CDC Workplace Safety and Health

NIOSH HEALTH HAZARD EVALUATION REPORT:

HETA #2001-0144-2867
Superior Label Systems
Mason, Ohio

February 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 Elena Page, Calvin Cook, Charles Mueller, and Vincent Mortimer of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Ophthalmologic examinations were performed by Michael Hater, M.D., of the Cincinnati Eye Institute. Field assistance was provided by Elaine Moore, Jenise Brassell, Kristen Gwin, Joshua Harney, Gregory Burr, and Bradley King of DSHEFS. Analytical support was provided by Ardith Grote, Division of Applied Research Technology and by DataChem Laboratories. Desktop publishing was performed by Elaine Moore. Review and preparation for printing were performed by Penny Arthur.

Copies of this report have been sent to employee and management representatives at Superior Label Systems, Inc. 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 Visual Disturbances Related to Amine Exposure

NIOSH received a request for a health hazard evaluation (HHE) from Superior Label Systems, Inc. (SLS) in Mason, Ohio, on January 24, 2001. The request stated that employees in the line division of the plant were experiencing blurry vision at work, and that one employee had been evaluated by an ophthalmologist who found a "film over his eyes."

What NIOSH Did

- We took air samples of 2 amines, dimethylisopropanolamine (DMIPA), and dimethylaminoethanol (DMAE).
- We handed out a questionnaire about eye problems, work and medical history, and looked at the ventilation system.
- We performed eye examinations on employees at the beginning and the end of their shift for a week.

What NIOSH Found

- Most employees in the line division reported blurry vision at work.
- The blurry vision made it hard to do their job and/or drive home
- Concentrations of DMIPA in the air were higher in the line division than in the prime division.
- Concentrations of DMAE in the air were higher in the prime division than in the line division.
- Exposure to amines at SLS was associated with blurry, halo, and blue-grey vision, clouding of the cornea, and decreased vision.
- The visual problems are reversible, but are a safety hazard, both on the job and when driving home.
- No visual complaints have occurred since management began to dilute pH adjuster (which contains DMIPA) with water.

What Superior Label Systems, Inc. Managers Can Do

- Continue to dilute the pH adjuster.
- Cover all ink pails to reduce the amount of chemicals vaporizing into the work environment.
- Improve local exhaust ventilation at printing presses.
- Do not supply latex rubber gloves. Supply and instruct workers to wear gloves made of materials that provide better protection.

What Superior Label Systems, Inc. Employees Can Do

- Keep all ink pails covered to reduce the amount of chemicals vaporizing into the work environment.
- Do not wear latex rubber gloves to handle chemicals. Instead, wear gloves made of materials that provide better protection.

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 #2001-0144-0867

Health Hazard Evaluation Report 2001-0144-2867
Superior Label Systems
Mason, Ohio
October 2001

Elena H. Page, M.D., M.P.H.
Calvin K. Cook, M.S., C.S.P.
Charles A. Mueller, M.S.
Vincent Mortimer, M.S., P.E.

SUMMARY

The National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from Superior Label Systems, Inc. (SLS) in Mason, Ohio, on January 24, 2001. The request stated that employees in the line division of the plant were experiencing intermittent blurred vision, and that one employee had been evaluated by an ophthalmologist who found a "film over his eyes." Employees in the prime division of the plant were not experiencing visual disturbances. Workers and management had not been able to associate these visual changes with any particular substance in use.

A site visit was conducted on February 8, 2001, that included an opening meeting with management and employee representatives, an overview of the process, and a walk-through of the plant. Medical questionnaires, eye exams, and extensive industrial hygiene monitoring for two types of tertiary amine compounds, dimethylisopropanolamine (DMIPA) and dimethylaminoethanol (DMAE), were performed from April 23-26 and April 30-May 3, 2001.

Eighty-nine percent of line workers reported having experienced blurry vision while at work in the past 12 months, compared to 12.5% of prime workers ($p<0.01$). Findings were similar for halo and blue-grey vision. Forty-seven percent of those reporting blurry, halo, or blue-grey vision experienced eye irritation along with the visual changes, 44% reported difficulty performing their job due to the visual changes, and 39% reported difficulty driving home due to vision problems.

