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**HETA 97-0214-2689**  
**Dorma Door Controls, Inc.**  
**Reamstown, Pennsylvania**

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**Gregory M. Kinnes, CIH, RS**

## PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, technical and consultative assistance to Federal, State, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease. Mention of company names or products does not constitute endorsement by the National Institute for Occupational Safety and Health.

## ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Gregory M. Kinnes of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Kevin Roegner. Analytical support was provided by Ardith Grote, of the Division of Physical Sciences and Engineering (DPSE), and DataChem Laboratories. Desktop publishing was performed by Nichole Herbert. Review and preparation for printing was performed by Penny Arthur.

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**Health Hazard Evaluation Report 97-0214-2689**  
**Dorma Door Controls, Inc.**  
**Reamstown, Pennsylvania**  
**May 1998**

**Gregory M. Kinnes, CIH, RS**

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## **SUMMARY**

On May 21, 1997, the National Institute for Occupational Safety and Health (NIOSH) received a confidential request for a health hazard evaluation (HHE) from employees of Dorma Door Controls, Inc. located in Reamstown, Pennsylvania. The request was prompted by the occurrence of adverse health effects that employees associated with exposures to airborne contaminants from the paints and other chemicals used during the manufacture of hydraulic door closers. The request also indicated concerns about the ventilation system not continuously operating in the paint drying/arms assembly area (dryline room) of the facility. On December 3-4, 1997, investigators from NIOSH visited the Dorma facility to conduct environmental sampling when the ventilation systems that service the dryline room would be operated intermittently. Environmental samples were collected for 2-butoxyethanol (EGBE), 2 (2-butoxyethoxy) ethanol (DGBE), trichloroethylene, dibutyl phthalate, and volatile organic compounds (VOCs).

The area samples for EGBE indicated airborne concentrations ranging from 1.2 to 4.1 parts per million (ppm), while EGBE concentrations for the personal breathing zone (PBZ) samples ranged from 0.07 to 2.5 ppm. The highest EGBE concentrations were obtained from samples collected in the paint room. The DGBE concentrations ranged from 0.32 to 0.90 ppm for the area samples and a trace concentration (value between 0.03 and 0.07 ppm) to 0.44 ppm for the PBZ samples. The highest DGBE concentrations (0.78, 0.89, and 0.90 ppm) were measured on the three area samples collected from locations in the dryline room. Area trichloroethylene concentrations were 3.5 and 0.71 ppm, and the major compounds identified with the VOC screen included trichloroethylene, EGBE, DGBE, and 2-ethyl-1-hexanol. All the area samples collected for dibutyl phthalate had concentrations that were non-detectable (below 0.002 milligrams per cubic meter). All the airborne contaminant concentrations determined during this investigation were below their relevant evaluation criteria. However, one of the partial shift samples collected from an area sample in the paint room had an EGBE concentration (4.1 ppm) which approached the NIOSH REL of 5 ppm.

The cursory inspection of the ventilation systems in the dryline room indicated that the paint room was under a negative pressure with respect to the dryline room and that most of the vapors generated in the dryline room were due to the evaporation of the paint during the drying process. This inspection also determined that paint emissions were escaping into the surrounding employee work areas from the initial infrared drying tunnel enclosure due to design deficiencies and that the design of the ventilation system may limit its overall effectiveness. The exhaust ventilation and enclosures for the paint booths and the trichloroethylene degreaser seemed to be adequately controlling the release of airborne contaminants. However, it may be possible for some contaminants to reenter the facility via the supply air system during certain atmospheric conditions.

Although no airborne contaminant concentrations determined during this investigation exceeded their relevant evaluation criteria, the EGBE concentration in the paint room approached the NIOSH REL of 5 ppm. These results indicate that the highest EGBE exposures are encountered inside the paint room and that overall exposures encountered by the paint room operators are dependent on the amount of time actually spent inside the paint room. The paint room operators currently alternate duties inside and outside of the paint room which reduces their overall exposures. However, additional environmental monitoring needs to be conducted to determine the extent of exposures contributed by manual spray operations performed outside the paint room and if there is a potential to achieve higher EGBE concentrations inside the paint room when the volume of parts being painted increases over that encountered during this investigation. A cursory ventilation system inspection indicated that the initial infrared drying tunnel was not effectively controlling paint vapors generated during the drying process since emissions were observed to be escaping the enclosure into the dryline room environment. The highest airborne concentrations of DGBE were measured from locations in close proximity to this drying tunnel. The escape of these emissions from this enclosure may be one plausible explanation for the occurrence of adverse health effects reported among dryline room employees.

Keywords: SIC 3429 (Hardware, Not Elsewhere Classified) 2-butoxyethanol, ethylene glycol monobutyl ether, EGBE, butyl cellosolve, 2-(2-butoxyethoxy) ethanol, diethylene glycol mono-*n*-butyl ether, DGBE, butyl carbitol, trichloroethylene, dibutyl phthalate, water based paints, painting, door closers.

