CDC Workplace Safety and Health

NIOSH HEALTH HAZARD EVALUATION REPORT:

HETA #98-0153-2883
Custom Products, Inc.
Mooresville, NC

November 2002

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

NIOSH

PREFACE

The Hazard Evaluations and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (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 (OSHA) 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.

HETAB 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 NIOSH.

ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Dr. Christopher Reh, Mr. Vince Mortimer, Dr. Jeffrey Nemhauser, and Dr. Doug Trout of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Mr. Kevin Dunn, Mr. Joshua Harney, MS, and Mr. Calvin Cook, MS. Analytical support was provided by Datachem, Salt Lake City, UT. Desktop publishing was performed by Patricia McGraw. Review and preparation for printing were performed by Penny Arthur.

Copies of this report have been sent to employee and management representatives at Custom Products and the OSHA Regional Office. This report is not copyrighted and may be freely reproduced. Single copies of this report will be available for a period of three years from the date of this report. To expedite your request, include a self-addressed mailing label along with your written request to:

NIOSH Publications Office
4676 Columbia Parkway
Cincinnati, Ohio 45226
800-356-4674

After this time, copies may be purchased from the National Technical Information Service (NTIS) at 5825 Port Royal Road, Springfield, Virginia 22161. Information regarding the NTIS stock number may be obtained from the NIOSH Publications Office at the Cincinnati address.

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Highlights of the NIOSH Health Hazard Evaluation

Evaluation of Exposure to Spray Adhesive (1-bromopropane [1-BP])

This Health Hazard Evaluation was requested by the North Carolina Department of Labor to address concerns about possible health problems related to working with a spray adhesive (that contains the chemical 1-bromopropane [1-BP]).

What NIOSH Did

- We checked the air for 1-BP level.
- We checked the ventilation in the plant.
- We asked employees to fill out a questionnaire and checked samples of blood for blood counts.
- We made recommendations to improve ventilation to decrease air levels of 1-BP.
- After the ventilation was improved by the addition of spray booths, we rechecked the air levels and the ventilation.

What NIOSH Found

- Before the ventilation was improved all employees were exposed to high levels of 1-BP and the old ventilation was not working well.
- Most of the blood counts were normal. The few abnormal results we observed did not appear to be related to 1-BP exposure.
- Some employees reported symptoms in the questionnaire but none of the symptoms could be related to 1-BP exposure.
- After spray booths were added in the Covers and Assembly areas, air levels of 1-BP were much lower.
- Some spray booth filters were clogged.
- Some employees were spraying cushions outside the spray booths, which may be adding to worker exposure to 1-BP.

What Custom Products Managers Can Do

- Inspect the spray booth filters regularly and replace them when they are clogged.
- Train employees so that they use the spray booths correctly and perform all spraying inside the booths.
- Re-evaluate employee exposures to 1-BP periodically to determine if further controls are needed to decrease exposures to 1-BP.

What Custom Products Employees Can Do

- Attend all training and education sessions given by the management.
- Follow instructions on proper us of the adhesive spray equipment and spray booths.

CDC Workplace Safety and Health

What To Do For More Information:
We encourage you to read the full report. If you would like a copy, either ask your health and safety representative to make you a copy or call 1-513-841-4252 and ask for HETA Report #98-0153-2883

National Institute for Occupational Safety and Health NIOSH

Health Hazard Evaluation Report 98-0153-2883

Custom Products, Inc.
Mooresville, NC
November 2002

Christopher M. Reh, PhD, CIH
Vincent D. Mortimer, PE
Jeffrey B. Nemhauser, MD
Douglas Trout, MD, MHS

SUMMARY

On March 17, 1998, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) at Custom Products, Inc. in Mooresville, North Carolina. The request was submitted by the North Carolina Department of Labor, and centered on workers' exposure to 1-bromopropane (1-BP) during the spray application of solvent-based adhesives. In response to this request, NIOSH investigators conducted two surveys at the facility.

At the time of the first survey all employees at Custom Products (working in four departments: Saw, Assembly, Sew, and Covers) were considered potentially exposed to 1-BP and 2-bromopropane (2-BP). 2-BP may be found in most commercially available 1-BP formulations as a contaminant. The first survey consisted of exposure, ventilation, and medical assessments. Personal breathing zone (PBZ) sampling for 1-BP was conducted in the Assembly, Covers, and Saw departments, and area air sampling for 1-BP was performed in the Sew department. Air velocity in and around the spray booths and unventilated tables was measured. Other aspects of the ventilation assessment included evaluation of spray booth filter maintenance, and observation of air movement (using smoke tubes), work tasks and movements of workers, and positioning of spray booth exhaust discharges. The medical assessment included questionnaire administration for all employees in the Assembly, Cover, and Saw departments and collection of blood samples and analysis of complete blood count (CBC). A CBC was drawn to determine if 1-BP exposure had any effect on workers' ability to make blood cells.

Sixty-nine full-shift, time-weighted average (TWA) 1-BP personal breathing zone (PBZ) exposure measurements and 11 area air samples were collected during the first exposure assessment. The mean 1-BP full-shift PBZ exposure concentration for participating workers was 168.9 parts per million (ppm), and the exposures ranged from 60.0 to 381.2 ppm. All of the exposures were above 25 ppm, a concentration that has been suggested as an exposure guideline by several organizations. On average, the highest exposures were in the Covers department (mean of 197.0 ppm), followed by the Assembly department (169.8 ppm), and the Saw department (117.1 ppm). The mean area 1-BP air concentration in the Sew department was 128.1 ppm. Sprayers (working in the Covers and Assembly departments) were exposed to a higher concentration of 1-BP than were other workers. The initial ventilation assessment found that the Assembly department spray booths (there were no spray booths in the Covers department) were inadequate. During the ventilation assessment, NIOSH investigators identified exhaust filters that were either partially or completely clogged with spray adhesive, observed workers spraying some work pieces outside the spray booths, and found that the spray booth exhaust discharge stacks were located in close proximity to roof-top air intakes.

Forty-six (66%) of the 70 employees in the three departments completed the questionnaire and provided blood for a CBC. The median cell counts, platelet counts, and hemoglobin concentrations were all within the normal ranges provided by the laboratory. Several symptoms suggestive of excessive exposure to solvents were prevalent among all workers surveyed; the prevalence of these symptoms was not statistically different between the higher-exposed group compared to the lower-exposed group. Thirty-two (70%) of the 46 medical survey participants had PBZ air sampling for 1-BP; for those 32 persons, additional statistical analyses were performed to examine the relationship between individual exposures and the questionnaire and CBC results. The mean 1-BP concentration was not statistically significantly greater among workers reporting symptoms compared to those not reporting symptoms. There were no statistically significant relationships between the individual 1-BP exposure measures and the corresponding CBC results. Several factors, including the fact that all participants in our survey were exposed to 1-BP, limited our ability to assess potential health effects.

Subsequent to the first site visit and the interim NIOSH report (May 26, 1999), Custom Products installed new spray booths with local exhaust ventilation for all adhesive spraying operations (Assembly and Covers departments). Follow-up exposure and ventilation surveys were conducted which included both PBZ and area air sampling for 1-BP and 2-BP.

The mean 1-BP PBZ exposure concentration at the follow-up survey was 19.0 ppm (range: 1.2 to 58.0 ppm), and a total of 10 (43%) of the 23 1-BP PBZ exposure measurements exceeded 25 ppm. The mean 2-BP PBZ exposure concentration was 0.14 ppm. The 1-BP PBZ air concentrations in the Sew department ranged from 1.1 to 1.9 ppm, and no 2-BP was detected in any of the five samples collected in this department. The average velocity of air flowing into the three spray booths measured during the follow-up ventilation assessment in the Assembly area was approximately 100 ft/min, and the average velocity for the six booths in the Covers area was approximately 125 ft/min. Both of the values are below the recommended 150 ft/min; however, the hoods performed well based on qualitative evaluation. Individual filter average velocities were higher for filter sections that were less clogged by spray adhesive. For work performed inside the booths, air-flow visualization indicated that very little, if any, contaminant would be recirculated into the worker's breathing zone. We found that some pieces were being sprayed outside the booths.

The first NIOSH survey documented that all evaluated workers were exposed to 1-BP at concentrations above 25 ppm, and that the old spray booths in the Assembly department were ineffective in reducing workers' 1-BP exposures. Following the installation of new spray booths in the Covers and Assembly departments, the second exposure assessment documented significantly reduced air concentrations of 1-BP, though some employees were still exposed to concentrations of 1-BP above 25 ppm. Some of our ventilation measurements in the follow-up assessment revealed less-than-recommended air velocity in the spray booths, which may have been due to filter clogging by spray adhesive.

Analysis of the symptom and CBC data did not show meaningful relationships with 1-BP exposure levels; however, given the limitations of our survey and lack of toxicologic data relevant to 1-BP in general, we are unable to determine if worker exposure to 1-BP at Custom Products constitutes a health hazard. Considering this, and while further data are being collected, NIOSH investigators believe that occupational exposure to 1-BP and 2-BP should be minimized. Implementation of standard engineering, administrative, and work practice controls has been effective in greatly reducing worker exposure to 1-BP. Recommendations are made in this report to further assist in this goal, including recommendations concerning improved employee education and work practices.

KEYWORDS: SIC 2531 (Seats: Automobile, Vans, Aircraft, Railroad, and Other Public Conveyances) foam fabrication, spray adhesives, 1-bromopropane, 2-bromopropane, n-propyl bromide, isopropyl bromide, engineering controls, ventilation, spray booths, CBC, complete blood count, headache, reproductive abnormalities.

TABLE OF CONTENTS

INTRODUCTION

On March 17, 1998, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) at Custom Products, Inc. in Mooresville, North Carolina. The request was submitted by the North Carolina Department of Labor, and centered on workers' exposure to 1-bromopropane (also known as n-propyl bromide) during the spray application of solvent-based adhesives. In response to this request, NIOSH investigators conducted several site visits to the facility.

The first survey consisted of exposure, ventilation, and medical assessments. On November 10–12, 1998, NIOSH industrial hygienists conducted a 1-bromopropane (1-BP) exposure assessment, and a NIOSH engineer conducted a ventilation assessment at the facility on November 23–24, 1998. NIOSH medical officers conducted a medical assessment on December 1-3, 1998. The findings from the exposure and ventilation assessments were summarized in an interim report (dated May 26, 1999) which included recommendations for spray booths and local exhaust ventilation. The findings from the medical assessment, and individual notification of test results, were reported in December 1999.

Subsequent to the May 26, 1999, interim report, Custom Products installed spray booths with local exhaust ventilation for all adhesive spraying operations. Consequently, follow-up exposure and ventilation surveys were conducted. The purpose of the follow-up assessments was to document the change in exposures and airflow patterns associated with the installation of the new spray booths. The NIOSH industrial hygienists conducted 1-BP and 2-bromopropane (2-BP [also known as isopropyl bromide]) exposure assessments at Custom Products on November 16, 2000. The results from that exposure assessment were provided to Custom Products on December 20, 2000. In addition, a final ventilation assessment was conducted on April 19, 2001. This report summarizes all the previously reported information and also the results from the second ventilation survey.