A total of 108 full-shift personal breathing-zone (PBZ) air samples for the amines were collected, 93 in the line division and 15 in the prime division. The mean time-weighted average (TWA) concentration of DMIPA was significantly higher in the line division than in the prime division (7.70 mg/m^3 vs. 2.08 mg/m^3, $p<0.01$), as was the mean TWA concentration for total amines (9.96 mg/m^3 vs. 5.56 mg/m^3, $p<0.01$). The mean TWA concentration of DMAE was higher in the prime division than the line division (3.47 mg/m^3 vs. 2.27 mg/m^3, $p<0.01$).

There was a positive association between reported visual symptoms and concentrations of total amines. Higher levels of total amines were associated with increased risk of reporting blurry vision (odds ratio [OR]=1.78, 95% confidence interval [CI]=1.41, 2.26), halo vision (OR=1.38, 95% CI=1.20, 1.58), and blue-grey vision (OR=1.77, 95% CI= 1.31, 2.39). All OR reported refer to a per unit increase of 1 mg/m^3 in amine concentration. Symptom reporting increased with exposure to increasing concentrations of amines.

The risk of corneal opacity rose with increasing exposure to total amines (OR=1.15, 95% CI= 1.02, 1.30). The prevalence of corneal opacity also increased with increasing concentration of total amines. The

prevalence of increased corneal thickness in either eye increased with higher levels of exposure to total amines, as did both the mean and median changes in thickness. Median corneal thickness increased with increasing grades of corneal opacity.

There was a statistically significant relationship between total amine concentration and increased risk of reduced bilateral visual acuity and 2.5% contrast sensitivity (OR=1.2, 95% CI=1.001,1.43; OR=1.28, 95% CI=1.14,1.43, respectively).

At the time of the site survey, NIOSH investigators notified SLS management that the pH adjuster may be responsible for workers visual complaints. SLS management promptly began to dilute the pH adjuster, which contains DMIPA, with water. This action resulted in a resolution of visual complaints among the workers.

Exposure to tertiary amines at SLS was found to be associated with visual and ocular changes. While this appears to be a reversible phenomena, these visual changes pose a safety hazard, both on the job and when driving home. Recommendations include: (1) continuing to dilute the pH adjuster; (2) covering all 5-gallon ink pails to reduce the amount of chemicals vaporizing into the work environment; and (3) improving local exhaust ventilation at printing presses.

Keywords: SIC Code 2759 (Commercial Printing, Not Elsewhere Classified), blurry vision, halo vision, cornea, amines, tertiary amines, dimethylaminoethanol, dimethylisopropanolamine, DMIPA, DMAE.

Table of Contents

INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from Superior Label Systems, Inc. (SLS) in Mason, Ohio, on January 24, 2001. The request stated that employees in the line division of the plant were experiencing intermittent blurred vision, and that one employee had been evaluated by an ophthalmologist who found a "film over his eyes." The blurred vision was described as looking through a fog or a mist. It was most noticeable when looking at lights, causing a halo appearance. The visual changes typically resolved within a couple of hours after leaving work. This had occurred on an intermittent, unpredictable basis, but appeared to have been increasing in frequency. Workers and management had not been able to associate these visual changes with any particular substance in use. The symptoms were reported only by employees in the line division of the plant, only on Mondays through Thursdays, and not on weekends when production was lower.

A site visit was conducted on February 8 , 2001, that included an opening meeting with management and employee representatives, an overview of the process, and a walk-through of the plant. Medical questionnaires, eye exams, and extensive industrial hygiene monitoring were performed from April 23-26 and April 30-May 3, 2001. Study participants were notified of the results of their eye examinations at the end of each shift.

BACKGROUND

Facility and Process Description

SLS is one of the largest flexographic printing operations for consumer product labeling in the United States. Flexography printing is a form of rotary web letter press that uses flexible rubber plates mounted to a printing cylinder. SLS has about 360 employees in four facilities located in Ohio, Texas, and Arizona. Corporate headquarters is located in Mason, Ohio. In addition to the corporate headquarters, there is a label production plant in Mason with approximately 100 production workers, which was the site of the HHE. The production facility in Mason opened in 1995. The plant operates two 10-hour shifts on Monday through Thursday, and has only skeleton crews working on Friday through Sunday.