# TABLE OF CONTENTS

Preface .....	ii
Acknowledgments and Availability of Report .....	ii
Summary .....	iii
Introduction .....	2
Background .....	2
Evaluation Design and Methods .....	3
Evaluation Criteria .....	4
2-Butoxyethanol .....	5
2 (2-Butoxyethoxy) ethanol .....	6
Trichloroethylene .....	6
Results and Discussion .....	7
Conclusions .....	9
Recommendations .....	10
References .....	11

## INTRODUCTION

On May 21, 1997, the National Institute for Occupational Safety and Health (NIOSH) received a confidential request for a health hazard evaluation (HHE) from employees of Dorma Door Controls, Inc. located in Reamstown, Pennsylvania. The request was prompted by the occurrence of adverse health effects that employees associated with exposures to airborne contaminants from the paints and other chemicals used during the manufacture of hydraulic door closers. The request stated that employees in the paint drying/arms assembly area (dryline room) were experiencing asthma, headaches, dizziness, nose bleeds, and drying of the lips and mouth. The request also indicated concerns about the ventilation system not being continuously operated in this area of the facility.

After this HHE request was received, a NIOSH investigator contacted the primary confidential requestor and the Dorma Door official responsible for health and safety to gather information concerning the perceived health concerns and to discuss the scope of the NIOSH investigation. Information pertaining to the operation of the ventilation systems, results from previous industrial hygiene surveys, and the material safety data sheets (MSDS) for the paints and other chemicals used in the dryline room was requested and reviewed.

Based on a review of the ventilation system's operation and conversations with the primary requestor and Dorma environmental/methods engineer, it was determined that the ventilation system for this area of the facility was designed to operate continuously during the summer months and intermittently during the winter months. Therefore, the initial site visit was delayed until December 1997. This delay was intended to allow the determination of potential employee exposures during colder outdoor weather when the ventilation systems would be operated in the winter mode. Indoor contaminant concentrations would likely be highest during the winter months when the ventilation systems would be cycling on/off, instead

of operating continuously as in summer mode. On December 3–4, 1997, investigators from NIOSH visited the Dorma facility to conduct environmental sampling for 2-butoxyethanol, 2 (2-butoxyethoxy) ethanol, trichloroethylene, dibutyl phthalate, and volatile organic compounds (VOCs).

## BACKGROUND

Dorma Door Controls, Inc. manufactures hydraulic door closers and employs approximately 175 employees on two shifts at their Reamstown facility. The processes at this facility include the machining, cleaning, assembling, painting, packing, and shipping of hydraulic door closers. Most of the metal parts used in this operation are composed of aluminum and steel. The machined parts are cleaned in an aqueous cleaning solution prior to the assembly process. After final assembly, some of the parts are cleaned in a conveyORIZED vapor degreaser, which uses trichloroethylene. The assembled and cleaned parts are then conveyed to the paint room, which consists of two Ransburg electrostatic paint booths, which apply a water-based primer and a water-based color coat. As the painted parts exit the paint room, they are transferred onto a line conveyor which carries the painted parts up to ceiling level where they travel through infrared heat tunnels to expedite the drying process. After drying, the finished parts are removed from the conveyor to be packed and shipped.

The paint drying/arms assembly and degreaser take-off areas are located in the dryline room with the paint room being adjacent to the dryline room. The dryline room is approximately 5,110 square feet. Air is exhausted through two exhaust units each capable of handling 7,500 cubic feet per minute (CFM). One exhaust unit is located on the roof near the dryline conveyor, which is in the north half of the room. The exhaust ducts for this unit are all located at ceiling level above the dryline conveyor except for an exhaust duct that is dedicated to remove contaminants generated by the first infrared heat tunnel. The second exhaust unit is mounted on the roof above the vapor degreaser in the south end of

the room. The exhaust ducts for this unit extend to floor level near the degreaser along the south wall of the dryline room. All the openings for the exhaust ducts for these two units are rectangular grills of various sizes. Air is supplied to the room via two Reznor gas air make-up units each capable of supplying 7,000 CFM. The ducts for these air make-up units run from the south side of the area to the north side with outlet grills located on the east and west sides.