BACKGROUND

Custom Products manufactures seat cushions for the commercial aircraft industry. The cushions are foam padded, and the foam is covered with Nomex™ and a decorative fabric. The cushions consist of several pieces of cut foam glued together with a spray adhesive. The cushion is inserted into the Nomex cover, and the same spray adhesive is used to seal the Nomex around the cushion. Finally, the fabric exterior is applied to the cushion. The spray adhesive used in these operations contains 1-BP as a solvent vehicle.

The production areas are divided into four departments: Saw, Assembly, Sew, and Covers. Bulk foam is cut with various saws in the Saw department. In the Assembly department, the adhesive is sprayed on the foam pieces, and the pieces are pressed together (by hand) to form the cushion. Thus, the workers in the Assembly department are either sprayers or assemblers. The Nomex covers are produced from bulk material in the Sew department, and the covers are placed around the cushions in the Covers department. All production workers in the Covers department are sprayers. All employees in these four departments are potentially exposed to 1-BP and 2-BP. The Assembly sprayers and assemblers, and Covers workers work directly with the adhesive formulations. Employees in the Saw and Sew departments are indirectly exposed due to their proximity to the spraying operations in the other departments.

At the time of the first NIOSH survey, spray booths for adhesive spraying operations were present in the Assembly department. Custom Products had fabricated these five spray booths using metal tubing for a frame and clear plastic sheeting for the sides and top of the enclosures. The booths were approximately 76 inches high, 60 inches wide, and 54 inches deep. Each booth contained an adjustable-height work surface, and was ventilated though a duct opening in the back or side wall. The air from the booths was exhausted directly to the outside.

After receiving the findings and recommendations from the first exposure and ventilation assessment (Appendix 1), Custom Products installed new spray booths at all adhesive spraying stations in the Assembly and Covers departments. The new booths differed somewhat from the NIOSH recommended design; the most significant design deviation was the absence of baffles in the back of the booths. In the Assembly department, the original five spray booths were replaced with three angle-iron and sheet-metal booths. These new booths were approximately 84 inches high, 60 inches wide, and 32 inches deep with a plenum at the back. Each booth had a work surface about 36 inches above the floor so that the open area at the face of the booth was approximately 56 inches by 48 inches. The ceiling of each booth extended 24 inches beyond the front edge of the work surface out over where the worker stood while spraying adhesive on foam cushion components inside each booth.

Six new booths had also been fabricated for the Covers area. The design was similar to that described above except that the booths were wider to allow two workers to use a booth to spray adhesive and insert finished cushions into covers. These booths were approximately 84 inches high and 96 inches wide, with an open area of approximately 92 inches by 48 inches. One of these booths had a 32-inch deep work surface, another was approximately 30 inches deep, and the depth of the other four was approximately 26 inches.

In both areas, the top of each hood extended 24 inches beyond the work surface edge. The edges of the side panels were angled to connect the front of the work surface with the extended front edge of the top surface of the hood. At the back of the hoods, the air entered the plenum through 20-inch square filter elements. Each filter was a grid of 16 open areas, 4-1/4 inch square. The single-worker hoods in the Assembly area had four filters; the wider hoods in the Covers area had eight filters. The filters collected the excess adhesive, preventing the stringy, "cotton-candy-like" strands from being drawn into the exhaust system.

At the time of the second NIOSH survey, two different adhesives were used at Custom Products. The Assembly department used Whisper Spray (Imperial Adhesives, Cincinnati, Ohio), which contains 60–70% by weight 1-BP. The adhesive used in the Covers department was Fire Retardant Soft Seam 6460 (Mid South Adhesives, Memphis, Tennessee), which contains 60–80% by weight 1-BP. A small percentage of 2-BP is usually present as a contaminant in most 1-BP-containing formulations.

METHODS

Exposure Assessments

For the first NIOSH survey, all workers in the Assembly, Covers, and Saw departments were asked to participate in at least one shift of 1-BP inhalation exposure measurement. Also, area air sampling for 1-BP was performed at randomly selected work stations in the Sew department. During the second survey, all employees in the Assembly, Covers, and Saw departments were again targeted for a full-shift 1-BP and 2-BP inhalation exposure measurement. Short-term (15-minute) 1-BP and 2-BP inhalation exposure measurements were also collected from sprayers in the Assembly and Covers departments. In addition, area air sampling for 1-BP and 2-BP was conducted at various locations and work stations in the Sew Department. Employee participation in both surveys was voluntary. For the employees' inhalation exposure measurements, the sampling pumps and sample trains were worn by the subjects, and the sample media were placed in the subjects' breathing zones (personal breathing zone [PBZ] samples).

During both surveys, air sampling was conducted using a NIOSH draft analytical method for 1-BP and 2-BP. In this method, air is drawn through a standard charcoal tube (SKC Anasorb® CSC Lot 2000) at a nominal flowrate of 50 to 100 milliliters per minute (ml/min) using a calibrated personal sampling pump. After sampling, the charcoal tubes were capped and shipped refrigerated to the analytical laboratory. The front and back sections of the charcoal tubes were placed in glass vials, and each section was desorbed for 30 minutes with 1 ml of carbon disulfide. Each sample was analyzed for both 1-BP and 2-BP using gas chromatography with a flame ionization detector.

The 1-BP limit of detection (LOD) and limit of quantification (LOQ) for the draft NIOSH method were 1 microgram per sample (µg/sample) and 4 µg/sample, respectively. The LOD and LOQ for 2-BP were 1.0 and 3 µg/sample, respectively. LODs and LOQs are values determined by the analytical procedure used to analyze the samples, and are not dependent on sample volume. Minimum detectable concentrations (MDCs) and minimum quantifiable concentrations (MQCs) are determined by dividing the LODs and LOQs by air sample volumes appropriate for the given set of samples. For this HHE site visit, the average sample volume for a given set of samples was used to calculate these values. MDCs and MQCs for all exposure data can be found at the bottom of the appropriate data tables and appendices. Summary data are presented in this report; complete data for the two exposure assessments are presented in Appendices 2 and 3.

Ventilation Assessments

Air velocity in and around the spray booths and tables, where spraying and/or assembling operations were performed, was measured with a hot-wire anemometer (TSI VelociCalc Plus model 8386). The center-point velocity for each small filter grid opening was measured, giving 64 readings for each single-station hood and 128 readings for each double-station hood. For computation, each 16-grid filter was averaged separately to give 4 values for each single-station hood, and 8 values for each double-station hood. Additionally, air velocity 12-inches above the work surface was measured at 6, 12, 18, 24, and 30 inches (if the work surface was deep enough) from the back of the hood at the center and 1 foot in from each side panel. The center line was measured twice and the readings were compared and averaged to give one set of values for the line.

A rating of filter clogging was estimated by visual inspection for each small filter opening. An 11-point scale was used, with zero being no clogging and 10 being no-flow. Each 16-grid filter was averaged separately, and the number was reported as a percentage of openness.

The movement of air was observed using smoke tubes, small glass tubes which release a thin trail of chemical smoke showing the direction of air flow. At the same time, the work tasks and movements of the workers were noted. The flow of air under and around the doors leading to the outdoors was also observed using smoke tubes. The position of the spray booth exhaust discharges relative to the location of the air-handler outside air intakes on the roof was noted, and the flow of air around these units was observed using smoke tubes.

Medical Assessments

A questionnaire was offered to all employees in departments in which PBZ sampling was occurring, which included the Assembly, Covers, and Saw departments (on both morning and evening shifts). The questionnaire included questions concerning basic demographic information and work and medical history. Questions used to assess possible effects of overexposure to solvents included questions about headache, feeling "drunk," abnormal fatigue, and problems concentrating. Several questions were asked in the questionnaire concerning history of reproductive problems. All employees filling out the questionnaire were asked to provide a sample of blood, after providing informed consent, for a complete blood count (CBC). The CBC was performed on participants to evaluate whether exposure to 1-BP can result im impaired production of blood cells. Elements of the CBC used for the purpose of this evaluation included the red blood cell, platelet, and white blood cell counts and hemoglobin concentration. Hemoglobin (the oxygen-carrying protein of red blood cells) concentration is a commonly used clinical measure of the ability of blood to carry oxygen.

Forty-six (66%) of the 70 employees in the three participating departments (Assembly, Covers, and

Saw) present at the time of the evaluation completed the questionnaire and provided blood for a CBC. Because all employees taking part in this HHE were exposed to 1-BP, the relationship between exposure to 1-BP and potential health effects was evaluated by grouping workers into exposure groups based primarily on job title (sprayers [in Assembly and Covers departments], assembly workers [Assembly department], and others [Saw department workers and one supervisor from the Covers department]). Exposure groups were created based on the industrial hygiene sampling data for each job title at the time of the first NIOSH exposure survey. For example, the mean 1-BP concentration for sprayers was assigned as the exposure for all sprayers.

Among the 46 participants, three had jobs for which there was no quantitative information concerning exposure to 1-BP. Those three were excluded from this group analysis, leaving 43 participants with exposure information available from the NIOSH survey. Group exposure information was used to determine whether workers in different exposure groups had statistically significant differences in their CBC endpoints or in questionnaire responses concerning health problems. To compare the distribution of CBC results (red blood cell, white blood cell, platelet counts, and hemoglobin concentration) between the sprayers and the non-sprayers (assembly workers and others), the median was used as the measure of central tendency and the Wilcoxon two-sample test was used to test for statistical significance. The prevalence of symptoms potentially related to excessive exposure to 1-BP was calculated for each of the three exposure groups. The magnitude of the relationship between sprayers and non-sprayers was assessed by the prevalence ratio (PR); a 95 percent confidence interval (95 % CI) which excluded one was considered to indicate a statistically significant finding. The PR represents the prevalence of an outcome (for example, the occurrence of headache) in the sprayers relative to the prevalence in the non-sprayers. A PR of one means there is no association between the outcome and "greater exposure." A PR of greater than one indicates evidence of an association. For example, a PR of two would mean that a sprayer may be twice as likely to have reported the outcome than a non-sprayer.

Thirty-two of the medical survey participants had PBZ air sampling conducted for 1-BP. For those 32 persons, statistical analyses were performed to examine the relationship between individual 1-BP exposures and the questionnaire and CBC results (even if the CBC results were within the normal ranges provided by the laboratory). Linear regression was used to assess the relationship between the CBC elements and individual 1-BP exposure measurements. Non–occupational factors that were taken into account in the analyses of CBCs included: age, gender, current cigarette smoking status, and alcohol use. For symptoms reported in the questionnaire, the mean 1-BP exposure concentration among persons reporting a symptom (compared to those not reporting the symptom) was evaluated using a t-test to test for statistical significance. Analyses were done using SAS software (Version 8.2). A p-value of $\leq .05$ was used to indicate statistical significance.

