&D program of the U.S. Government.
- R&D results from Japan, West Germany, Great Britain, and some 20 other countries, most of it reported in English.

NTIS also operates two centers that can provide you with valuable information:

- The Federal Computer Products Center - offers software and datafiles produced by Federal agencies.
- The Center for the Utilization of Federal Technology - gives you access to the best of Federal technologies and laboratory resources.

For more information about NTIS, send for our FREE *NTIS Products and Services Catalog* which describes how you can access this U.S. and foreign Government technology. Call (703)487-4650 or send this sheet to NTIS, U.S. Department of Commerce, Springfield, VA 22161. Ask for catalog, PR-827.

Name _____

Address _____

Telephone _____

- Your Source to U.S. and Foreign Government
Research and Technology.



U.S. DEPARTMENT OF COMMERCE
Technology Administration
National Technical Information Service
Springfield, VA 22161 (703) 487-4650