The exhaust and air make-up systems are tied together electrically so that both systems operate at the same time. A Tork Model W120 seven day calendar dial time switch, located on the east wall of the dryline room, turns the systems on at 5:00 a.m. and off at midnight each work day. The systems are automatically turned off during the weekends when there are no production operations. The time switch is also equipped with a manual device to select one of two modes, either summer or winter. During summer mode, the air handlers (both exhaust and air make-up) run continuously during the time selected on the seven day timer, 5:00 a.m. through midnight. However, the system is manually switched to winter mode when outside temperatures make it uneconomical to continuously heat approximately 14,000 CFM of air. During winter mode, the air handlers cycle on and off every 20 minutes throughout the time selected on the timer. During the 20 minute on cycle, the make-up air can be gas heated, if required, to maintain a minimum pre-set temperature in the production area. At the end of 20 minutes, the air handlers shut down for the following 20 minutes unless the indoor temperature falls below the pre-set minimum temperature in, which case, the air handlers turn on and provide heated make-up air until the temperature again reaches the pre-set indoor minimum. This function is controlled by a thermostat located next to the seven day timer, but operates independently of the 20 minute on/off cycle.

## EVALUATION DESIGN AND METHODS

On December 3, 1997, NIOSH investigators held an opening conference attended by Dorma Door representatives, a selected employee representative from the area of concern, an employee safety committee representative, and a representative from the Pennsylvania Department of Health. During this conference, the HHE request, which prompted the investigation and the scope of the NIOSH investigation were discussed. After the opening conference, a plant walk-through inspection was conducted which emphasized the dryline room, the area of concern listed in the HHE request.

On December 4, 1997, the NIOSH investigators, with assistance from the health department representative, conducted environmental monitoring to determine potential employee exposures to airborne contaminants present in the facility. Both personal breathing zone (PBZ) and area samples were collected for 2-butoxyethanol and dibutyl phthalate, which are the primary components of the water-based paints as determined by the review of the MSDS. Area samples were also collected for trichloroethylene which is used in the vapor degreaser and for other VOCs that may be present. The ventilation systems were visually inspected with the aid of smoke tubes to trace air flow patterns and a TSI, Inc. Model 8360 VelociCalc Plus air velocity meter.

Four area samples were collected using thermal desorption tubes to qualitatively identify any airborne VOCs that may be present in the dryline room. Stainless steel tubes configured for the Perkin-Elmer ATD 400 thermal desorption system were connected via Tygon® tubing to battery-powered sampling pumps calibrated to operate at a flow rate of 0.05 liters per minute (L/min). Each thermal desorption tube contained three beds of sorbent materials: a front layer of Carbopack Y (~90 milligram [mg]), a middle layer of Carbopack B (~115 mg), and a back section of

Carboxen 1003 (~150 mg). The sorbent tubes were dry purged with helium for 30 minutes at 0.1 L/min prior to analyses to remove any excess water from the samples. Samples were then analyzed using the ATD 400 automatic thermal desorption system containing an internal focusing trap packed with Carboxen b/Carboxen 1000 sorbents. The thermal unit was interfaced directly to a HP5890A gas chromatograph and HP5970 mass selective detector (TD-GC-MSD).

Nine PBZ and area samples were collected to determine potential employee exposures to 2-butoxyethanol using NIOSH Method 1403.<sup>1</sup> All samples, except those located in the paint room, were collected over a full shift. Both the PBZ and area samples collected in the paint room were collected using two partial shift samples to prevent sorbent break-through. These partial shift samples were then used to determine the full shift exposure. The location and duration of these samples are presented in Table 1. Samples were collected using 100 mg/50 mg, activated charcoal sorbent tubes connected via Tygon tubing to a battery-powered sampling pump calibrated to operate at a flow rate of 0.05 L/min. The samples were then analyzed for 2-butoxyethanol and 2 (2-butoxyethoxy) ethanol, which had been previously identified as also being present during the qualitative VOC analysis. Since no analytical method is available for the analysis of 2 (2-butoxyethoxy) ethanol, the samples were analyzed for both 2-butoxyethanol and 2 (2-butoxyethoxy) ethanol according to NIOSH Method 1403 (for alcohols including 2-butoxyethanol) with minor modifications. The samples were desorbed for 30 minutes in 1.0 milliliter (mL) of methylene chloride containing 5% methanol as a desorbing aid. The resulting solutions were analyzed with a Hewlett-Packard Model 5890IIA gas chromatograph equipped with a 30 meter (m) x 0.32 millimeter (mm) fused silica capillary column coated internally with 1.0 micrometer ( $\mu\text{m}$ ) of DB-5ms and a flame ionization detector.

