Industrial Hygiene Survey Report
of
DELTA AIR LINES, INC.
Technical Operations Center
Hartsfield Atlanta International Airport
Atlanta, GA 30320

Survey Conducted By:
David Votaw, Toxicologist (NIOSH)
Radha Krishnan, P.E., Project Director (PEI)
Paula Morelli-Schroth, I.H.I.T., Industrial Hygienist (PEI)

Dates of Survey:
June 13-14, 1988

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

Date of Report:
January 18, 1989

Report Number:
134.20.12

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

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO.	2.	3. PB89-186605
4. Title and Subtitle Industrial Hygiene Survey Report of Delta Air Lines, Inc., Technical Operations Center, Hartsfield Atlanta International Airport, Atlanta, Georgia, Report No. IWS-134-2012			5. Report Date 89/01/18 6.
7. Author(s) Piacitelli, G., and R. Krishnan			8. Performing Organization Rept. No. IWS-134-20-12
9. Performing Organization Name and Address Industrywide Studies Branch, NIOSH, Cincinnati, Ohio			10. Project/Task/Work Unit No. 11. Contract (C) or Grant(G) No. (C) (G)
12. Sponsoring Organization Name and Address			13. Type of Report & Period Covered 14.

15. Supplementary Notes

16. Abstract (Limit: 200 words) A visit was made to the technical operations center of Delta Air Lines (SIC-4511), Atlanta, Georgia to evaluate worker exposure, personal protective equipment and engineering controls in work areas where ethylene glycol ethers were used. At this facility the potential for inhalation and dermal exposure to the ethers exists primarily in the hangers during spray coating of the aircraft, small parts and ground support equipment. Approximately 20 male workers were potentially exposed directly during painting operations; approximately 50 to 60 workers working in adjacent areas may have been indirectly exposed. Concentrations of 2-ethoxyethyl-acetate (111159) (2-EEA) ranged from 0.29 to 2.77 parts per million (ppm); the OSHA permissible exposure limit was 100ppm, and the NIOSH recommended exposure limit was the lowest feasible level. The actual inhaled dose would be much lower as a result of the use of personal protective equipment during painting operations. A potential for exposure to 2-EEA was also noted during the mixing of the paints and after the painting was completed. Protective equipment was not normally used at these times. The authors recommend that efforts to minimize these exposures should focus on improving exhaust ventilation in the hanger painting bays, providing impermeable coveralls to workers in the paint shop, and enclosing/separating the hanger paint bay from adjacent work bays.

17. Document Analysis a. Descriptors

b. Identifiers/Open-Ended Terms NIOSH-Publication, NIOSH-Author, NIOSH-Survey, Field-Study, IWS-134-20-12, Region-4, Maintenance-workers, Paint-shops, Painters, Spray-painting

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages 23
	22. Security Class (This Page)	22. Price

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.

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:	David R. Hesterlee, Chief Materials and Process Engineer Warren M. Underwood, Materials and Process Engineer Harold Rogers, Paint Shop General Foreman
EMPLOYEE REPRESENTATIVES CONTACTED:	None (Non-union)
SIC Code:	4511

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 to determine the extent of occupational exposure to these compounds to help assess whether an epidemiologic study is feasible. In addition, the Occupational Safety and Health Administration (OSHA) is interested in this information because they are proposing to revise its current regulations for 2-methoxyethanol, 2-ethoxyethanol, and their respective acetates.

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 Delta Airlines, Inc. Technical Operations Center in Atlanta, GA are presented in this report. At this facility, the potential for inhalation and dermal exposure to the ethylene glycol ethers exists primarily during the spray painting of aircraft, small parts and ground support equipment.

The monitoring results from the survey indicated the detectable concentrations of 2-EEA for all monitored operations; actual inhalation doses, however, should be much lower as a result of the regular use of respiratory protective equipment during painting operations. There is also a potential for exposure to 2-EEA while preparing for painting (e.g., mixing and thinning of paints) and after painting is complete (e.g., handling of painted parts in the paint shop); protective equipment is not typically worn during these activities.

Efforts to minimize exposures at the Technical Operations Center should focus on 1) improving exhaust ventilation in the hangar painting bays; 2) providing impermeable coveralls to workers in the paint shop; and 3) enclosing/separating the hangar paint bay from adjacent work bays.

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, fetotoxictiy, 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*). The 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 evaluating 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 Delta Airlines Inc., Technical Operations Center, while painting in an airline hangar, during June 13-14, 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). 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-EEA) 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 thymuš of rats and rabbits. Grant et al. [1985] have reported at least 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].