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 criteria. 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 increases 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),[1] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[2] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[3] Employers are encouraged to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion.

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970, Public Law 91–596, sec. 5.(a)(1)]. Employers should understand that not all hazardous chemicals have specific OSHA exposure limits such as PELs and short-term exposure limits (STELs). However, an employer is still required by OSHA to protect their employees from hazards, even in the absence of a specific OSHA PEL.

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

1-BP and 2-BP Evaluation Criteria

Little information was available concerning potential health effects related to occupational exposure to 1-BP at the time this HHE was initiated. A review of the literature concerning 1-BP and 2-BP is presented in Appendix 4. As with other solvents, occupational exposure to 1-BP may occur via both inhalation and skin absorption. Potential health effects related to overexposure to 1-BP (and many other solvents) may include irritation of the eyes, mucous membranes, upper respiratory tract, and skin. At higher levels of exposure, central nervous system depression (characterized by headache and dizziness, and possibly leading to loss of consciousness) may occur. A few studies have addressed the issue of specific health effects among workers occupationally exposed to 2-BP. In a series of studies, 33 electronic assembly workers working with 2-BP as the major component in a cleaning solution were evaluated.[1,2] Those evaluations suggested that occupational exposure to 2-BP may have been associated with damage to both male and female organs of reproduction (ovarian failure and sperm abnormalities) and also bone marrow failure (pancytopenia [low blood counts]). Animal studies have suggested that 2-BP may cause testicular and bone marrow abnormalities in rats.[3] Because of the concern that 1-BP may cause health effects similar to those reported for 2-BP, this HHE primarily addressed reproductive (by questionnaire) and hematologic (by questionnaire and CBC) concerns in our medical assessment.

Currently, there are no NIOSH, ACGIH, or OSHA exposure evaluation criteria for 1-BP. Albemarle Corporation, a manufacturer of 1-BP, has developed an occupational exposure limit for 1-BP which is based on the initial, unaudited data from a two generation reproductive study in rats.[4] Based on the results of that study and a 10-fold safety factor, Albemarle set their 1-BP recommended exposure guideline at 25 ppm as an 8-hour TWA exposure.[5] More recently, after a review of available exposure data and human and animal toxicologic data, but based primarily on data from animal studies (including effects on the male reproductive system [sperm motility]), the Environmental Protection Agency (EPA) has proposed an Acceptable Industrial Exposure Limit (AEL) for 1-BP of 25 ppm.[6] This AEL currently exists only in draft form and may be subject to further revision following public comment.

The South Korean Ministry of Labor is the only group that has developed an occupational exposure guideline/limit for 2-BP. In 1998, the Ministry of Labor issued an exposure standard for 2-BP of 1 ppm as an 8-hour TWA.[7] This standard was based on a limited number of workplace epidemiological studies and toxicological (animal) studies which found that 2-BP exposure produces reproductive effects in both males (low sperm count) and females (ovarian dysfunction), and also affects the hematopoietic system.[8,9,10,11,12,13,14]

RESULTS

First NIOSH Survey

Exposure Assessment

During the two-day period, a total of 138 half-shift, TWA air samples were collected from workers in the Assembly, Saw, and Covers departments. Air sampling was conducted for one day on all workers in the Saw and Covers departments, and for two days on workers in the Assembly department. These samples resulted in 69 full-shift, TWA 1-BP exposure determinations for workers in these departments. In addition, 11 area air samples were collected from randomly selected work stations in the Sew department.

The data from the 1-BP exposure determinations are presented in Appendix 2, and summary results based on these data are in Table 1. The mean 1-BP full-shift exposure concentration from all PBZ samples was 168.9 ppm, and the exposures ranged from 60.0 to 381.2 ppm. All of the exposures were above 25 ppm, and only two exposures were less than 100 ppm. On average, the highest exposures were in the Covers department (mean of 197.0 ppm), followed by the Assembly department (169.8 ppm), and the Saw department (117.1 ppm). The highest 1-BP exposure was found in a Covers department worker (381.2 ppm), and the two exposures that were below 100 ppm were found in a Saw operator (85.1 ppm) and an Assembly department assembler (60.0 ppm).

A comparison of the exposures of sprayers in the Covers department versus sprayers in the Assembly department revealed no significant difference in 1-BP concentrations between these two groups ($p = 0.4$). 1-BP exposures were higher among sprayers (in both Covers and Assembly departments) compared to all other workers ($p < 0.0001$), and exposures were higher in Assembly department sprayers compared to Assembly department assemblers ($p=0.04$). The data from the area air sampling in the Sew department are shown in Table 2. The mean area 1-BP air concentration in this department was 128.1 ppm, and the concentrations ranged from 107.3 to 160.9 ppm.

Ventilation Assessment

The measured exhaust flow rates for the five booths were between 200 and 900 cubic feet of air per minute (CFM). The lowest value was less than 250 CFM due to the filter for booth #2 being more than half covered with the spray adhesive. When a new filter was installed, the flow rate doubled.

With an open area for each booth of about 32 square feet, the average velocity over the face of each booth, calculated from the exhaust flow rate, ranged from 13 to 25 ft/min. The average face velocity measured in the top half of the booth was higher, ranging from 24 to 40 ft/min. The average face velocities and flow rates are summarized in Table 3.

The general flow of air within the Assembly area was from the northeast to the southwest, although in front of booths 1 and 2, the flow was more towards the northwest. In the Covers area, the general flow was from south to north along the east wall of the building where the work tables were located. Specifically, in front of booth 1, air from in front of the booth did flow around the left edge of the booth, across the work table. In front of booth 2, air flowed across the work table, around the right edge of the booth, and across the front of the booth. For both booths, smoke released from a smoke tube close to the face of the booth entered the booth, but smoke released a few feet from the face did not enter the booth. The flow of air around booths 3 and 5 was similar to booth 2, and the flow of air around booth 4 was similar to booth 1.

Although the booths were adequately sized for the work being performed, some pieces were sprayed outside the booth. Some pieces were sprayed while on the work table to add adhesive during the assembly; others were sprayed in front of the booth, possibly because the lighting was better or because the piece had already been removed from the booth and then a need for more adhesive was noticed. In the Covers area, although the amount of spraying was less than in the Assembly area, the workers got just as close to the sprayed pieces while putting the fabric covers over the foam.

The differential pressures inside the plant were all negative with respect to outside the plant, so that air came into the plant through all the outside doors. The temperature inside the plant was approximately 75°F, and the relative humidity was approximately 50 %.

On the roof, the spray booth exhaust discharge stacks extended only 3-1/2 ft above the roof, and each was capped with a weather-cap which obstructed and deflected the vertical flow of air from the discharge pipe. The discharge points for booths 1 and 2 and for booth 5 were located only a few feet southwest of the air intake of two of the roof-top air-conditioners. The discharge point for booths 3 and 4 was located approximately 10 feet southeast of the air intake of a third roof-top air-conditioner. The height differences between discharge and intake openings were only a few feet.

Medical Assessment

Table 4 presents information describing the 43 survey participants. The majority of participants were female, and the length of time working at their current job varied for Assembly and Covers employees (four years) compared to Saw employees (nine years).

CBC Testing

The median red blood cell count was 4.3 million cells per cubic millimeter (mm^3) (laboratory normal range 3.8 - 5.8 million per mm^3), the median hemoglobin concentration was 13.6 grams per deciliter (g/dl) (laboratory normal range 11.6 - 17.1 g/dl), the median white blood cell count was 6,700 cells per mm^3 (laboratory normal range 3,900 - 11,400 per mm^3), and the median platelet count was 202,000 per mm^3 (laboratory normal range 140,000 - 400,00 per mm^3). Five of the CBC measurements were outside the normal ranges. One person had a white blood cell count of 3,700 per mm^3, one person had a platelet count of 540,000 per mm^3, and three had hemoglobin concentrations outside the normal range. All three of these latter participants were in the Covers department; two of the three had PBZ measurements (these were 127 ppm and 265 ppm). The rest of the CBC measurements were within the normal ranges. None of the participants had decreases of all three blood components. The median values of the red blood cell counts and hemoglobin concentrations of sprayers were less than those values from non-sprayers, although the differences were not statistically significant (Table 5).

To evaluate a possible association between CBC test results and 1-BP exposure, linear regression analyses were performed between red blood cell, hemoglobin, white blood cell, and platelet counts and 1-BP exposure (as determined by PBZ 1-BP concentrations). We found that hemoglobin and red blood cell counts were correlated (r=0.63) and that women participants were more likely to have both lower red blood cell counts (and hemoglobin concentrations) and greater exposure to 1-BP. There were no statistically significant relationships between the individual 1-BP exposure measures and the CBC results, including white blood cells (β=0.008, p=0.3), platelets (β=0.064, p=0.8), red blood cells (β= -0,.008, p=0.6; controlling for gender), and hemoglobin concentration (β= -0.0057, p=0.14; controlling for gender).

Symptom/Medical History Survey

Symptoms suggestive of excessive exposure to solvents were prevalent among all workers surveyed (Table 6). Among these symptoms, having a headache at least once per week, having painful tingling in hands or feet, reporting a tremor, and "feeling drunk" when not drinking, were all reported more commonly among sprayers compared to non-sprayers, although none of the differences were statistically significant (Table 6). Further analyses of symptoms were performed for the 32 persons who had participated in PBZ exposure sampling. Analyses of PBZ 1-BP exposure among employees by presence or absence of symptoms are reported in Table 7. For each of the symptoms evaluated, air concentrations of 1-BP were not statistically different between those employees reporting the symptom compared to those not reporting the symptom.

Questions concerning reproductive health were asked in the questionnaire in several ways. In response to the question "Have you ever been to the doctor for reproductive/fertility problems," one participant answered yes and 42 answered no. The one person answering yes worked in the Saw department and (compared to other sampled employees) had a relatively low PBZ air concentration of 1-BP. Of the 41 participants answering question concerning fertility, two of nine males, and one of 32 females, reported that they have failed to have a child after attempting for a full year. The individual exposures to 1-BP for those three individuals ranged from 110 - 157 ppm.

Second NIOSH Survey

Exposure Assessment

The data from the 30 full-shift 1-BP and 2-BP inhalation exposure measurements are shown in Appendix 2, and are summarized for 1-BP in Table 8 and for 2-BP in Table 9. The mean 1-BP exposure concentration was 19.0 ppm, and the measurements ranged from 1.2 to 58.0 ppm. The Covers department had the highest mean 1-BP exposure level (29.2 ppm), followed by the Assembly department with a mean level of 18.8 ppm and the Saw department with a mean level of 1.8 ppm. Eight of the 12 (66.7%) 1-BP exposure measurements from the Covers department exceeded 25 ppm; two of the 11 (18.1%) 1-BP exposure measurements from the Assembly department exceeded 25 ppm.