Two consecutive partial shift area samples were collected for trichloroethylene from a location near

the degreaser take-off inspection station. Samples were collected using 100 mg/50 mg, activated charcoal sorbent tubes connected via Tygon tubing to a battery-powered sampling pump calibrated to operate at a flow rate of 0.2 L/min. The samples were desorbed for 30 minutes in 1.0 mL of carbon disulfide and analyzed with a Hewlett-Packard Model 5890IIA gas chromatograph equipped with a 30 m x 0.32 mm fused silica capillary column coated internally with 0.5  $\mu\text{m}$  of DB-wax and a flame ionization detector according to NIOSH Method 1022.<sup>1</sup>

Six PBZ and area samples were collected for dibutyl phthalate according to NIOSH Method 5020.<sup>1</sup> These samples were collected from the same four locations as the area samples for 2-butoxyethanol (Table 1). In addition to the four area samples, two partial shift PBZ samples were collected from a paint room operator. The samples were collected using 0.8  $\mu\text{m}$  mixed cellulose ester membrane filter cassettes connected via Tygon tubing to a battery-powered sampling pump calibrated to operate at a flow rate between 1.1 and 1.3 L/min. The filters were sonicated for 30 minutes in 2.0 mL of carbon disulfide. The resultant solution was then analyzed with a Hewlett-Packard Model 5890IIA gas chromatograph equipped with a 30 m x 0.32 mm fused silica capillary column coated internally with 1.0  $\mu\text{m}$  of DB-5ms and a flame ionization detector.

## EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a



pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH recommended exposure limits (RELs)<sup>2</sup>, (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®)<sup>3</sup> and (3) the U.S. Department of Labor, OSHA permissible exposure limits (PELs)<sup>4</sup>. In July 1992, the 11th Circuit Court of Appeals vacated the 1989 OSHA PEL Air Contaminants Standard. OSHA is currently enforcing the 1971 standards which are listed as transitional values in the current Code of Federal Regulations; however, some states operating their own OSHA-approved job safety and health programs continue to enforce the 1989 limits. NIOSH encourages employers to follow the 1989 OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criteria. The OSHA PELs reflect the feasibility of controlling exposures in various industries where the agents are used, whereas NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required to meet those levels specified by an OSHA standard and that the OSHA PELs included in this report reflect the 1971 values.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure

limits (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

## 2-Butoxyethanol

2-Butoxyethanol is also known as butyl cellosolve®, Dowanol EB®, Jeffersol EB®, Ektasolve EB®, butyl Oxitol®, or ethylene glycol monobutyl ether (EGBE).<sup>5</sup> EGBE is a useful coupling agent with excellent solvent power for many of the resins used in surface coatings (paints, lacquers, inks).<sup>6</sup> EGBE is also used as a coupling agent in metal cleaning formulas and household cleaners, as an intermediate in the production of ethylene glycol monobutyl ether acetate, and as a component in herbicides and automotive brake fluids.<sup>5</sup> EGBE is an irritant of the eyes and mucous membranes, and in animals it is a hemolytic (destroys red blood cells) agent.<sup>7</sup> The toxic effects of EGBE have been reported in many publications reviewed by NIOSH.<sup>5</sup> However, only a limited number of studies describe the effects of EGBE exposure on humans. The principal human health effects attributed to EGBE exposure involve the central nervous system, the blood and hematopoietic system, and the kidneys.<sup>5</sup> The following toxic effects have been reported in humans exposed by inhalation to 100 to 200 parts per million (ppm) EGBE: ocular and nasal irritation, disturbed taste, vomiting, headache, and belching.<sup>8</sup> In animal studies, acute (short-term) exposures to this compound have caused congested lungs and kidneys, as well as other damage to the kidneys which included extreme tubular necrosis and degeneration, osmotic fragility of erythrocytes, and damaged spleens.<sup>5</sup> Chronic (long-term) exposure may break down red blood cells, causing anemia, and cause damage to the liver and kidneys. No evidence from animal studies indicates that EGBE causes adverse reproductive or developmental effects.<sup>5</sup> Although experimental results indicate that rats are more susceptible than humans to the hemolytic effects of EGBE, human hemolytic effects have been shown in vitro, and it was concluded that the osmotic fragility of human erythrocytes would be expected to increase after inhalation of EGBE at

concentrations above 200 ppm.<sup>5,8</sup> EGBE also penetrates the skin readily, and toxic action from excessive skin exposure may be more likely than from vapor inhalation.<sup>8</sup>

Based on the ability of EGBE to cause hemolytic effects and the prevalence of anemia in the human population, ACGIH recommends an 8-hour TWA of 25 ppm. This TLV was established to maintain exposures to EGBE below levels that are found to cause blood changes in experimental animals.<sup>6</sup> The NIOSH REL for EGBE is 5 ppm as a 10-hour TWA. Because of the absence of sufficient human data, NIOSH based its REL on data used to determine the human dose corresponding to a 50-ppm no observable adverse effect level (NOAEL) in rats.<sup>5,9</sup> The OSHA PEL for EGBE is 50 ppm as an 8-hour TWA. All three exposure limits have a “skin” notation. The skin notation indicates that a significant portion of the overall exposure to a chemical is by the cutaneous (skin) route, including the mucous membranes and eyes.