TABLE 1

PHYSICIAL 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	$C_3H_8O_2$	$C_5H_{10}O_3$	$C_4H_{10}O_2$	$C_6H_{12}O_3$
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/m3 (25°C,760mmHg)	3.11	4.83	3.69	5.41
1 mg/m3=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

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 ethyoxyacetic 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; Zavon 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; no quantitative estimates of exposure concentrations were provided [Cook et al. 1982]. A cross-sectional evaluation of semen quality among men exposed to 2-EE (concentrations ranged from zero to 23.8 ppm 2-EE) found significantly lower sperm count per ejaculate [NIOSH 1986]. Painters exposed to both 2-EE and 2-ME (full-shift exposure concentrations of 2-EE averaged 15 ppm; the concentration of 2-ME was not mentioned) 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 and embryotoxic effects, including teratogenesis, in the offspring of the exposed pregnant females [NIOSH 1983]. The NIOSH current recommended exposure limit (REL) 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 been published (as summarized in ECETOC 1985). These data are currently being evaluated 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 (TWA_8)
[s] Skin notation
* Reduce exposure to lowest feasible level

HISTORY AND DESCRIPTION OF THE FACILITY

The Delta Air Lines Technical Operations Center (TOC), located at the Hartsfield Atlanta International Airport in Atlanta, Georgia, is an aircraft overhaul facility (SIC Code 4511) covering 42 acres of hangar, shop and office space. The TOC includes two hangars where all Delta aircraft are brought for heavy maintenance (including structural/mechanical repairs and inspections, replacement of interior furnishings, exterior painting, etc. involving approximately 10,000 manhours per plane) on a scheduled basis. The larger hangar (which is 90 feet high) was built in 1970, whereas the smaller hangar (50 feet high) was built in 1960. The main hangar is large enough to simultaneously hold eight to nine planes while the smaller hangar can hold an additional four to six aircraft. Delta aircraft are scheduled for heavy maintenance on a four- to five-year cycle.

PROCESS DESCRIPTION

Delta aircraft are repainted every four to five years in open bays in either of the aircraft hangars located at the Technical Operations Center. A plane is completely stripped (versus only sanded) prior to every other painting (this allows better inspection of the metal). Workers, using portable

scaffolding units to move along the perimeter of the aircraft, remove old paint from the aircraft using a chemical stripper containing formic acid, phenol, and methylene chloride. After stripping the old paint, the aircraft is cleaned with methyl ethyl ketone to remove any remaining paint and paint stripper; the surface is then wiped down with a tack rag to remove remaining solvents and dust. Primer and top coat enamels are applied using electrostatic spray painting machines, generally with one machine on each side of the plane. Each machine has two spray guns and it takes four spray painters approximately 30 minutes to apply one coat each of primer or top coat enamel.

Approximately 118 pounds (dry weight) of paint are applied on a B-727 airplane--the most common type of aircraft painted. Delta reported that 2-EEA is a component of four of the enamel paints used. The gloss white enamel, which is applied as the primary top coat, contains approximately 15 percent 2-EEA and three other enamels used in detailing also contain 2-EEA (grey 5%; blue 20% and orange 5%). An epoxy primer containing 2-EEA, which had previously been used at this facility, has been replaced with a non-glycol ether epoxy primer.

Paints containing 2-EEA are also used in the paint shop where small parts and ground support equipment are painted. Two of the 2-EEA-containing paints used in the hangar (white and gray enamel) are also used daily in the paint shop. Gloss gray enamel, which was used during the short-term exposure monitoring in the paint shop, contains approximately five percent 2-EEA and five percent propylene glycol monomethyl ether acetate. Blue enamel paint containing 2-EEA is also used occasionally in the paint shop. No other paint formulations containing ethylene glycol ethers are used in the paint shop. Painting is conducted in the paint shop approximately four hours per shift.

DESCRIPTION OF EXPOSURE CONTROLS

Delta engineering personnel were interviewed to identify any controls (engineering and/or protective equipment) that directly or indirectly reduce workplace exposures to glycol ethers. These controls are presented herein by type and area/task.

A. Engineering Controls

Several engineering controls are used at the Delta Technical Operations Center to control the release of ethylene glycol ethers to the workplace.

Hangars. Spray painting of aircraft is conducted in only one of the bays in each aircraft hangar. Each paint bay is open to the adjacent bays; during spray painting operations, the door to the outside is closed. Several fans located in the bay door are used to "pull" air from the hangar to the outside while mobile fans are positioned at the opposite end of the bay to "push" air towards the bay door. On the day of the monitoring survey, a mobile fan was positioned only on the left side of the aircraft being painted.