The operation at the Mason plant involves printing labels made of paper or plastic materials using water-based, ultraviolet (UV), and flourescent inks. Presses are also capable of applying a laminating overprint and adhesive backing at the customers request. The building is approximately 300 feet x 260 feet, with approximately 78,000 square feet (ft^2) of floor area. The eastern side of the building has approximately 11,500 ft^2 of office space. The western side of the building has over 34,000 ft^2 of warehouse space.

The production area is divided into two divisions, the line division and the prime division. The line division, occupying approximately 15,000 ft^2, has eight high-speed printing presses (approximately 400 feet per minute) that use primarily water-based inks for printing lower quality labels such as those used on milk jug and orange juice containers. There is occasional use of fluorescent inks, but no use of UV inks. The prime division has seven printing presses in an approximately 9000 ft^2 area; these presses operate at lower speeds (150-175 feet per minute) and use mainly water-based inks to print higher quality labels such as those found on cosmetic and automotive productss. UV and fluorescent inks are also used in the prime division, but less commonly than water-based inks. Each press has several 5-gallon pails for holding inks before the inks are pumped to ink troughs where plate rolls and cylinders are mounted.

The water-based inks contain 1% dimethylaminoethanol (DMAE) and, depending on the specific ink, varying concentrations of ammonia, isopropyl alcohol, and glycol ether. A solution containing 5.3% isopropyl alcohol is used as a color booster. A compound called clean print additive (containing 45% DMAE and 55% water) is used, primarily on the prime side, to increase drying time on the inks. A pH adjuster containing dimethylisopropanolamine (DMIPA) is used daily, primarily in the line division. About 98 gallons of the pH adjuster are reportedly used about every 3-4 weeks. Print additives, such as the pH adjuster and color booster, are manually added to inks stored in the 5-gallon pails. Both the line and the prime divisions use adhesives and UV varnishes for overprint laminating. After UV inks and laminating overprint are printed and applied onto labels, curing is done by passing printed labels through an enclosed UV lamp unit, then rolled into master rolls.

There are three primary jobs in the production areas: press operators, rewinder operators, and press assistants. Press operators run the printing presses, which includes filling pails with inks and additives as needed, inspecting printed labels for defects, and trouble shooting. The press assistants perform a variety of duties that include setting up cylinders, plates, and the 80 to 200 pound rollstock onto presses; removing printed rolls from presses; and filling in when the press operator is absent. Rewinder operators run a stand-alone rewinder machine that spins and cuts master rolls of printed labels into smaller rolls to prepare for shipment. Various cleaning agents, including alcohol, ammonia, ethyl acetate, 2-butoxy ethanol, and mild soap and water, are routinely used to clean inks, varnishes, and adhesives on presses and other equipment. Gloves made of cotton, latex rubber, and nitrile rubber are used for hand protection while operating and cleaning presses and equipment.

Ventilation Description

Since the fall of 1998, each press has been equipped with blowers to cool UV lamps and exhaust ventilation to control ozone generated by UV lamps. Conditioned make-up air is supplied to the production areas by fan coil units (three each for the line division and the prime division). The warehouse has one wall fan on the south wall exhausting the area where 55-gallon drums of chemicals are stored, and another wall fan on the west wall. Ventilation of the warehouse side of the plant occurs mainly through open loading-dock doors.

The exhaust ducts on the outside of the building had previously terminated on the north wall below the roof line. Concerned that the re-entry of air contaminants into the building from printing press exhaust may be causing or contributing to the eye problems, the company was having the duct work extended above the roofline on the day of the first NIOSH visit. The extensions were configured to curve downward at the end, aiming the discharge toward the surface of the slightly sloped roof.

Measures of Vision

Visual acuity is the most common measure of visual function.[1,2] Visual acuity is measured on the Snellen eye chart, which consists of multiple rows or lines of letters of various sizes. The person reads the smallest letter possible at a distance of 20 feet. If the person cannot read the 20/20 line, then the smallest line that can be read is documented, such as 20/80, which means that the person is able to read at 20 feet what a person with 20/20 vision can read at 80 feet. 20/20 is considered physiologic vision,[3] but the range of normal vision is 20/12.5 to 20/25.[4] The most common cause of diminished visual acuity is refractive error, which is an abnormality in the ability of the eye to focus an image on the retina.