## 2 (2-Butoxyethoxy) ethanol

2 (2-Butoxyethoxy) ethanol is also known as butyl carbitol<sup>®</sup>, Dowanol DB<sup>®</sup>, Glycol ether DB, Ektasolve DB<sup>®</sup>, Butyl Dioxitol<sup>®</sup>, or diethylene glycol mono-*n*-butyl ether (DGBE).<sup>10</sup> DGBE is used primarily as a solvent in hard-surface cleaners and inks, and as a solvent and coalescing agent in paints and other coatings.<sup>11</sup> DGBE has a low order of acute toxicity by the oral and dermal routes, and is not toxic by the inhalation route, possibly due in part to the low vapor concentration that could be generated.<sup>10</sup> The dermal route is the most likely route for human exposure because of the extensive use of DGBE in cleaning products and coatings: DGBE has been extensively tested by this route, and has caused no target organ, fertility, developmental, or nervous system toxicity in animal studies.<sup>10</sup> Hematotoxicity, associated with EGBE in rats, was reported in only one study at very high doses of DGBE; and like other glycol ethers, DGBE was not genotoxic.<sup>10</sup> Except for one case of hypersensitivity associated with DGBE in an office worker, there are no reports of adverse effects in humans from the use

of DGBE-containing products.<sup>10,12</sup> No occupational standards have been established for exposure to DGBE.

## Trichloroethylene

Trichloroethylene (TCE) is used primarily as a degreasing solvent, in dry cleaning and extraction, as a chemical intermediate, and has limited use as an anesthetic and analgesic. The predominant physiological response for TCE is one of central nervous system depression (CNS) with symptoms including dizziness, light-headedness, lethargy, and impairment in visual-motor response tests. Some evidence of mild liver dysfunction has occurred in workers exposed to levels (>300 ppm) sufficient to produce marked CNS effects, and prolonged exposure at toxic levels also may result in hearing defects.<sup>7</sup> Workers exposed to estimated TCE concentrations between 100 and 200 ppm have reported increased incidences of fatigue, vertigo, dizziness, headaches, memory loss, impaired ability to concentrate, muscular pains, and gastrointestinal disturbances.<sup>7</sup> TCE is mildly irritating to the skin, and repeated contact may cause chapping and erythema due to defatting.<sup>7</sup>

TCE reduces tolerance to alcoholic beverages, and some individuals who have been exposed to TCE experience “degreaser’s flush” after consuming alcohol. This apparently benign condition is typically of short duration, and consists of red areas of skin on the face, neck, shoulders, and back.<sup>13</sup> It has been suggested that ingestion of alcohol may potentiate the effects of TCE intoxication.<sup>14</sup>

On March 21, 1975, the National Cancer Institute (NCI) reported preliminary results of a carcinogen bioassay which indicated no carcinogenic effects in rats but the induction of hepatocellular carcinomas in mice. After reviewing the NCI study, NIOSH recommended that TCE be considered a suspect human carcinogen and transmitted this message to industry via a 1975 Current Intelligence Bulletin.<sup>15</sup> Since there is no known safe level of exposure to a carcinogen, NIOSH recommended that exposure be minimized to the lowest extent possible. An REL of

25 ppm was originally proposed in a 1978 technical report based on engineering controls available at that time and is currently included in the NIOSH Pocket Guide.<sup>16,17</sup> However, the TLV Committee considers TCE to be in Group A5, not suspected as a human carcinogen, because the substance has been more recently demonstrated by well-controlled epidemiological studies not to be associated with any increased risk of cancer in exposed humans.<sup>6</sup> The current ACGIH TLV is 50 ppm as an 8-hour TWA with a STEL of 100 ppm. The OSHA PEL for TCE is 100 ppm as an 8-hour TWA with a 200 ppm ceiling concentration.

## RESULTS AND DISCUSSION

On the day of sampling, outdoor temperatures ranged from the low 30s°F early in the morning to the low 50s°F in the afternoon. Therefore, the ventilation system was operating in winter mode, with the system cycling on and off every 20 minutes unless the indoor temperature dropped below 69°F. According to Dorma records, the number of parts painted on the day of sampling was slightly below the average number for the previous month (November 1997). Therefore, the environmental samples were collected while the ventilation system was operating in winter mode on a day that would be considered typical in terms of production numbers. However, several employees noted that the conditions inside the plant, specifically the paint vapors, were not that noticeable. These employees stated that on previous occasions the paint vapors inside the plant were much more perceivable and unpleasant.