Electrostatic spray painting (i.e. applying a charged paint to a grounded surface) is presently used at this facility. This painting method is more efficient than conventional compressed air, or airless methods and reduces overspray. The conversion from the previous airless spray painting method occurred around 1982 at a cost of approximately $40,000; a total of six electrostatic spray units have been purchased by Delta.

Delta representatives reported that an 18-month project was underway to construct a new aircraft hangar at the Technical Operations Center which will be used exclusively for aircraft paint stripping and maintenance painting. The new hangar will be totally enclosed and equipped with downdraft flow-through ventilation for the control of vapors during paint stripping and maintenance painting. This hangar will have the capacity for three different types of aircraft simultaneously. The cost estimate for construction of the new paint hangar and its associated ventilation equipment was reported to be $20 million.

Paint Shop. Small parts and ground support equipment are spray painted in an enclosed area (the "paint shop") equipped with downdraft ventilation and a water spray collection system. Airless spray paint guns with "cup collars" (conical-shaped which slightly protrude past the nozzle) are used to help minimize overspray.

B. Personal Protective Equipment

Hangars. Delta Air Lines requires all painters in the hangars to wear disposable long-sleeved Tyvek coveralls (including hoods), rubber gloves, and half-mask air-purifying respirators with cartridges approved by NIOSH for organic vapors and paint mists during spray painting of aircraft. Two types of Tyvek coveralls are used at the facility: a disposable coverall which is discarded after each use and a coverall constructed of a material with breathing pores which is used for three or four days before discarding. The disposable type were used by the spray painters during the monitoring survey. Workers generally wear personal protective equipment only during that time spent painting, approximately two to three hours of each shift.

Paint Shop. Painters in the small parts paint shop are provided reusable neoprene gloves and half-mask air-purifying respirators with organic vapor cartridges. While the use of respiratory protection during spray painting in the paint shop is recommended, it is not mandatory. However, most workers do wear respirators while spray painting, which is performed intermittently through the shift (approximately four hours per shift total).

DESCRIPTION OF THE WORKFORCE

The Delta Air Lines Technical Operations Center operates three 8-hour shifts, seven days per week, 360 days per year. There are approximately 6,000 employees at the facility. Delta Airline employees with a potential for exposure to 2-EEA at this facility can be grouped into the following job classifications:

Spray Painter (Hangar) - There are approximately eight spray painters assigned to aircraft spray painting activities at the Technical Operations Center. Their job duties include final preparation of the aircraft for painting (e.g., wipe down of the aircraft with paint stripper and cleaning cloths), mixing the paint with paint thinner prior to painting, and spray painting the aircraft with primer and final coat paints. Generally, four spray painters actually paint an aircraft; these painters are assisted by two to three helpers who monitor the electrostatic spray paint unit for problems.

Painter (Paint Shop) - Two painters per shift work in the paint shop where painting is conducted for approximately four hours per shift. Additional paint shop painter duties include unloading painted parts from the drying room, mixing and thinning paints in quart-size cans within the paint shop, and other non-painting duties in other areas of the facility.

Porter (Paint Shop) - There are a total of six workers designated as porters within the paint shop, three on the first shift, two on the second shift, and one on the third shift. The porter's job duties are similar to the paint shop painters which include transferring parts to and from the paint shop and mixing and thinning paints. Porters may also perform spray painting as necessary.

Table 5 provides a breakdown (by job title, gender, and age) of the number of workers at the Technical Operations Center who may be directly exposed to ethylene glycol ethers. (Also, an additional 50-60 people work immediately adjacent to the paint bays and may be indirectly exposed).

TABLE 5

NUMBER OF WORKERS POTENTIALLY EXPOSED TO
ETHYLENE GLYCOL ETHERS AT
DELTA AIRLINES TECHNICAL OPERATIONS CENTER

Job Title	Number of Workers Exposed			
	Males All	Males < age 45	Females All	Females < age 45
Painter (Hangars)	8	0	0	0
Painter (Paint Shop)	6	0	0	0
Porter (Paint Shop)	6	0	0	0

MEDICAL AND INDUSTRIAL HYGIENE PROGRAMS

Preemployment physicals are required for all employees at the Technical Operations Center. These are general medical examinations and are not specific for assessing past exposures to glycol ethers. The industrial

hygiene program is an ancillary responsibility of the Materials and Process Engineer at the site. Exposure monitoring of various operations have been conducted at the Technical Operations Center; however, no monitoring results are available for the ethylene glycol ethers.