Contrast sensitivity refers to a person's ability to detect a pattern from a homogenous background where there are no sharp borders to demarcate the differences.[1] It is a very sensitive means of detecting eye disease. Contrast sensitivity can be diminished even though visual acuity is normal. Common causes of decreased vision, such as cataracts and glaucoma, reduce contrast sensitivity more than visual acuity.[1,2] Contrast sensitivity can also be decreased in certain toxic exposures. Since there is a wide range of normal at all contrast levels, it is best to compare workers to their own baseline taken pre-exposure.[2] Visual acuity measurement is the equivalent of contrast sensitivity at 100% or full contrast.

The Cornea

The cornea is the clear, transparent tissue that covers the front of the eye. It provides a physical barrier that protects the inside of the eye from harmful matter. It also acts as the eye's outermost lens by refracting (bending) light onto the lens of the eye. The cornea is normally clear. Causes of corneal cloudiness include glaucoma, refractive surgery, and certain inherited diseases such as Fuch's Dystrophy.

Amines

Aliphatic amines are ammonia derivatives in which an alkyl or alkanol group replaces one or more hydrogen atoms. They are classified as primary, secondary, or tertiary amines based on the number of substitutions. They are used as solvents, chemical intermediates, catalysts, preservatives, drugs, and herbicides.[5]

The tertiary amines are irritants to both the skin and mucous membranes. Systemic symptoms related to inhalational exposure to tertiary amines include headache, nausea, and faintness. A number of reports describe blurred vision, halo vision, or blue-grey vision (glaucopsia) among persons exposed to a variety of amines. In all published reports these effects have been reversible. Proposed mechanisms for the visual changes include swelling of the cornea or dilation of the pupil and paralysis of the ciliary muscle.[6] Amines reported to cause these visual disturbances include ethylamine, diethylamine, diisopropylamine, dimethylamine, ethylenediamine, *N*-ethylmorpholine, dimethylaminopropylamine, *N*-methylmorpholine, tert-octylamine, tetramethylbutanediamine, and tetramethylethylenediamine. The most extensively studied amines are triethylamine (TEA) and dimethylethylamine (DMEA).

Exposure to TEA has been reported to cause the above visual changes in both industrial and experimental settings.[7,8,9,10] Åkesson et al. documented pronounced epithelial corneal edema by slit lamp examination and increased corneal thickness in two subjects exposed to concentrations of TEA of 48 milligrams per cubic meter of air (mg/m^3) for four hours.[8] Subjects reported symptoms of foggy vision that started one hour after the onset of exposure, but very minimal discomfort. Similar but less severe findings were noted after exposure to concentrations of TEA of 34 mg/m^3 for four hours. In both cases, subjective and objective findings disappeared within hours. In a different experiment, four persons exposed to TEA at concentrations of 40.6 mg/m^3 for four hours, experienced moderate to severe blurred vision but no eye irritation.[10] Visual acuity decreased by one row and contrast sensitivity at 2.5% decreased by 1-3 rows in three of the four subjects; the fourth had no changes in vision tests. Slit lamp exam demonstrated edema in the corneal epithelial cells.

In another study, symptoms of foggy vision and blue haze were reported by polyurethane foam production workers exposed to TEA at concentrations of 12-13 mg/m^3 as an 8-hour time-weighted average (TWA) with peak concentrations during the sampling period twice that high.[9] Symptoms resolved within hours of leaving work. Visual acuity, slit lamp examination, and pachymetry were normal but were not conducted when workers were symptomatic. It was noted that experimental exposure to similar TWA levels in other studies did not cause similar effects, and that exposure to brief peak concentrations may account for at least some of the effects reported by workers.