The results of the environmental samples for 2-butoxyethanol (EGBE), 2-(2-butoxyethoxy) ethanol (DGBE), and trichloroethylene are included in Table 1. The area samples for EGBE had concentrations that ranged from 1.2 to 4.1 ppm while the PBZ samples had EGBE concentrations that ranged from 0.07 to 2.5 ppm. The highest EGBE concentrations were both obtained from partial shift

samples collected during the morning in the paint room. Two partial shift samples were each collected from an area in the paint room (4.1 and 2.5 ppm) and from a paint room operator (2.5 and 1.1 ppm). The time-weighted average concentrations for these partial shift samples were 3.7 ppm for the area sample in the paint room and 1.9 ppm for the PBZ sample from the paint room operator. The remaining area samples were collected in the dryline room. The two area samples collected at floor level near an assembly station and the transfer line both had concentrations of 1.2 ppm, while an area sample collected from a location near the exit from the initial infrared drying tunnel (ceiling level) had a concentration of 1.7 ppm. Two PBZ samples were also collected from employees at the arm assembly stations. The concentrations for these samples were 0.54 and 0.07 ppm.

DGBE concentrations were also determined for these samples. The DGBE concentrations ranged from 0.32 to 0.90 ppm for the area samples and a trace concentration to 0.44 ppm for the PBZ samples. A trace concentration is defined as the detected value of an analyte between the analytical limit of detection (LOD) and limit of quantitation (LOQ). The LOD and LOQ for DGBE during these analyses were 0.004 and 0.01 milligrams per sample (mg/sample), respectively. These correspond to a minimum detectable concentration (MDC) of 0.03 ppm and a minimum quantifiable concentration (MQC) of 0.07 ppm, which was calculated assuming a sample volume of 23 liters. The highest DGBE concentrations (0.78, 0.89, and 0.90 ppm) were determined on the three area samples collected from locations in the dryline room. The two partial shift samples collected in the paint room had concentrations of 0.69 and 0.32 ppm, with a full shift TWA of 0.61 ppm. The partial shift concentrations determined from the paint room operator were 0.42 and 0.44 ppm, with a TWA of 0.43 ppm. The two PBZ samples collected from the assembly station employees had DGBE concentrations at a trace level and 0.30 ppm.

All the EGBE concentrations determined during this investigation were below the relevant evaluation

criteria. However, one of the partial shift area samples collected in the paint room had a concentration (4.1 ppm) which approached the NIOSH REL of 5 ppm. This sample was collected during the morning when most of the parts painting was occurring. The EGBE concentration for the afternoon partial shift area sample was 2.5 ppm and the full shift TWA was 3.7 ppm. The partial shift PBZ samples collected from a paint room operator were also collected at approximately the same intervals. The PBZ sample collected from the paint room operator during the morning had an EGBE concentration (2.5 ppm) which was lower than the corresponding area sample. This operator then switched duties with another operator and worked outside the paint room during the afternoon. The EGBE concentration for the partial shift PBZ sample collected during the afternoon was 1.1 ppm while the TWA for the full shift was 1.9 ppm. Since there are typically two employees who operate the paint room, one employee is usually stationed within the paint room while the other employee remains outside the paint room and performs support duties as well as some manual spraying of parts in a separate paint booth. These employees typically alternate duties by spending half of the shift performing the outside functions and half of the shift performing the inside functions. The paint room operator who wore the PBZ sample worked inside the paint room during the morning and then switched to the outside during the afternoon. This individual's exposure to EGBE was also higher when stationed inside the paint room during the morning and lower when outside the paint room in the afternoon, thereby reducing his overall exposure. Therefore, this alternation of duties could be considered an administrative control which limits the amount of time an operator spends inside the paint room where the highest exposures to EGBE occur. The overall exposure encountered by the operator would be correlated to the amount of time spent inside the paint room. However, more sampling would need to be conducted to determine the extent of exposure contributed by the manual spray operation since only minimal manual spraying was observed during this investigation. In addition, the potential for dermal exposure existed in the paint room. Although protective gloves were available, it

appeared that the gloves were not always used. These sample results also indicate that, although area EGBE concentrations in the paint room only approached the NIOSH REL during this investigation, the potential may exist for EGBE concentrations inside the paint room to reach the NIOSH REL on days when more parts are painted. Again, additional sampling would need to be conducted to verify this possibility. If EGBE concentrations inside the paint room are shown to exceed the NIOSH REL, it would be prudent to implement engineering controls, in addition to the administrative control of alternating duties, to reduce the overall EGBE exposures encountered by the paint room operators.

There are no evaluation criteria for DGBE. The highest DGBE concentrations determined during this investigation were found on area samples collected in the dryline room, ranging from 0.32 to 0.90 ppm (2.1 to 6.0 mg/m<sup>3</sup>). Since DGBE has a low vapor pressure and concentrations were higher in the dryline room than the paint room, the infrared drying tunnels may be facilitating the release of DGBE and other VOCs in the dryline room.