SAMPLING STRATEGY AND METHODS

A one-shift sampling survey was conducted at the Delta Airlines Technical Operations Center to measure the extent of exposures associated with the usage of paints containing 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.

Paint formulations containing any of the four subject ethylene glycol ethers (2-ethoxyethanol, 2-methoxyethanol, 2-ethoxyethyl acetate, and 2-methoxyethyl acetate) were initially identified from material safety data sheets; the hangar and the paint shop were found to be the only areas in which glycol ether-containing paints are used.

Long-term samples were collected on spray painters who performed aircraft painting on the day of the survey; short-term samples were collected on spray painters in the hangar during actual application of a top coat enamel containing 2-EEA. Additionally, painters and porters in the paint shop were monitored for a full shift; one short-term sample was collected in the paint shop during the actual use of a paint containing 2-EEA.

OSHA Method 53 [OSHA 1985] was used for sampling and analysis of all NIOSH samples. 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 6 presents the analytical limit of detection (LOD) and limit of quantitation (LOQ) for the ethylene glycol ether sampled at the Delta facility. 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 6 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 6

LIMIT OF DETECTION (LOD) AND LIMIT OF QUANTITATION (LOQ)
FOR 2-ETHOXYETHYL ACETATE (2-EEA)

Analytical Limits (mg/sample)		Sampling Limits (ppm/sample)			
		TWA8[a]		Peak[b]	
LOD	LOQ	LOD	LOQ	LOD	LOQ
0.01	0.03	0.02	0.06	0.12	0.37

[a] 8-hour time-weighted average sample collected at 0.2 Lpm.
[b] 15-minute short-term sample collected at 1.0 Lpm.

MONITORING RESULTS

A total of 18 field samples were collected and analyzed for 2-EEA. All sample results indicated the presence of 2-EEA above both the limit of detection (0.01 milligrams per sample) and the limit of quantitation (0.03 milligrams per sample) of the analytical method. Individual sample results are reported in Table 7 as time-weighted averages (TWAs) over the respective sampling duration.

Long-Term Sampling. A total of 13 long-term (5-8 hours) samples (12 personal and one area) were collected during the monitored workshift. Sample results of the eight personal samples collected in the hangar ranged from 0.87 ppm to 2.77 ppm; the arithmetic mean for all eight samples was 1.82 ppm. Four personal samples and one area sample were collected in the paint shop. The area sample result indicated a concentration of 2-EEA of 0.29 ppm for the monitored shift; the personal sample results ranged from 0.46 ppm to 1.54 ppm, with an arithmetic mean of 0.97 ppm. All monitored "spray painters" and "porters" shown in Table 7 wore respirators whenever painting (which generally averaged two to four hours per shift).

Short-term Sampling. Four short-term personal samples were collected in the hangar to evaluate peak exposures to 2-EEA during the application of the white enamel (containing 2-EEA) to an aircraft. The sample results ranged from 1.73

TABLE 7

MONITORING RESULTS FOR 2-ETHOXYETHANOL ACETATE (2-EEA)
DELTA AIRLINES TECHNICAL OPERATIONS CENTER, ATLANTA, GEORGIA
June 14, 1988

Sample ID	Job/area	Time Start-Stop	Flow (cc/min)	Duration (min)	Air volume, (L)	Concentration (ppm)[a] 2-EEA
DL-1	Hangar: spray painter[b]	10:13-10:44	980.0	31	30.4	2.62
DL-2	Paint shop: porter	7:00-14:45	197.0	465	91.6	1.54
DL-3	Hangar: spray painter[b]	10:10-10:45	1001.0	35	35.4	1.73
DL-4	Paint shop: area	9:26-14:44	200.5	318	63.8	0.29
DL-5	Hangar: spray painter[r]	8:14-14:05	103.1	351	36.2	1.23
DL-7	Hangar: spray painter[b]	10:12-10:45	990.0	33	32.7	11.91
DL-8	Hangar: spray painter[l]	8:18-14:28	100.0	370	37.0	2.35
DL-10	Paint shop: foreman	7:08-14:32	200.3	444	88.9	0.46
DL-11	Hangar: spray painter[r]	8:17-14:50	98.5	393	38.7	1.91
DL-14	Hangar: spray painter[l]	8:40-14:51	102.8	371	38.1	2.77
DL-16	Hangar: spray painter	8:26-14:48	198.5	382	75.8	2.69
DL-19	Paintshop: spray painter[b]	13:55-14:10	980.0	15	14.7	4.66
DL-20	Hangar: spray painter[r]	8:43-14:50	100.2	367	36.8	1.41
DL-21	Paint shop: porter	7:04-14:46	200.3	462	92.5	0.82
DL-26	Hangar: spray painter[l]	8:36-14:49	97.4	373	36.3	0.87
DL-28	Hangar: spray painter[r]	8:20-14:50	98.1	390	38.3	1.36
DL-30	Paint shop: spray painter	6:54-14:47	100.3	473	47.4	1.05
DL-31	Hangar: spray painter[b]	10:12-10:38	980.0	26	25.5	5.89