A study of industrial exposure to TEA in foundry cold box workers measured airborne concentrations ranging from less than 0.3-20.3 mg/m^3.[7] Symptoms of blurred vision, halo vision, and blue hazy vision were more common in workers with exposure to TEA greater than 10 mg/m^3, but this finding was not statistically significant. Corneal thickness did not increase significantly by the end of the shift, either in exposed workers or in symptomatic workers. In another study, Jarvinen et al. measured contrast sensitivity of foundry cold box core makers with exposure to TEA.[11] Contrast sensitivity decreased significantly over the shift, but this did not correlate with concentrations of TEA in the urine. Airborne concentrations of TEA ranged from 0.3-60 mg/m^3, with very high peak concentrations, suggesting that exposure to high peak concentrations may be responsible for symptoms, or that it may be an "on-off" as opposed to a dose-response phenomena.

Blurred, hazy vision has also been reported with exposure to DMEA.[12,13] Symptoms were reported at DMEA concentrations of 6-10 mg/m^3 as an 8-hour TWA , and 25-29 mg/m^3 over 15 minutes in three workers at an aluminum casting foundry.[13] Workers without symptoms had exposure to concentrations of DMEA over a full-shift of up to 24 mg/m^3, therefore investigators concluded that the visual disturbances were due to short-term exposures to high peak concentrations of DMEA. Corneal edema and increased corneal thickness, along with visual disturbances, were noted at airborne concentrations of DMEA of 40-50 mg/m^3 over 8 hours in human experiments.[12] The same paper reports that in an occupational setting with median 8- hour TWA exposures of 3.5 mg/m^3, 2 of 12 workers experienced visual symptoms and one had corneal edema in one eye. These two worker's exposures were about 25 mg/m^3 as an 8-hour TWA with peak exposures above 100 mg/m^3. The authors concluded that the differences between their findings and reports of visual disturbances at lower concentrations in workplace settings may be due to high peak concentrations in the workplace.

DMAE, which is present in the inks at SLS, is another tertiary amine. No reports were found in the literature of humans experiencing visual disturbances after exposure to DMAE. However, animal experiments did document corneal opacification, corneal edema, and ulcerative keratitis at exposures greater than 288 ppm (861 mg/m^3).[14] Exposure to 24 ppm (71.8 mg/m^3) resulted in corneal opacity that regressed during non-exposure periods.

DMIPA, which is the primary component of the pH adjuster used at SLS, has not been reported to cause visual disturbances in humans.

METHODS

Industrial Hygiene Evaluation

Air Sampling

Following the initial site visit on February 1, 2001, NIOSH investigators made several return visits during the months of February, March, and April to conduct preliminary industrial hygiene air sampling and to evaluate the exhaust ventilation system serving the plant. Material Safety Data Sheets (MSDSs) were gathered and the plant's ink technician was interviewed to learn more about the plant's ink systems. The preliminary industrial hygiene monitoring involved an air sampling strategy designed to screen for potential air contaminants in the line division (complaint area) and the prime division (non-complaint area), and to identify air contaminants unique to these production areas. A total of 20 air samples were collected for about two-hour periods on thermal desorption tubes and later analyzed by gas chromatography-mass spectrometry (GC-MS). The analytical results showed the most abundant compounds were DMIPA, DMAE, ethyl acetate, ammonia, ethanol, and isopropyl alcohol. In addition, the screening results showed much more DMIPA in the line division than in the prime division, with DMAE present in both areas. After reviewing the screening results and MSDS's, DMIPA and DMAE were selected as the chemical agents for which to conduct further monitoring because: (1) they were the most abundant compounds identified during industrial hygiene screening; (2) other amine compounds (e.g., DMEA, diisopropylamine) with similar chemical structures are known to cause visual disturbances (i.e., blurry vision, halo vision) consistent with those reported by SLS workers; and (3) no other chemical agents present in the plant are known to cause such visual disturbances.

The NIOSH Manual of Analytical Methods (NMAM) No. 2007 is commonly used to monitor amine compounds in air. However, the reliability of the NMAM No. 2007 has been questioned in recent years because this method has a history of yielding non-detectable results even when amine compounds are known to be present in a work environment. The NMAM No. 2007 uses a silica gel (300 milligram [mg]/150 mg) sorbent tube and is believed to inhibit recovery of certain amine compounds after collection from air. Before attempting to collect and analyze numerous air samples using silica gel tubes to assess workers' exposures to DMIPA and DMAE, a NIOSH laboratory conducted a "mini" desorption study on several types of sorbent tubes to determine if a suitable sorbent tube could be found for sampling

DMIPA and DMAE. Sorbent tubes that were tested included silica gel, Carbosieve S III, carbon molecular sieve (CMS), XAD-2 resin, and XAD-7 resin. In the desorption study, using methanol as a solvent, DMIPA and DMAE were recovered at the highest rate from XAD-7 tubes, and at the lowest rate from silica gel. Therefore, an air sampling strategy using the XAD-7 tubes was devised for further industrial hygiene monitoring.