DGBE, as well as other VOCs, may be associated with the reported occurrence of adverse health effects (i.e., asthma, upper respiratory symptoms) among employees in the dryline room. Recent medical investigations have shown that painters using water based paints have an increased prevalence of bronchial hyperresponsiveness and asthma symptoms possibly related to VOC exposure.<sup>18</sup> In addition, one case of hypersensitivity to DGBE has been previously documented.<sup>12</sup> The DGBE concentrations from this investigation were also comparable to those measured in another study of house painters using water-based paints.<sup>19</sup>

Two partial shift samples for trichloroethylene were collected from an area near the degreaser take-off inspector. The trichloroethylene concentrations for these samples were 3.5 and 0.71 ppm. The full shift TWA for these samples was 2.3 ppm. These concentrations were well below the evaluation criteria for trichloroethylene.

Four area samples were collected using the thermal desorption tubes to identify the VOCs present in the facility. The major compounds detected were trichloroethylene, EGBE, DGBE, and 2-ethyl-1-hexanol. Other compounds identified as being present at lower concentrations included acetone, ethyl oxirane, butanol, butyl formate, toluene, alkyl benzenes, dipropylene glycol methyl ether isomers, 1-methyl-2-pyrrolidinone, triethylamine, xylene, various C<sub>9</sub>-C<sub>12</sub> aliphatic hydrocarbons, diethylformamide, and ethyl acetate. One of these samples was collected from a location next to the outdoor air intake for the ventilation system to determine if the potential existed for the paint room exhaust being re-entrained into the supply air. The outdoor air intake was between 30-50 yards from the exhaust stacks for the paint booths and was at approximately the same height as the exhaust stacks for the paint booths. Low concentrations of trichloroethylene, EGBE, and DGBE were detected on this sample. This indicates that the potential exists for the exhaust emissions reentering the facility via the supply during certain weather conditions (i.e., winds are from the northwest).

Six area samples for dibutyl phthalate were also collected during this investigation. All these samples were below the LOD of 0.001 mg/sample which corresponds to a MDC of 0.002 mg/m<sup>3</sup> assuming a sample volume of 608 liters.

The cursory inspection of the ventilation system indicated that the paint room was under a negative pressure with respect to the dryline room. This meant that the potential for vapors escaping the paint room would be minimal and that most of the vapors generated in the dryline room would be due to the evaporation of the paint during the drying process. However, the cursory inspection and a design plan review of the initial infrared drying tunnel revealed that the amount of air being introduced into the enclosure through the individual infrared units was exceeding the amount of air being exhausted from the enclosure. This meant that paint vapors emitted during the drying process in this unit were escaping into the surrounding environment. This drying

tunnel was located against the north wall in close proximity to several employees who work at stations underneath the unit. In addition, the exhaust duct for this unit is connected to the ducting of one of the rooftop exhaust units. Although this could not be confirmed during this investigation due to the restricted access created by the process, this connection may interfere with the ability of the unit to exhaust air through the ceiling mounted vents. The air flow through the two exhaust vents and the enclosure for the trichloroethylene degreaser seemed to be adequately controlling the release of trichloroethylene. The presence of low concentrations of trichloroethylene at the degreaser take-off station was most likely due to the evaporation of residual trichloroethylene on the parts.

## CONCLUSIONS

Although there were no contaminant concentrations determined during this investigation which exceeded their relevant evaluation criteria, the airborne EGBE concentration in the paint room approached the NIOSH REL of 5 ppm. These results indicated that the highest EGBE exposures would be encountered inside the paint room and that overall exposures encountered by the paint room operators would be dependent on the amount of time actually spent inside the paint room. The paint room operators currently alternate duties inside and outside of the paint room which reduces their overall exposures. However, additional environmental monitoring needs to be conducted to determine the extent of exposures contributed by manual spray operations performed outside the paint room and if there is a potential to achieve higher EGBE concentrations in the paint room when the volume of parts being painted increases over that encountered during this investigation. The initial infrared drying tunnel was not effectively controlling paint vapors generated during the drying process. With the aid of smoke tubes, it was observed that emissions were escaping the enclosure into the dryline room environment. The highest airborne concentrations of DGBE were measured from locations in close proximity to this

drying tunnel. The escape of these emissions from this enclosure may be one plausible explanation for the occurrence of adverse health effects reported among dryline room employees. In addition, the presence of trichloroethylene, EGBE, and DGBE on a sample collected at the outdoor air intake indicated that the potential exists for the exhaust emissions reentering the facility via the supply air during certain weather conditions (i.e., winds are from the northwest).

## RECOMMENDATIONS

The following recommendations are based on the environmental sampling results and observations made during this investigation and are offered in the interest of improving the general conditions at this facility.