[a]Samples were not time-weighted to 8-hour concentrations.
[b]Short-term monitoring samples.
[r]Spray painter was positioned on right side of aircraft during painting operations.
[l]Spray painter was positioned on left side of aircraft during painting operations.

ppm to 11.9 ppm (arithmetic mean of 5.54 ppm). One short-term sample was collected in the paint shop during spray painting of a small part with the gray enamel containing 2-EEA. The sample result indicated a concentration of 4.66 ppm of 2-EEA during this operation. All workers monitored for short-term exposures wore respirators during the entire sampling duration shown in Table 7.

SUBSTITUTES

Delta did not identify any possible substitutes for the four types of paints containing ethylene glycol ethers (2-EEA) which are currently used at the Technical Operations Center. However, they did indicate that an epoxy primer containing 2-EEA which was previously used at the facility had been replaced with a non-glycol ether containing epoxy primer.

DISCUSSION

Sampling results clearly indicate that exposures to 2-EEA are occurring during spray painting activities in the hangar and paint shop at the Technical Operations Center. All samples had detectable results which ranged from 0.27-2.77 ppm (long-term samples) and from 1.73-11.9 ppm (short-term samples).

In the hangar, where the exposures ranged from 0.89-11.9 ppm, actual inhalation doses should be lower because of the regular use of respiratory protection worn during painting activities. But, workers were not as well protected while performing other tasks with potential for exposure to 2-EEA such as the preparation for painting (e.g., mixing and thinning of paints) and after painting is completed (e.g., handling of painted parts in the paint shop). Also, while protective clothing was required to be worn while spray painting in the hangar, the actual skin protection afforded is lessened because employees were observed to have cut holes or slits in the coveralls and rubber gloves in an effort to improve cooling.
In the paint shop, where exposures ranged from 0.29-4.66 ppm, inhalation exposures were controlled, to some extent, through the recommended use of respirators during actual painting activities. Though not required, most employees were observed during the survey to wear respirators while painting. And while some skin protection was afforded by neoprene gloves, the workers otherwise wore only street clothes (often with short- or rolled-up sleeves) with no outer covering.

CONCLUSIONS AND RECOMMENDATIONS

At the Delta Air Lines Technical Operations Center in Atlanta, Georgia, glycol ether-containing formulations are used in (1) aircraft maintenance painting in the hangars, and (2) small parts and ground equipment painting in the paint shop. The sampling results from the survey indicated detectable concentrations of 2-EEA for all monitored operations. Long-term exposures ranged from 0.29-2.77 ppm, which compare to the 100 ppm OSHA PEL, the 5 ppm ACGIH TLV, and the "lowest feasible level" NIOSH REL. These exposures are considerably lower than the concentrations in those few studies in which

exposed workers were observed to have reproductive effects (see [Cook et al. 1982]; [NIOSH 1986]; [Welch and Schrader 1986]). Also, actual inhalation doses at the Delta facility should be much lower as a result of the use of respiratory protective equipment during spray painting activities. There is also a potential for exposure to 2-EEA during performance of tasks in preparation for painting (e.g., mixing and thinning of paints) and after painting is complete (e.g., handling of painted parts in the paint shop); no personal protection is worn during these activities. Although protective clothing is required for painters in the hangar during spray painting, the potential for dermal exposure to 2-EEA is not fully minimized due to alterations by the employee to the coveralls and gloves worn. In the paint shop, street clothes (including short-sleeves) were allowed; no coveralls were provided to employees in this area.

Efforts to minimize exposures at the Technical Operations Center should focus on 1) improving exhaust ventilation in the hangar paint bays; 2) providing impermeable coveralls to workers in the paint shop and discouraging any alterations to this clothing (also applicable to hangar painters); and 3) enclosing/separating the hangar painting bay from adjacent work bays. NIOSH recommends that engineering controls be applied prior to resorting to personal protective equipment for adequating reducing employee exposures in the workplace.

Employee exposures to 2-EEA during spray painting of aircraft at the facility are expected to decrease in the near future when Delta's new painting hangar (to be exclusively used for painting aircraft), utilizing a more effective downdraft ventilation system, is completed.

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 tis 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.