For eight workdays (April 23-26 during the second shift and April 30 through May 3, 2001, during the first shift), comprehensive industrial hygiene monitoring was performed to assess workers' full-shift and short-term exposures to DMIPA and DMAE. A total of 108 full-shift personal breathing-zone (PBZ) air samples for the amines were collected, 93 in the line division and 15 in the prime division. In the line division, a total of 30 short-term PBZ air samples were collected for 15-minute periods. No short-term samples were collected in the prime division. Twelve area air samples were collected in the office area of the plant and outdoors. Each air pre-and post- sample was collected on an XAD-7 tube connected to air sampling pumps pre- and post calibrated at 100 cubic centimeters of air per minute (cc/min). In accordance with NMAM No. 2007, each sample collected was analyzed for both DMIPA and DMAE by gas chromatography (GC) equipped with a flame ionization detector (FID). Four quality assurance field blanks and blind spiked samples were submitted along with the samples collected for analyses. A calibrated real-time photo-ionizing (PID) detector instrument (MiniRAE 2000 PID Monitor, RAE Systems, Sunnyvale, California.) was used in the survey mode to evaluate emission sources at printing presses's ink pails, ink trays, and blowers.

Ventilation

A qualitative assessment of the ventilation system was performed during the initial visit on February 8 by releasing a glycol-based aerosol "fog" from the new exhaust discharge location on top of the roof on the north side of the building and from below the roof line, high on the north outside wall of the building, simulating the previous exhaust discharge location. The fog was observed and videotaped.

A tracer gas study was conducted on February 27, to quantitatively determine if exhaust re-entered the plant through air intake grilles located close to the exhaust discharges on the north side of the building. Ten MIRAN-203 infrared specific vapor analyzers, three B&K-1302 photoacoustic infrared multi-gas monitors, and an INOVA-1312 photoacoustic multi-gas monitor were positioned inside the plant. Six instruments (four MIRAN's, a B&K, and the INOVA) were placed at widely separated locations in the line division, one MIRAN was located in the office area, two MIRAN's were placed near the shredder/compactors in the warehouse area, one MIRAN was placed in the Ink area, and two MIRAN's and a B&K were set-up in the prime division. One B&K multi-gas monitor was used for mobile monitoring wherever needed. A low toxicity gas, sulfur hexafluoride (SF_6) was then released first from the opening of one of the curved exhaust discharges on the roof, then from the previous exhaust discharge location on the side of the building.

Tracer gas was also used inside the building to assess the transport and dispersion contaminants in the line division. With the instruments in the same locations as described above, SF_6 was released from a location under one of the supply air inlets in the south center of the room to simulate a re-entry of previously exhausted air.

The concentrations recorded by the instruments were stored in a digital format to be analyzed later, both tabulated on computer spreadsheets and visualized on concentration versus time charts. Starting with the known time of SF_6 release, the visualized concentration charts were inspected for any increases that could be identified as coming from the released SF_6. If peaks were identified, the time between the release of SF_6 and the appearance of the peak was noted, as was the duration and magnitude of the peak.

Medical

All pressmen, rewinders, and assistants in the line division were recruited to take part in the evaluation. Those who were wearing contact lenses at the time of the evaluation were not eligible to participate because of the possibility of absorption of the chemicals into the contacts and because contact lenses can cause changes in the corneal epithelium.[10] Workers were informed of this in advance, so they could discontinue contact lens use in order to participate, if desired. The medical evaluation consisted of a baseline questionnaire to determine whether the worker had blurred or foggy vision, halo vision, or blue-grey vision in the last year; if these symptoms were accompanied by eye irritation; and if they caused difficulty working or driving home. A history of eye disease or injury was obtained as well.