1. The exhaust ventilation for the initial (DriQuick) infrared drying tunnel should be increased so that paint vapors will not escape from the enclosure. Currently, the enclosure is under a positive pressure relative to the dryline room. This system should be modified to prevent the escape of emissions by ensuring that the enclosure is under a negative pressure relative to the dryline room. It is recommended that Dorma Door Controls contact the manufacturer or an industrial ventilation consultant whenever modifications to ventilation systems are needed to insure proper operation. In addition, the current configuration of this exhaust system being directly connected to the ducting of one of the rooftop exhaust systems should be evaluated to ensure that air flow through the ceiling mounted exhaust vents is not adversely affected by the addition of the drying tunnel exhaust. It may be more appropriate to investigate the installation of a separate rooftop exhaust for this drying tunnel.

2. Additional environmental monitoring for EGBE should be conducted in the paint room to determine if engineering control modifications or additions are required. The EGBE concentrations determined during this investigation approached the NIOSH REL of 5 ppm. If additional, comprehensive

monitoring indicates that concentrations above 5 ppm can occur, engineering control modifications or additions should be investigated. Currently, parts exiting the primer application booth are air dried on a conveyor in the paint room for approximately 15 minutes before entering the final coat booth. A partition, equipped with an additional exhaust unit separating the drying area behind the two spray booths from the operators' area, may limit the contaminant emissions during the drying process. This could be accomplished with some type of plastic curtain system that still allowed easy access to the area behind the spray booths.

3. The spray booths should be periodically evaluated to ensure that they are performing to specifications and that the current preventative maintenance program is adequate. During times when a high volume of parts are painted, it may be necessary to replace the filters more often to ensure proper exhaust.

4. The safety committee should address the use of proper work practices and personal protective equipment (PPE) to prevent exposure to EGBE. Gloves which are impermeable to EGBE, such as butyl rubber, should be used. Since EGBE is readily absorbed thru the skin, the use of additional PPE such as appropriate aprons and other methods to prevent skin contact should be evaluated. Workers should be trained in the proper use of all PPE.

5. If additional environmental monitoring indicates that EGBE concentrations can exceed the NIOSH REL, appropriate respiratory protective equipment should be used in the paint room until engineering controls can be implemented. An appropriate respiratory protection program which complies with the requirements described in 29 CFR 1910.134 should be implemented. Publications developed by NIOSH, which should also be referenced, include the NIOSH Guide to Industrial Respiratory Protection and NIOSH Respirator Decision Logic.

6. The potential for exhaust emissions from the paint room reentering the facility via the supply air should be investigated further. This may be one

reason for the variable employee perceptions regarding the amount of paint vapors in the dryline room.

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**Table 1**  
**Summary of Airborne Contaminant Concentrations**  
**Dorma Door Controls, Inc.**  
**HETA 97-0214-2689**  
**December 4, 1997**

Sample Description	Duration (minutes)	Air Volume (liters)	2-butoxyethanol (ppm)	2 (2-Butoxyethoxy) ethanol (ppm)
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**Area samples**

Between arm assembly stations	497	25	1.2	0.78
Above netting along north wall	533	27	1.7	0.89
Transfer line station near paint room	494	25	1.2	0.90
Paint room (partial shift samples)	383	19	4.1	0.69
	113	5.6	2.5	0.32
<i>TWA for paint room area samples</i>	<i>496</i>	<i>24.6</i>	<i>3.7</i>	<i>0.61</i>

**Personal Breathing Zone samples**

Arm assembly	460	23	0.54	0.30
Arm assembly	460	23	0.07	trace
Paint room operator (partial shift samples)	278	14	2.5	0.42
	193	9.6	1.1	0.44
<i>TWA for paint room PBZ samples</i>	<i>471</i>	<i>23.6</i>	<i>1.9</i>	<i>0.43</i>
<b>Evaluation Criteria</b>	<b>NIOSH REL ACGIH TLV OSHA PEL</b>		<b>5 (skin) 25 (skin) 50 (skin)</b>	<b>n/a n/a n/a</b>

**Area samples for trichloroethylene**

Sample Description	Duration (minutes)	Air Volume (liters)	Trichloroethylene (ppm)
Degreaser take-off near inspector (partial shift samples)	319	64	3.5
	238	48	0.71
<i>TWA for degreaser take-off area samples</i>	<i>557</i>	<i>112</i>	<i>2.3</i>
<b>Evaluation Criteria</b>	<b>NIOSH REL ACGIH TLV OSHA PEL</b>		<b>25 50 100</b>

**trace** – Detected value was between the MDC of 0.03 ppm and minimum quantifiable concentration (MQC) of 0.07 ppm, calculated assuming a sample volume of 23 liters.

**(Skin)** – The notation “skin” indicates that airborne of direct exposure by the cutaneous route (including mucous membranes and eyes) contributes to overall exposure.

**ppm** – Parts per million

**TWA** – Time-weighted averaged concentration for the consecutive partial shift samples

**n/a** – There are no applicable criteria for 2 (2-butoxyethoxy) ethanol.



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