The mean 2-BP exposure concentration was 0.14 ppm; concentrations ranged from below the MDC (none detected) to 0.55 ppm. The highest 2-BP exposures were found in the Assembly department (mean of 0.30 ppm), followed by the Covers department (0.06 ppm) and the Saw department (0.04 ppm). Two of the 30 2-BP exposure measurements were below the MDC, and none of the measurements exceeded the South Korean exposure limit.

Twelve short-term (15-minute) 1-BP and 2-BP inhalation exposure measurements were collected from sprayers in the Assembly and Covers departments (Table 10). These measurements were collected to document peak 1-BP and 2-BP exposure concentrations during spray adhesive applications. The 1-BP short-term exposures ranged from 12.3 to 26.0 ppm in the Assembly department, and from 13.4 to 95.8 ppm in the Covers department. In addition, the 2-BP short- term exposures ranged from 0.2 to 0.4 in the Assembly department, and from below the MDC to 0.1 ppm in the Covers department.

Area air sampling was conducted at five randomly selected work stations in the Sew department to estimate employees' 1-BP and 2-BP exposures. The airborne concentration data from this sampling are shown in Table 11. The 1-BP concentrations in the Sew department ranged from 1.1 to 1.9 ppm, and no

2-BP was detected in any of the five samples collected in this department (2-BP MDC of 0.01 ppm).

Table 12 contains several comparisons between the exposure data collected during the first NIOSH survey (November 1998) and the second NIOSH survey (November 2000). Considering all 1-BP exposure data collected during these two site visits, the mean exposure levels were reduced from 168.9 ppm to 19.0 ppm. 1-BP exposures in the Sew and Saw departments have been reduced from over 100 ppm to less than 2 ppm, 1-BP exposures in the Assembly department have been reduced from a mean of 169.8 to 18.8 ppm, and those in the Covers department from 197.0 to 29.2 ppm.

Ventilation Assessment

The average velocity of air flowing into the three spray booths (1-3) measured during the follow-up ventilation assessment in the Assembly area was approximately 100 ft/min, and the average velocity for the six booths (4-9) in the Covers area was approximately 125 ft/min (Table 13). Both of the values are below the recommended 150 ft/min; however, the hoods performed well based on air-flow visualization, with air flowing into all booths all across the face of each booth and being drawn decisively to the back of the booths and exhausted. No air from inside the booths was observed to escape into the room. The percent openness of the filters ranged from 52% to 98%. (Table 13) Although not evident from the hood averages, the individual filter average velocities were higher for filter sections that were less clogged with spray adhesive.

For work performed inside the booths, air-flow visualization indicated that very little, if any, contaminant was recirculated into the worker's breathing zone. Observed work practices revealed that some pieces were still sprayed outside the booth, but this seemed to occur less frequently than observed on the previous survey.

The plant was under negative pressure with respect to the outside when the ventilation for all booths was operating, but not to the extent that door opening/closing and climate control were affected. A make-up air unit had been installed to keep infiltration of unconditioned air to a minimum when all booths were on.

DISCUSSION AND CONCLUSIONS

Exposure Assessment

At the time of the first NIOSH survey, most workers in the Assembly, Covers, and Saw departments were exposed to 1-BP above 100 ppm as a TWA, and all were exposed above the guideline of 25 ppm proposed by Albemarle Corporation and the EPA. Based on our area sampling, workers in the Sew department were probably exposed to similar concentrations of 1-BP. The fact that workers in the Sew and Saw departments had high exposures indicates that 1-BP vapors from the sprayers readily migrated into their work areas. A comparison of the workers' exposures for the Covers department sprayers and the Assembly department sprayers during our first exposure assessment found no significant difference in 1-BP concentrations between these two groups. This indicated that the spray booths in the Assembly department were ineffective in reducing workers' 1-BP exposures. According to ACGIH, the velocity of air flowing into half-height (*e.g.,* table-top) spray booths should be 150 feet per minute (ft/min) for face areas over 4 sq-ft. The duct velocity should be 2000 ft/min.[15]

Based on these findings, the NIOSH investigators recommended engineering controls for reducing 1-BP exposures. Specifically, the recommendations were for the installation of spray booths for all adhesive spraying operations (including Covers and Assembly departments) based on designs of booths used in spray painting operations. Air flow rates had also been found to be inadequate, and recommendations were provided for increasing the air flow capacity.

Following the installation of the spray booths in the Covers and Assembly departments by Custom Products, the second exposure assessment documented significantly reduced air concentrations of 1-BP, though some employees were still exposed to concentrations of 1-BP above 25 ppm. Specifically, 18% of the exposure measurements from the Assembly department and 67% of the exposure measurements from the Covers department exceeded 25 ppm during the second exposure assessment. The data from the second survey did, however, indicate that 1-BP concentrations were reduced to ≤ 2 ppm in the Sew (area samples) and Saw departments.

We observed less-than-recommended average face velocity for the spray booths at our follow-up ventilation assessment; a reason for this may be filter clogging with spray adhesive. When a filter is clogged with adhesive, the flow of air is restricted and less air is able to be drawn through the booth. Based on the velocities being drawn through unclogged filters, it is estimated that the average face velocity of all the booths could be approximately 150 ft/min with all new filters. Replacing filters when then become 50 percent clogged would limit the face velocity degradation, keeping the average face velocity closer to the recommended value.

No 2-BP exposures above 1 ppm were found in any of the departments. We observed that the 2-BP exposures were higher in the Assembly department sprayers when compared to the Covers department sprayers. The mean 2-BP exposure in Assembly sprayers was 0.33 ppm, whereas the mean exposure for the Covers sprayers was 0.07 ppm. One difference between the two departments that may account for this is the use of two different brands of spray adhesive: the Assembly department used Whisper Spray, while the Covers department used Fire Retardant Soft Seam 6460. The difference in 2-BP exposure between the two departments may indicate there is more 2-BP contaminant in the Whisper Spray compared to the Fire Retardant Soft Seam 6460. NIOSH investigators believe it is prudent to use a spray adhesive formulation with the lowest concentration of 2-BP.

1-BP Exposure and Health Effects

Although we found that Assembly and Covers departments employees at Custom Products continue to be exposed to 1-BP after installation of engineering controls, we are unable to determine if these exposures constitute a health hazard. Our assessment of health effects among Custom Products employees was limited to the questionnaire (self-reports of symptoms and medical concerns) and CBC testing among employees agreeing to participate in our survey. Selected symptoms consistent with, but not specific for, excessive exposure to solvents were prevalent among the workers surveyed, all of whom were exposed to 1-BP. Analysis of the symptom data did not reveal meaningful relationships with exposure levels. CBC testing found no clinically relevant abnormalities in the cell and platelet counts, and our statistical analyses of the individual cell and platelet counts and hemoglobin concentrations by exposure to 1-BP revealed no statistically significant findings within the normal ranges of the CBC indices. Several factors, including the relatively low participation rate, the small number of participants, and the fact that all the participants in our survey were exposed to 1-BP limited our ability to assess potential health effects.

There are very little published data on human health effects associated with 1-BP exposure, and a limited amount of toxicologic data from studies in animals (see Appendix 3). The exposure criteria of 25 ppm discussed above are based on preliminary evaluations of limited data. Considering the lack of data concerning 1-BP exposure and possible human health effects, and while further data are being collected, NIOSH investigators believe that occupational exposure to 1-BP and 2-BP should be minimized. As more data are gathered concerning recommended exposure guidelines for 1-BP, it is reasonable to use the 25 ppm guideline that has been suggested by some in industry and by the EPA. We have shown in this HHE that implementation of standard engineering controls are effective in greatly reducing worker exposure to 1-BP. While further engineering controls (such as improved ventilation) would be a means to further reduce exposures, other important factors in minimizing exposure to 1-BP are improved employee education and work practices. Specifically, Custom Products must first ensure that spray booths are designed properly and are adequate for workers' tasks. Training, and periodic re-training, concerning proper work practices involved with use of the spray booths (such as performing all spraying inside the spray booths) is indicated to ensure that existing engineering controls work as designed.

RECOMMENDATIONS

1. Custom Products should ensure that spray booths in the production area are designed to be adequate for the job tasks being performed.

2. Custom Products should inspect the spray booth filters regularly as part of a routine maintenance program. A filter should be replaced with a new filter when most of the filter is covered with some adhesive – this determination should be made by qualitative evaluation of the filters by a person with experience in maintaining these types of spray booths.

3. Custom Products should educate and train employees concerning the importance of proper use of all spray booths; specifically, employees should be educated and trained concerning the importance of performing all spraying activities inside a spray booth.

4. Custom Products should reevaluate employee exposures to 1-BP in the Covers and Assembly areas after maintenance procedures for the spray booths have been maximized (for example, regular filter maintenance being practiced) and after appropriate work practices are being routinely practiced (for example, all spraying tasks being performed inside the spray booths). As more data are being gathered concerning recommended exposure guidelines for 1-BP, it is reasonable to use the 25 ppm guideline that has been suggested by some in the industry and by the EPA. Engineering (such as ventilation) and administrative (such as product substitution and change in work practices) are the recommended types of controls that should be used to decrease occupational exposures to substances in the workplace.

5. Personal protective equipment is the least desirable method of exposure control. In general, NIOSH recommends PPE be used as an interim solution before the installation and testing of new exposure controls, and when engineering/administrative controls have not successfully lowered exposures. The following is information relevant to the use of personal protective equipment in workplaces where there may be occupational exposure to 1-BP.

a. For protection from dermal exposures, gloves and aprons made from flexible laminates (e.g., Viton™, 4H™ (PE/EVAL), Silver Shield™) can be used.

b. If respirators are used for protection from inhalation exposures to 1-BP, NIOSH-approved air-purifying respirator with organic vapor cartridges should be used. Respirators should only be used in the context of a comprehensive respiratory protection program.[16] Respirator users must be trained, fit-tested, and medically cleared for their assigned respirator.

6. Custom Products should consider the extent of 2-BP contamination when selecting a 1-BP-based adhesive. If 1-BP-based adhesives are used, those adhesives which have the minimum level 2-BP contamination should be selected for use.

7. Custom Products should remain up-to-date with ongoing development of guidelines concerning occupational exposure to 1-BP, and also with any regulatory activities occurring concerning the bromopropanes.

REFERENCES

1. NIOSH [1992]. Recommendations for occupational safety and health: compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for

Occupational Safety and Health, DHHS (NIOSH) Publication No. 92-100.

2. ACGIH [2001]. 2001 TLVs® and BEIs®: threshold limit values for chemical substances and physical agents. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. CFR [1997]. 29 CFR 1910.1000. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

4. Fensterbeim RJ [2000]. Letter of March 15, 2000 from Robert J. Fensterbeim, Brominated Solvents Consortium to the TSCA 8(e) Coordinator, Document Control Office, U.S. Environmental Protection Agency.

5. Smith RL [2000]. Presentation titled "N-Propyl Bromide" which was given on November 6, 2000, at a meeting between the U.S. Environmental Protection Agency and the Brominated Solvents Consortium.