The same baseline questionnaire was administered to workers in the prime division. Workers in the prime division who reported having experienced blurred, halo, or blue-grey vision in the past were asked to participate in the study.

Eye examinations were performed each day from Monday through Thursday at the beginning and end of both shifts. The exam consisted of visual acuity, contrast sensitivity at 2.5% and 1.2% contrast, ultrasonic pachymetry to determine corneal thickness, and a slit lamp examination to determine the presence of corneal opacity. Visual acuity and contrast sensitivity were performed at a distance of 10 feet with a luminance level of 125 candelas per square meter (Precision Vision, LaSalle, Illinois). 10/10 vision is the same as 20/20. The range of normal vision is 20/12.5 (10/6.3) to 20/25 (10/12.5). A loss of at least one line or row on the chart was considered a reduction in visual acuity or contrast sensitivity. Corneal thickness was performed using an ultrasonic pachymeter (Sonomed, Inc. Micropach model 200P) reported in millimeters. Corneal opacity was graded on a scale of 0, 1, 2, and 3, with 0 representing a clear cornea.[10] The slit lamp exams and pachymetry were conducted by a board-certified ophthalmologist. Employees were administered a brief questionnaire at each exam documenting current symptoms. The visual test examiners were unaware of current visual symptoms of employees.

Statistical Analysis

SAS Version 8.1 software (SAS Institute, Cary, North Carolina) was used for the statistical analyses. SAS Proc Mixed, which can take into account the multiple measures for some subjects, was used to compare amine exposure means for those in the line and prime divisions, and for those with and without visual symptoms/signs. A p-value of $\leq$ 0.05 was considered statistically significant. SAS Proc Genmod, which also handles repeated measures for subjects, was used to do logistic regression analyses. Logistic regression was used to examine possible relationships between visual symptoms/signs and the amine exposure levels. The logistic regression analyses generated an odds ratio (OR) as a measure of association. Odds ratios greater than one indicate a positive relationship between a symptom/sign and an amine exposure level. The OR reflects a per unit increase of 1 mg/m^3 in amine concentration. Along with the OR, a 95% confidence interval (CI) for the OR was calculated. The OR is considered statistically significant if the 95% CI does not include the number one.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs),[15] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[16] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[17] Employers are encouraged to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs®, or whichever is 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)]. Thus, employers should understand that not all hazardous chemicals have specific OSHA exposure limits such as PELs and short-term exposure limits (STELs). An employer is still required by OSHA to protect their employees from hazards, even in the absence of a specific OSHA PEL.

A 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.

There are no occupational exposure limits for either DMIPA or DMAE.

RESULTS

Industrial Hygiene Evaluation

Air Sampling

The full-shift PBZ air sampling results are summarized in Table 1. The mean TWA concentration of DMIPA was significantly higher in the line division than in the prime division (7.70 mg/m^3 vs. 2.08 mg/m^3, $p<0.01$), as was the mean TWA concentration for total amines (9.96 mg/m^3 vs. 5.56 mg/m^3, $p<0.01$). The mean TWA concentration of DMAE was higher in the prime division than the line division (3.47 mg/m^3 vs. 2.27 mg/m^3, $p<0.01$). The short-term air sampling results are summarized in Table 2. The 15-minute TWA concentrations ranged from 0-48.7 mg/m^3 (median 9.3 mg/m^3) for DMIPA,, from 0-86.7 mg/m^3 (median 3.7 mg/m^3) for DMAE, and from 0-135.3 mg/m^3 (median 12.0 mg/m^3) for total amines. Total amine TWA concentrations in the office areas ranged from 0.2-1.9 mg/m^3 and were non-detectable outdoors. Compete results for industrial hygiene air sampling data for each day are presented in Appendix A.

Ventilation

From the outside, the smoke-like fog revealed that air flowed into the plant through all doorways. Inside the plant, air flowed into the line division from all surrounding areas. Within the line division, air moved from the southeast corner to the north and east where the label printing equipment local exhaust removed it from the plant.

A small amount of tracer gas (SF_6) was detected inside the building following both outside releases. However, due to the inability to determine a concentration of tracer gas in the outdoor air in the unbounded vicinity of the air intakes, in the presence of variable, wind-driven air currents, a numerically accurate quantification of the amount of contaminant re-entering the building cannot be calculated.