6. EPA [2002]. Unpublished draft document: Acceptable Industrial Exposure Limit for N-Propyl Bromide.

7. Yu IJ, Kim HY, Lim CH, et al. [1999]. The occupational exposure level (OEL) for 2-bromopropane: the first OEL established by Korea. Appl Occup Environ Hyg 14:356–358.

8. Park JS, Kim Y, Park DW, et al. [1997]. An outbreak of hematopoietic and reproductive disorders due to solvents containing 2-bromopropane in an electronic factory, South Korea: epidemiological survey. J Occup Health 39:138–143.

9. Kim Y, Jung K, Hwan T, et al. [1996]. Hematopoietic and reproductive hazards of South Korean electronics workers exposed to solvents containing 2-bromopropane. Scand J Work Environ Health 22:387–391.

10. Ichihara Y, Yu S, Kamijima M, et al. [1997]. An occupational health investigation of a factory producing 2-bromopropane in China. J Occup Health 39 suppl: S327.

11. Ichihara G, Aseda N, Kumazawa T, et al. [1997]. Testicular and hematopoietic toxicity of 2-bromopropane, a substitute for ozone layer depleting chlorofluorocarbons. J Occup Health 39:57–63.

12. Kamijima M, Ichihara G, Yu X, et al. [1997]. Disruption of ovarian cyclicity due to 2-bromopropane in the rat. J Occup Health 39:3–4.

13. Yu IJ, Chung YH, Lim CH, et al. [1997]. Reproductive toxicity of 2-bromopropane in Sprague Dawley Rats. Scand J Work Environ Health 23:281–288.

14. Lim CH, Maeng SH, Lee JY, et al. [1997]. Effects of 2-bromopropane on the female reproductive function in Sprague Dawley rats. Ind Health 35:278–284.

15. ACGIH [2001]. Industrial Ventilation, 24st Edition, A Manual of Recommended Practice. Cincinnati, OH: American Conference of Governmental Industrial Hygienists. pages 10-113 - 10-115.

16. CFR [2000]. 29 CFR 1910.134. Code of Federal Regulations. Respiratory Protection. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

TABLE 1
Descriptive Statistics for 1-Bromopropane Exposure[1]
HETA 98-0153, Custom Products, Inc.
November 11-12, 1998

Sample Set (Number[2])	*1-Bromopropane Concentration*		
	Mean[3]	*Minimum [3]*	*Maximum[3]*
All Exposures (69)	168.9	60.0	381.2
Assembly (36)[4]	169.8	60.0	250.7
Sprayers (15)	193.0	115.3	250.7
Assemblers (20)	154.7	60.0	234.9
Covers (21)	197.0	117.3	381.2
Saw (12)	117.1	85.1	159.2

1 These statistics are determined using the exposure data in Appendix I. All exposure data are full-shift time-weighted average air samples collected from each worker's breathing zone.
2 Number of full-shift, time-weighted average exposures in the given sample set.
3 Numbers in these columns represent the mean (average), minimum, or maximum 1-bromopropane exposure concentrations in the given sample set. The concentration data are in units of parts per million (ppm) of 1-bromopropane.
4 Data from one supervisor omitted.

TABLE 2
Results from Area Air Sampling for 1-Bromopropane
HETA 98-0153, Custom Products, Inc.
First NIOSH Survey, November 11-12, 1998

Location	Sample Start-Stop Time	Sample Volume[1]	Concentration[2]
Sew	0757-1531	26.2	115.8
Sew	0757-1531	22.8	122.4
Sew	0757-1531	27.1	160.9
Sew	0757-1531	27.1	124.0
Sew	0757-1531	22.7	126.1
Sew	0757-1531	22.6	123.3
Sew	0747-1533	23.3	124.6
Sew	0749-1533	23.2	107.3
Sew	0750-1533	23.2	143.7
Sew	0752-1533	26.6	126.0
Sew	0751-1533	23.0	135.1
Minimum Detectable Concentration (MDC)			**0.01**
Minimum Quantifiable Concentration (MQC)			**0.03**

1 Sample volumes are in liters (L) of air.
2 The concentration data are in units of parts per million (ppm) of 1-bromopropane.

TABLE 3
Exhaust Flow Rates and Face Velocities for each Fabricated Spray Booth
HETA 98-0153, Custom Products, Inc.
First NIOSH Survey, November 11-12, 1998

Booth ID#	Estimated Exhaust Flow Rate (CFM)[1]	Calculated Average Velocity Over Full Face of Booth (ft/min)[2]	Measured Average Face Velocity Over Top Half of Booth (ft/min)[2]
1	795[3]	25[3]	40
2	401[3]	13[3]	31
3	NM[4]	NM[4]	24
4	779	25	NM[4]
5	624[3]	20[3]	27

[1] Units are in cubic feet of air per minute
[2] Units are in feet per minute. The recommended rate is 150 ft/min.
[3] The reported value is an average of two measurements.
[4] NM - No measurement. The measurements could not be completed due to recurring fan shut-off during employee break time when measurements were being made.
[5] Not applicable

TABLE 4
HETA 98-0153, Custom Products
Description of the 43 Medical Survey Participants

Gender	34 (79%) female; 9 (21%) male
Age (years)	Mean 31; Range 18-64
Work Location	Saw department - 7 participants Covers department - 18 participants Assembly department - 18 participants (6 sprayers, 12 assemblers)
Exposure Category, Number in Category, Mean Exposure (parts per million [ppm] 1-bromopropane)	Other (Saw department and one supervisor from Covers department), N=8, 117 ppm Assemblers, N=12, 155 ppm Sprayers (Covers and Assembly departments), N=23, 195 ppm
Median (Range) Length of Time Working at Current Job (years)	Saw department - 9 years (1 year - 37 years) Covers department - 4 years (3 months - 8 years) Assembly department - 4 years (6 months - 10 years)

TABLE 5
HETA 98-0153, Custom Products
Median Value for Blood Count Test Results Among 43 Participants in the Medical Survey, By Exposure Category

Exposure Category[1]	Red Blood Cell Count [2]	Hemoglobin Concentration[3]	White Blood Cell Count[4]	Platelet Count[5]
Other	4.5	14.1	6.7	185
Assemblers	4.3	13.6	6.6	203
Sprayers	4.3[6]	13.5[7]	6.7	207

[1] Others includes Saw department employees and supervisor from Covers department.
[2] million cells per cubic millimeter (mm^3)
[3] grams per deciliter
[4] thousand cells per mm^3
[5] thousand per mm^3
[6] Wilcoxon two sample test for comparison between sprayers and non-sprayers p=0.15
[7] Wilcoxon two sample test for comparison between sprayers and non-sprayers p=0.18

TABLE 6
HETA 98-0153, Custom Products
Number of Participants with Specific Symptoms Grouped by Exposure Category, With Prevalence Ratio and 95% CI
Total Number of Participants = 43

Exposure category[1]	Painful Tingling[2] # (%) Yes	Tremor[3] # (%) Yes	Headache[4] # (%) Yes	Felt "Drunk"[5] # (%) Yes	Abnormal Fatigue # (%) Yes	Problems Concentrating # (%) Yes
Other	2 (25)	3 (38)	4 (50)	3 (38)	4 (50)	5 (63)
Assemblers	4 (33)	3 (25)	4 (33)	5 (42)	6 (50)	4 (33)
Sprayers	12 (54)	10 (43)	14 (61)	10 (45)	9 (39)	9 (39)
Prevalence Ratio (95% CI)	1.8 (0.8 - 3.9)	1.4 (0.6 - 3.3)	1.5 (0.8 - 2.9)	1.1 (0.6 - 2.3)	0.8 (0.4 - 1.5)	0.9 (0.4 - 1.8)

[1] Others includes Saw department employees and supervisor from Covers department.
[2] Painful tingling in your hands or feet
[3] Tremor (trembling in your hands)
[4] Headache at least once per week.
[5] Positive response to the question: "Have you felt "drunk" when you have not been drinking?"
[6] Prevalence ratio and 95% CI for prevalence of symptom among sprayers compared to that among non-sprayers.

TABLE 7
Mean PBZ 1-BP Exposure Among Persons Reporting Presence/Absence of Symptoms
HETA 98-0153, Custom Products

Symptom	Response (Number)	Mean 1-BP (ppm)	p value[1]
Headache[2]	No (N=16)	173	.9
	Yes (N=16)	172	
Abnormal Fatigue	No (N=19)	172	1.0
	Yes (N=13)	172	
Problem Concentrating	No (N=18)	165	.2
	Yes (N=13)	182	
Feel "Drunk"[3]	No (N=18)	170	.8
	Yes (N=13)	174	
Painful tingling in your hands or feet	No (N=19)	164	.1
	Yes (N=12)	187	
Tremor (trembling in your hands)	No (N=18)	165	.2
	Yes (N=14)	182	

[1] Two-sample t-test, two sided
[2] Headache at least once per week.
[3] Positive response to the question: "Have you felt "drunk" when you have not been drinking?"

TABLE 8

Descriptive Statistics for 1-Bromopropane Exposure[1]
HETA 98-0153, Custom Products, Inc.
Second NIOSH Survey, November 16, 2000

Sample Set (Number[2])	1-Bromopropane Concentration		
	Mean[3]	Minimum [3]	Maximum[3]
All Exposures (30)	19.0	1.2	58.0
Assembly (11)	18.8	6.1	32.0
Covers (12)	29.2	2.8	58.0
Saw (6)	1.8	1.6	2.0
Sew (1)	1.2	NA[4]	NA

1 All exposure data are full-shift time-weighted average air samples collected from each worker's breathing zone.
2 Number of full-shift, time-weighted average exposures in the given sample set.
3 Numbers in these columns represent the mean (average), minimum, or maximum 1-bromopropane exposure concentrations in the given sample set. The concentration data are in units of parts per million (ppm) of 1-bromopropane.
4 Not applicable.

TABLE 9
Descriptive Statistics for 2-Bromopropane PBZ Exposure[1]
HETA 98-0153, Custom Products, Inc.
Second NIOSH Survey, November 16, 2000

Sample Set (Number[2])	2-Bromopropane Concentration		
	Mean[3]	Minimum [3]	Maximum[3]
All Exposures (30)	0.14	<0.01	0.55
Assembly (11)	0.30	0.10	0.55
Covers (12)	0.06	(0.02)	0.11
Saw (6)	0.04	<0.01	0.05
Sew (1)	< 0.01	NA[4]	NA

1 All exposure data are full-shift time-weighted average air samples collected from each worker's breathing zone.
2 Number of full-shift, time-weighted average exposures in the given sample set.
3 Numbers in these columns represent the mean (average), minimum, or maximum 2-bromopropane exposure concentrations in the given sample set. The concentration data are in units of parts per million (ppm) of 2-bromopropane. Concentrations in parentheses are between the MDC and MQC and are considered semi-quantitative. Concentrations preceded by a "less than" (<) symbol are below the MDC.
4 Not applicable.

TABLE 10
Short-Term Exposures to 1- and 2-Bromopropane
HETA 98-0153, Custom Products, Inc.
Second NIOSH Survey, November 16, 2000

Job Title	Location	Elapsed Sample Time[1]	Sample Volume[2]	Concentration[3]	
				1-BP	2-BP
Sprayer	Assembly-1	15	3.7	19.0	0.3
Sprayer	Assembly-2	15	3.7	16.6	0.3
Sprayer	Assembly-3	15	3.7	12.3	0.2
Sprayer	Assembly-2	16	4.0	17.1	0.2
Sprayer	Assembly-1	16	3.9	26.0	0.4
Sprayer	Assembly-3	15	3.7	12.9	(0.2)
Sprayer	Covers-2	17	4.2	20.8	ND
Sprayer	Covers-1	17	4.1	95.8	(0.1)
Sprayer	Covers-2	15	3.7	30.0	ND
Sprayer	Covers-5	15	3.7	52.6	(0.1)
Sprayer	Covers-4	15	3.7	26.6	(0.1)
Sprayer	Covers-6	15	3.7	13.4	ND
Minimum Detectable Concentration (MDC)				**0.1**	**0.1**
Minimum Quantifiable Concentration (MQC)				**0.2**	**0.2**

1 Elapsed sample time is in minutes.
2 Sample volume is in liters.
3 The exposure concentrations are in parts per million (ppm). Concentrations in parentheses are between the MDC and MQC and are considered semi-quantitative. ND - none detected, less than the MDC.

TABLE 11
Results from Area Air Sampling for 1- and 2-Bromopropane
HETA 98-0153, Custom Products, Inc.
Second NIOSH Survey, November 11-12, 1998

Location	Sample Time	Sample Volume[1]	Concentration[2]	
			1-BP	2-BP
Sew	0735-1524	23.3	1.4	ND
Sew	0735-1523	25.3	1.3	ND
Sew	0735-1517	23.3	1.2	ND
Sew	0735-1522	25.2	1.1	ND
Sew Together	0752-1523	22.1	1.9	ND
Minimum Detectable Concentration (MDC)			**0.01**	**0.01**
Minimum Quantifiable Concentration (MQC)			**0.03**	**0.03**

1 Sample volumes are in liters (L) of air.
2 The concentration data are in units of parts per million (ppm); ND - none detected, less than the MDC.

TABLE 12
Comparison Between the Mean Full-shift 1-BP Exposures Measured During the November 1998 Survey Versus the November 2000 Survey
HETA 98-0153, Custom Products, Inc.
November 16, 2000

Sample Set	November 1998 Mean 1-BP Exposures[1]	November 2000 Mean 1-BP Exposures[1]
All Exposure Data	168.9	19.0
Assembly Data	169.8	18.8
Sprayers	193.0	21.7
Assemblers	154.7	19.5
Covers Data	197.0	29.2
Saw Data	117.1	1.8
Sew Data[2]	128.1	1.4

1 Exposures are in parts per million (ppm).
2 Exposures are estimated from area air sampling data.

TABLE 13
Airflow and filter openness for all adhesive spray booths
HETA 98-0153, Custom Products, Inc.
April 19, 2001

Hood number	Flow rate CFM	Average face velocity ft/min	Filter percent openness
1	1978	106	72
2	1823	98	52
3	2192	117	67
4	4106	134	82
5	4006	131	98
6	3747	122	88
7	3960	129	88
8	3942	129	96
9	4065	133	96

APPENDIX 1
Discussion and Recommendations From First HHE Ventilation Assessment at Custom Products

Based on the initial NIOSH exposure and ventilation assessments, spray booths are needed for spraying operations at Custom Products. Air flow rates through existing spray booths in the Assembly area are inadequate, and spray booths have not yet been installed in the Covers area. Properly designed spray booths with adequate air flow rates should be installed at each work station where spraying operations are performed.

Although an adhesive, not paint, is being sprayed, a spray booth design similar to the paint spray booths presented in drawing VS-75-01 in the ACGIH Industrial Ventilation Manual is recommended for the Assembly area. New booths could be sized similarly to existing booths, measuring approximately 60 inches wide and 76 inches in overall height. For a large booth with the operator standing outside the booth, a minimum flow rate of 100 CFM/sq-ft is recommended. For a booth with an opening of the size mentioned above, over 3000 cubic feet per minute (CFM) of air flow would be needed. This air flow requirement can be reduced by raising the floor of the spray booth 28 inches above the plant floor. The work is currently placed on an adjustable stand, which could still be used in the new booths; however, the area below the stand platform is not needed for spray operations. Decreasing the area of the face of the booth by installing a floor in the booth just below the lowest level of the adjustable work platform will allow the required flow rate to be reduced to approximately 2000 CFM.

For the Covers area, smaller (table-top) booths may be more practical, providing protection with a smaller requirement for exhaust ventilation volume flow rate. The booth should be 12 inches wider and 12 inches higher than the work size. For a typical first-class airplane seat, a booth 42 inches wide and 22 inches high should be adequate. For a small booth, a minimum flow rate of 150 CFM/sq-ft is recommended. For a booth with an opening of the size recommended above, 965 CFM would be needed.

It would be expected that the baffles and other interior surfaces of the booth would become covered with spray adhesive. To facilitate cleaning, each baffle could be hung on hooks at the two upper corners and held in position by supports at the two bottom corners. This could simplify removal and reinsertion of the baffles, making both the baffles and the walls of the booth easier to clean.

ACGIH recommends a minimum duct velocity of 2000 ft/min. For the portion of the ductwork carrying the 2000 CFM flow rate from a single booth, the existing 12-inch diameter ductwork should be adequate. If excessive noise becomes a problem in the portion of the ductwork carrying the 4000 CFM flow rate from two booths, substituting 17-inch diameter ductwork should reduce the noise. For the vertical discharge portion of the ductwork on the roof of the building, an offset elbow or a vertical discharge stackhead design is recommended for rain protection.

The negative pressure condition inside the building with respect to the outside was consistent with the provision of local exhaust ventilation without providing additional make-up air. At the time of the survey, the infiltration of outside air was slight, and temperature and relative humidity were within recommended limits; however, additional make-up air may need to be provided by the air-conditioning system when more local exhaust ventilation is installed. A potential recirculation problem exists on the roof with the exhaust fans discharge velocity and duct height. The intakes and discharges for all fans are generally close to the surface of the roof and close to the air intakes for air-conditioning units. It is possible that there may be some reentry of exhausted spray adhesive vapors, depending on the direction the wind is blowing.

On the roof, ventilation inlets and outlets should be located to minimize reentry of air from contaminated sources. The minimum stack height should cause the flow of the discharge plume to be above the building inlets and the building recirculation cavity. For many single-story buildings, an exhaust stack height of 16 ft has been found adequate for discharging contaminants above the roof cavity. A design velocity of 2560 ft/min is recommended.

Reference

ACGIH [2001]. Industrial Ventilation, 24th Edition, A Manual of Recommended Practice. Cincinnati, OH: American Conference of Governmental Industrial Hygienists. pages 10-113 - 10-115.

ASHRAE [1985]. Air Flow Around Buildings. In: Fundamentals, 1985 ASHRAE Handbook.. Atlanta, GA: American Society of Heating, Refrigerating, and Air–Conditioning Engineers, Inc., chap 14.

APPENDIX 2
Worker's Full-Shift Breathing Zone Exposure Data for 1-Bromopropane
November 11-12, 1998

Department	Job Title	Sample Time	Sample Volume[1]	1-BP Concentration[2]
Assembly	Sprayer	0710-1518	26.8	115.3
Assembly	Assembler	0712-1521	25.1	128.3
Assembly	Assembler	0713-1517	24.6	135.6
Assembly	Sprayer	0715-1521	24.8	150.3
Assembly	Sprayer	1100-1443	11.4	242.0
Assembly	Assembler	0719-1528	18.6	193.3
Assembly	Assembler	0719-1522	24.9	147.7
Assembly	Assembler	0726-1523	24.3	123.1
Assembly	Sprayer	0722-0928	6.3	156.5
Assembly	Supervisor	0724-1528	24.8	124.9
Assembly	Assembler	0728-1332	18.7	234.9
Assembly	Sprayer	0729-1522	24.3	249.1
Assembly	Sprayer	0729-1333	18.5	225.8
Assembly	Sprayer	0730-1310	12.8	198.9
Assembly	Assembler	0920-1524	18.5	199.3
Assembly	Assembler	0731-1423	20.6	222.4
Assembly	Sprayer	0732-1526	24.3	250.7
Assembly	Assembler	0733-1523	20.4	60.0
Assembly	Assembler	0918-1526	18.7	151.2
Assembly	Sprayer	0735-1521	23.9	227.1
Assembly	Assembler	0732-1534	24.1	121.3
Assembly	Sprayer	0730-1532	24.5	190.8
Assembly	Assembler	0730-1530	24.0	129.6

Department	Job Title	Sample Time	Sample Volume[1]	1-BP Concentration[2]
Assembly	Assembler	0730-1529	24.5	183.6
Assembly	Assembler	0730-1531	24.5	155.0
Assembly	Sprayer	0730-1410	20.0	211.7
Assembly	Sprayer	0730-1529	24.0	188.0
Assembly	Assembler	0732-1531	24.0	184.6
Assembly	Sprayer	0732-1529	24.5	184.8
Assembly	Sprayer	0732-1527	24.3	132.8
Assembly	Assembler	0734-1533	23.8	144.8
Assembly	Sprayer	0735-1533	18.1	171.4
Assembly	Assembler	0735-1533	24.2	179.6
Assembly	Assembler	0735-1533	24.3	158.3
Assembly	Assembler	0737-1533	24.3	127.2
Assembly	Assembler	0738-1533	23.7	114.1
Covers	Sprayer	0700-1533	25.0	211.1
Covers	Sprayer	0700-1533	25.2	232.7
Covers	Sprayer	0700-1533	25.5	157.0
Covers	Sprayer	0701-1533	24.8	235.0
Covers	Sprayer	0701-1533	24.8	278.5
Covers	Sprayer	0700-1533	25.3	381.2
Covers	Sprayer	0705-1533	24.7	241.1
Covers	Sprayer	0708-1533	25.3	147.3
Covers	Sprayer	0709-1533	24.7	181.4
Covers	Sprayer	0710-1533	24.6	264.8
Covers	Sprayer	0710-1533	25.1	161.0
Covers	Sprayer	0711-1533	11.4	176.3

Department	Job Title	Sample Time	Sample Volume[1]	1-BP Concentration[2]
Covers	Sprayer	0712-1533	25.2	194.5
Covers	Sprayer	0713-1533	27.0	142.9
Covers	Sprayer	0713-1533	25.1	180.7
Covers	Sprayer	0715-1533	24.8	203.3
Covers	Sprayer	0716-1533	25.2	221.0
Covers	Sprayer	0716-1533	24.7	126.8
Covers	Sprayer	0719-1533	24.8	140.5
Covers	Sprayer	0720-1533	24.2	117.3
Covers	Sprayer	0724-1533	24.3	142.8
Saw	Operator	0737-1417	20.5	104.1
Saw	Operator	0925-1537	19.1	140.9
Saw	Operator	0741-1525	23.2	127.3
Saw	Supervisor	0742-1523	23.4	117.4
Saw	Operator	0745-1523	22.9	159.2
Saw	Operator	0747-1524	23.3	106.0
Saw	Operator	0748-1523	23.1	109.7
Saw	Operator	0749-1520	23.1	85.1
Saw	Operator	0750-1525	23.3	111.8
Saw	Operator	0751-1523	22.8	110.0
Saw	Operator	0915-1525	18.9	123.5
Saw	Supervisor	0730-1534	24.2	110.3
Recommended Exposure Guideline				**25**
Minimum Detectable Concentration (MDC)				**0.01**
Minimum Quantifiable Concentration (MQC)				**0.03**

[1] Sample volumes are in liters of air.

[2] The 1-BP exposure concentrations are in parts per million. Concentrations in parentheses are between the MDC and MQC and are considered semi-quantitative. ND - none detected, less than the MDC.

APPENDIX 3
Worker's Full-Shift Breathing Zone Exposure Data for 1-BP and 2-BP
November 16, 2000

Job Title	Department[1]	Sample Time	Sample Volume[2]	Concentration[3]	
				1-BP	2-BP
Assembler	Assembly - 2	0705-1517	24.3	18.0	0.30
Assembler	Assembly - 2	0706-1518	24.9	20.7	0.35
Sprayer	Assembly - 2	0708-1519	24.3	32.0	0.48
Assembler	Assembly - 1	0709-1519	24.2	9.9	0.20
Sprayer	Assembly - 1	0710-1517	24.0	14.9	0.25
Assembler	Assembly - 1	0711-1519	49.8	24.4	0.40
Assembler	Assembly - 1	0712-1518	24.4	31.8	0.55
Assembler	Assembly - 3	0714-1520	24.1	11.5	0.19
Sprayer	Assembly - 3	0715-1520	24.1	18.1	0.26
Assembler	Assembly - 3	0715-1519	24.0	19.9	0.21
Foreman	Assembly	0756-1522	21.7	6.1	0.10
Sprayer	Covers - 1	0719-1520	23.7	58.0	0.11
Sprayer	Covers - 1	0720-1521	21.8	26.5	0.07
Sprayer	Covers - 3	0722-1522	23.6	25.3	0.06
Sprayer	Covers - 2	0723-1520	24.6	5.4	0.03
Sprayer	Covers - 2	0723-1522	70.9	33.7	0.07
Sprayer	Covers - 3	0725-1523	23.5	51.6	0.10
Sprayer	Covers - 4	0904-1519	18.3	28.2	0.05
Sprayer	Covers - 5	0727-1521	20.0	36.8	0.06
Sprayer	Covers - 5	0730-1520	23.3	45.3	0.10
Sprayer	Covers - 6	0730-1520	22.9	13.9	0.06
Sprayer	Covers - 6	0730-1521	22.3	23.2	0.05
Foreman	Covers	0734-1522	23.3	2.8	(0.02)
Foreman	Sew	0739-1522	22.8	1.2	ND
Operator	Saw	0741-1518	19.4	1.6	0.04
Operator	Saw	0743-1519	24.3	1.6	ND
Operator	Saw	0745-1517	22.5	2.0	0.05
Operator	Saw	0747-1519	45.4	1.7	0.03
Operator	Saw	0748-1518	22.1	1.9	0.04
Foreman	Saw	0756-1521	91.6	1.8	0.05
Recommended Exposure Guideline				**25**	**1**

Minimum Detectable Concentration (MDC)	**0.01**	**0.01**
Minimum Quantifiable Concentration (MQC)	**0.03**	**0.02**

[1] Spray booth number where the air sample was collected; [2] Sample volumes are in liters of air; [3] The 1-BP and 2-BP exposure (ppm). Concentrations in parentheses are between the MDC and MQC (semi-quantitative). ND - none detected, less than the MDC.

APPENDIX 4
Brominated Solvents Background and Significance

In 1990 the Clean Air Act (CAA) was amended to include more stringent provisions for the protection of stratospheric ozone and the phase-out of several ozone-depleting substances under Title VI of the law.[1] The law targeted the complete phase-out of several substances including chlorofluorocarbons, hydrochlorofluorocarbons, and methyl chloroform, each of which was being used by industry at that time. Industrial applications of these substances included non-aerosol solvent cleaning, adhesive coatings applications, and solvent applications.[2] The CAA amendment provisions were in part enacted to abide by the terms of a United Nations (UN) international agreement, The Montreal Protocol on Substances that Deplete the Ozone Layer adopted in 1987, which committed to reduce and eventually eliminate the use of ozone-depleting substances. As a result, several countries discontinued and prohibited further use of ozone-depleting substances.[3] Under Section 612 of the CAA, ozone-depleting substances were to be replaced with alternative substances or processes that reduced the risks to human health and the environment.[1] To fulfill the law's requirement, the Environmental Protection Agency (EPA) initiated the Significant New Alternatives Policy (SNAP) program intended to approve safe alternatives for ozone-depleting substances.[4]

The solvents 1-bromopropane (1-BP) and 2-bromopropane (2-BP) were introduced into workplaces around the world as substitutes for ozone-depleting substances following initiation of the 1987 UN international treaty. The physical properties of these two solvents, including high volatility and low flammability, were seen as favorable characteristics for a non-aerosol solvent. Due to photochemical breakdown, the solvents have a relatively short atmospheric half-life (17.5 to 24 days), possibly decreasing their ozone-damaging capacity.[5,6]

At the present time, 2-BP is not produced for commercial use in the United States (U.S.). However, 1-BP is produced and commercially available in the U.S. The purity of 1-BP is listed as 99% in Material Safety Data Sheets (MSDS) from two laboratory reagent manufacturers.[7,8] A 1999 Occupational Safety and Health Administration (OSHA) analysis of several commercial samples of 1-BP found them to contain 2-BP in concentrations ranging from 0.1 to 0.2 percent.[9] A voluntary consensus standard (D6368-00) published by the American Society For Testing and Materials has since been released covering vapor degreasing and general grade 1-BP and specifies that the content of 2-BP in these solvent grades remain below 0.1 percent.[10] Currently only 1-BP is being reviewed under the SNAP program as a potential alternative to ozone-depleting substances.[2] At this time, the EPA has not disapproved the use of 1-BP, so it may be used for any purpose in the U.S. (while 2-BP may not).[9]

Review of Literature—
1-Bromopropane

Animal exposure studies have demonstrated reproductive toxicity for both male and female rats when exposed to concentrations greater than or equal to 200 parts per million (ppm) of 1-BP.[11,12] Two studies noted mild hepatic changes in rats exposed to greater than or equal to 800 ppm of 1-BP; these changes were considered adaptive and reversible due to the absence of other signs of hepatotoxicity.[11,13,14] Although 2-BP exposure has been associated with pancytopenia, animal studies evaluating potential hematopoietic effects of 1-BP exposure have yielded no firm conclusions. The median lethal inhalation concentration of 1-BP for Sprague-Dawley rats has been estimated to be 14,374 ppm.[13]

Four studies have demonstrated some form of neurotoxicity in rats exposed to 1-BP. All studies involved exposure concentrations greater than or equal to 800 ppm. Three of the studies demonstrated decreased peripheral nerve functioning by electrophysiologic testing and morphologic or histopathologic abnormalities of central and peripheral nerves.[15,16,17] Two of these three studies also demonstrated a prominent weakness of the hind limbs following exposure.[15,17] A fourth study demonstrated decreased peripheral nerve functioning by electrophysiologic testing alone.[18] One of the five studies established that the muscle weakness and decreased electrophysiologic findings were both dependent on concentration and length of exposure period.[17] This same study and one other came to the conclusion that 1-BP was a more potent neurotoxicant than 2-BP; another study that evaluated the neurotoxicity of both 1-BP and 2-BP was unable to conclude that 1-BP was a more potent neurotoxicant.[15,18]

A total of four persons with health effects considered related to 1-BP exposure have been described in two published case reports. The first case report concerned a 19-year-old male working as a metal 'stripper'.[19] He was exposed on a daily basis over a two-month period to an industrial solvent (containing greater than 95.5 percent 1-BP by weight) used for degreasing and cleaning. His right hand was most commonly exposed to the solvent. The air concentration of 1-BP and type of ventilation were not discussed in the article. Presenting symptoms included "numbness and mild but progressive weakness of the proximal lower extremities and the right hand… transient dysphagia and urinary difficulties."[19] The physical findings, magnetic resonance imaging (MRI) of the brain, and electromyography (EMG) findings supported the diagnosis of a "primary demyelinating condition, predominantly affecting the lower extremities, in the distribution of an acquired neuropathy, but with evidence of central nervous system involvement as well." The EMG did not indicate any evidence of muscle denervation. The individual did demonstrate improvement following removal from exposure, but was lost to follow-up before it was determined if the health effects would fully resolve.

The second case report concerned three females, ages 35, 30, and 50, each working at cushion manufacturing companies in North Carolina.[20] The workers sprayed glue (containing 55 percent 1-BP as the base solvent) with a spray gun onto polyurethane foam pieces. A total of 15 workers performed this process in an open work area. Exhaust ventilation provided at each workstation was operated intermittently and workers wore latex gloves for dermal exposure protection. The first worker's symptoms developed one year following the replacement of a dichloromethane-based glue with the 1-BP-based glue. The remaining two workers developed symptoms six months and two months, respectively, following commencement of their employment in the exposure area. Airborne exposures of the three workers were not well described; the case report did state that one worker was found to have time-weighted average (TWA) exposures of between 60 to 261 ppm of 1-BP over several days of monitoring 5 months after symptoms had started.

"The three workers showed the common symptoms of staggering, numbness and paresthesia/dysesthesia with a similar distribution in their feet, legs, thighs, lower back and hips as well as a remarkable decrease in vibration sense, along with various symptoms of the central nervous system and autonomic symptoms."[20]

Other symptoms experienced by the workers included temporary menstrual cycle disruption for two of the three women, diarrhea, abnormal sweating, and urinary incontinence. The researchers concluded that 1-BP likely caused the peripheral and central nervous system deficits and that the other noted symptoms were likely related to autonomic system disruption secondary to 1-BP exposure. The study did not indicate if the symptoms improved or resolved upon removal from exposure.

Limited information is available from an unpublished abstract submitted at the 2002 Annual Meeting of the Society of Toxicology regarding the only 1-BP human health effect study performed to date.[21] The study evaluated a group of 25 female workers, exposed to low levels of 1-BP, for neurological effects, comparing them to a group of 27 unexposed controls. Neurobehavioral and electrophysiological assessments of nerve function were performed on both groups. Because of the limited nature of the information presented in this abstract, it is difficult to draw conclusions from this study.

Review of Literature—
2-Bromopropane

Following a report of the occurrence of secondary amenorrhea among female workers in a tactile switch assembly section of a South Korean factory, two studies were performed to evaluate the health effects of workers in the factory.[22,23] The studies found background area air sample concentrations of 2-BP to range from 9.2 to 19.6 ppm. The concentration of 2-BP detected during a short-term sample inside the hood of a cleaning bath was 4,140.7 ppm. One study theorized that workers might be exposed to higher concentrations of 2-BP for short periods of time when performing operations at the cleaning bath.[22] The other study theorized that because there were two uncovered 2-BP baths in the area and ventilated air was recirculated, 2-BP concentrations were routinely elevated in the work area.[23] Both studies concluded that 2-BP exposure was the probable cause of the health effects (ovarian failure in females, azoospermia or oligospermia in males, and pancytopenia) noted in the exposed workers.

Following these reports, several studies designed to evaluate health effects associated with exposure of rats to 2-BP were initiated; these studies demonstrated ovarian, testicular, and hematopoietic dysfunction beginning at exposure levels of greater than 300 ppm or 250 milligram per kilogram (mg/kg).[24,25,26,27,28] Two studies recently demonstrated peripheral neurotoxic changes and peripheral neuropathy in rats exposed to 1,000 ppm of 2-BP.[18,29] The median lethal inhalation concentration of 2-BP for the Sprague-Dawley rat has been estimated to be 31,171 ppm.[30]

One study has been conducted to evaluate the health effects of 2-BP on employees working at a 2-BP manufacturing plant. During the study, conducted in 1996, worker breathing zone exposure concentrations ranged from 0.80 to 16.18 ppm as an 8-hour TWA. The study included worker interviews, medical examinations, and specific testing of reproductive and hematological indices. "No severe cases of reproductive or hematopoietic disorders were found at (exposures) less than 10 ppm (TWA), but a possible adverse effect of 2-bromopropane on hematopoiesis could not be disproved."[31]

1-Bromopropane Biomarker of Exposure

A study has demonstrated that among seven different solvents, 1-BP was the only solvent that significantly ($p < 0.01$) influenced the concentration of 1-BP and bromine in the urine of exposed subjects, and thus either measure can be used as a biomarker of exposure.[32] In that study, 1-BP concentration in the urine was shown to be more highly correlated to the airborne 1-BP exposure ($p < 0.01$, $r = 0.952$) than was bromine concentration in the urine ($p < 0.01$, $r = 0.738$). However, urinary 1-BP detection requires gas chromatography-mass spectrometry (GCMS) instrumentation and the specimen must be immediately analyzed after collection. Most clinical laboratories can perform bromine detection, and analysis may be delayed without serious degradation of specimen quality. Cost constraints would be the main reason why bromine analysis might be chosen over GCMS analysis in a study.

APPENDIX 4 - REFERENCES

1. United States Code [1990]. 42 USC 7401 et. seq. Washington, DC: U.S. Government Printing Office.

2. 65 Federal Register 78977 [2000]. Environmental Protection Agency: Protection of stratospheric ozone: Notice 14 for significant new alternatives policy program; notice of acceptability; request for information.

3. United Nations Environmental Programme [2000]. Ozone Treaties. [http://www.unep.ch/ozone/treaties.shtml]. Date accessed: May 5, 2002.

4. 58 Fed. Reg. 54892 [1993]. Environmental Protection Agency: Protection of stratospheric ozone; final rule.

5. Donaghy T, Shanahan I, Hande M, Fitzpatrick S [1993]. Rate constants and atmospheric lifetimes for the reactions of OH radicals and Cl atoms with haloalkanes. Int J Chem Kinet *25*(4):273–84.

6. Meylan WM, Howard PH [1993]. Computer estimation of the atmospheric gas-phase reaction rate of organic compounds with hydroxyl radicals and ozone. Chemosphere *26*(12):2293–2300.

7. Aldrich Chemical Company. Material safety data sheet for 1-bromopropane, 99%. May 2002.

8. Acros Organics N.V. Material safety data sheet for 1-bromopropane, 99%. May 2002.

9. OSHA [1999]. Nomination of 1-bromopropane (1-BP) and 2-bromopropane (2-BP) for testing by the National Toxicology Program. Washington, DC: Department of Labor, Directorate of Health Standards Programs, U.S. Occupational Safety and Health Administration, DOL (OSHA).

10. ASTM [2001]. D6368-00 Standard specification for vapor-degreasing grade and general grade normal-propyl bromide. West Conshohocken, PA: American Society for Testing Materials.

11. Ichihara G, Yu X, Kitoh J, Asaeda N, Kumazawa T, Iwai H, Shibata E, Yamada T, Wang H, Xie Z, Maeda K, Tsukamura H, Takeuchi Y [2000]. Reproductive toxicity of 1-bromopropane, a newly introduced alternative to ozone layer depleting solvents, in male rats. Toxicological Sciences *54*:416–423.

12. Stump D [2001]. An inhlation two-generation reproductive toxicity study of 1-bromopropane in rats. Study No. WIL-380001.

13. Kim HY, Chung YH, Jeong JH, Lee YM, Sur GS, Kang JK [1999]. Acute and repeated inhalation toxicity of 1-bromopropane in SD rats. J Occup Health *41*:121–128.

14. NTP [2002]. NTP-CERHR expert panel report on the reproductive and developmental toxcity of 1-bromopropane. Washington, DC: U.S. Department of Health and Human Services, National Institutes of Health, National Institute of Environmental Health Sciences, National Toxicology Program, DHHS (NTP) Publication No. NTP-CERHR-1-BP-02.

15. Yu X, Ichihara G, Kitoh J, Xie Z, Shibata E, Kamijima M, Takeuchi Y [2001]. Neurotoxicity of 2-bromopropane and 1-bromopropane, alternative solvents for chlorofluorocarbons. Environmental Research *85*(1):48–52.

16. Wang H, Ichihara G, Ito H, Kato K, Kitoh J, Yamada T, Yu X, Tsuboi S, Moriyama Y, Sakatani R, Shibata E, Kamijima M, Itohara S, Takeuchi Y [2002]. Biochemical changes in the central nervous system of rats exposed to 1-bromopropane for seven days. Toxicological Sciences *67*:114–120.

17. Ichihara G, Kitoh J, Yu X, Aseda N, Iwai H, Kumazawa T, Shibata E, Yamada T, Wang H, Xei Z, Takeuchi Y [2000]. 1-bromopropane, an alternative to ozone layer depleting solvents, is dose-dependently neurotoxic to rats in long-term inhalation exposure. Toxicological Sciences *55*:116–123.

18. Zhao W, Aoki K, Xie T, Misumi J [1999]. Electrophysiological changes induced by different doses of 1-bromopropane and 2-bromopropane. J Occup Health *41*:1–7.

19. Sclar G [1999]. Encephalomyelo-radiculoneuropathy following exposure to an

industrial solvent. Clinical Neurology and Neurosurgery *101*:199–202.

20. Ichihara G, Miller JK, Ziolkowska A, Itohara S, Takeuchi Y [2002]. Neurological disorders in three workers exposed to 1-bromopropane. J Occup Health *44*:1–7.

21. Ichihara G, Li W, Shibata E, Ding X, Kamijima M, Wang H, Liang Y, Peng S, Itohara S, Fan Q, Zhang Y, Zhong W, Wu X, Valentine WM, Takeuchi Y [2002]. Neurological abnormality in workers of 1-bromopropane factory [Abstract]. Presented at the 41st Annual Meeting of the Society of Toxicology, Nashville, TN, March 17–21.

22. Kim Y, Jung K, Hwang T, Jung G, Kim H, Park H, Kim J, Park J, Park D, Park S, Choi K, Moon Y [1996]. Hematopoietic and reproductive hazards of Korean electronic workers exposed to solvents containing 2-bromopropane. Scand J Work Environ Health *22*:387–391.

23. Park J, Kim Y, Park DW, Choi KS, Park S, Moon Y [1997]. An outbreak of hematopoetic and reproductive disorders due to solvents containing 2-bromopropane in an electronic factory, South Korea: epidemiological survey. J Occup Health *39*:138–143.

24. Kamijima M, Ichihara G, Yu X, Kitoh J, Tsukamura H, Maeda K, Yu X, Xie Z, Nakajima T, Asaeda N, Hisanaga N, Takeuchi Y [1997]. Ovarian toxicity of 2-bromopropane in the non-pregnant female rat. J Occup Health *39*:144–149.

25. Kamijima M, Ichihara G, Yu X, Xie Z, Kitoh J, Tsukamura H, Maeda K, Nakajima T, Asaeda N, Hisanaga N, Takeuchi Y [1997]. Disruption in ovarian cyclicity due to 2-bromopropane in the rat. J Occup Health *39*:3–4.

26. Lim CH, Maeng SH, Lee JY, Chung YH, Kim TG, Park JH, Moon YH, Yu IJ [1997]. Effects of 2-bromopropane on the female reproductive function in Sprague-Dawley rats. Industrial Health *35*:278–284.

27. Yu IJ, Chung YH, Lim CH, Maeng SH, Lee JY, Kim HY, Lee SJ, Kim CH, Kim TG, Park JS, Moon YH [1997]. Reproductive toxicity of 2-bromopropane in Sprague-Dawley rats. Scand J Work Environ Health *23*:281–288.

28. Ichihara G, Asaeda N, Kumazawa T, Tagawa Y, Kamajima M, Yu X, Kondo H, Nakajima T, Kitoh J, Yu IJ, Moon YH, Hisanaga N, Takeuchi Y [1997]. Testicular and hematopoietic toxicity of 2-bromopropane, a substitute for ozone layer-depleting chlorofluorocarbons. J Occup Health *39*:57–63.

29. Yu X, Ichihara G, Xie Z, Shibata E, Kamijima M, Asaeda N, Hisanaga N, Takeuchi Y [1999]. Effect of inhalation exposure to 2-bromopropane on the nervous system in rats. Toxicology *135*:87–93.

30. Kim HY, Chung YH, Yi KH, Kim JG, Yu IJ [1996]. LC_{50} of 2-bromopropane. Industrial Health *34*:403–407.

31. Ichihara G, Ding X, Yu X, Wu X, Kamijima M, Peng S, Jiang X, Takeuchi Y [1999]. Occupational health survey on workers exposed to 2-bromopropane at low concentrations. Am J Ind Med *35*:523–531.

32. Kawai T, Takeuchi Y, Moriyama Y, Sakamoto K, Zhang ZW, Higashikawa K, Ikeda M [2001]. Biological monitoring of occupational exposure to 1-bromopropane by means of urinalysis for 1-bromopropane and bromide ion. Biomarkers *6*(5):303–312.