A much greater response of the instruments resulted when tracer gas was released inside the building. An air exchange rate of 1.2 air changes per hour was calculated from the tracer gas decay curve. Based on a floor area for the line division of over 14,000 ft^2 and an average ceiling height of 20 ft, the ventilation rate for the line side is estimated at approximately 6000 cubic feet per minute (CFM).

Medical Evaluation

All line and prime workers who were present at the time of the study filled out the baseline questionnaire, 24 from the prime division and 36 from the line division of the plant. Eighty-nine percent of line workers reported having experienced blurry vision while at work in the past 12 months, compared to 12.5% of prime workers ($p<0.01$). Findings were similar for halo and blue-grey vision, with 72% of line workers reporting halo vision compared to 8% of prime workers ($p<0.01$), and 14% of line workers reporting blue-grey vision compared to 0% of prime workers ($p=0.08$). None of the workers reported medical conditions that would affect their vision. Forty-seven percent of those reporting blurry, halo, or blue-grey vision experienced eye irritation along with the visual changes, 44% reported difficulty performing their job due to the visual changes, and 39% reported difficulty driving home.

Three of the 24 prime workers reported blurry vision while at work and therefore participated in the remainder of the study for at least one day. Twenty-seven of the 36 line workers participated in the remainder of the study for at least one full day. Therefore, 30 workers participated from one to four days each, for a total of 96 observations. Each observation includes both pre- and post-shift eye exams and environmental sampling.

None of the participants had any corneal opacity at the beginning of the shift on any day. Baseline, or beginning of shift, bilateral visual acuity was 10/10 or better, bilateral contrast sensitivity at 2.5% contrast was 10/32 or better, and bilateral contrast sensitivity at 1.25% contrast was 10/50 or better for all participants. During the course of the study, there were 43 episodes of blurred vision reported, 20 episodes of halo vision, and 15 episodes of blue-grey vision. All reports of halo or blue-grey vision occurred in workers who also reported blurry vision, however, the converse is not true. Symptoms developed an average of 4.3 hours after the beginning of the shift. There were 16 episodes of decreased (defined as loss of one row or more) bilateral visual acuity, 22 episodes of decreased bilateral contrast sensitivity at 2.5% contrast, and 35 episodes of decreased bilateral contrast sensitivity at 1.25% contrast. Decrements in bilateral visual acuity ranged from 1 to 2 rows, decrements in bilateral contrast sensitivity at 2.5% contrast ranged from 1 to 8 rows, and at 1.25% ranged from 1 to 6 rows. There were 23 observations of corneal opacity in the left eye (16 were grade 1, 5 were grade 2, and 2 were grade 3) and 24 in the right eye (13 were grade 1, 9 were grade 2, and 2 were grade 3) at the end of the shift. In all instances of corneal opacity, there was complete clearing by the beginning of the worker's next shift.

There was a positive association between reported visual symptoms and PBZ concentrations of total amines. Exposures to higher levels of total amines were associated with increased risk of reporting blurry vision (OR=1.78, 95% CI=1.41, 2.26), halo vision (OR=1.38, 95% CI=1.20, 1.58), and blue-grey vision (OR=1.77, 95% CI= 1.31, 2.39) at the end of a shift. All OR reported in this paper reflect a per unit increase of 1 mg/m^3 in amine concentration. Symptom reporting increased with exposure to increasing concentrations of amines (Table 3). Results were similar when evaluating the relationship between symptom reporting and exposure to the individual amines (DMIPA and DMAE).

The risk of developing corneal opacity over a shift rose with increasing exposure to total amines (OR=1.15, 95% CI= 1.02, 1.30). The prevalence of corneal opacity also increased with exposure to increasing concentrations of total amines (Table 4). Similar results were found when evaluating exposure to DMIPA and DMAE separately.

The prevalence of increased corneal thickness in either eye over a shift increased with higher levels of exposure to total amines, as did both the mean and median changes in thickness (Table 4). There was a positive association between increases in across shift corneal thickness and concentrations of total amines, however it was not statistically significant (OR=1.08, 95% CI=0.95, 1.23). Results were similar when evaluating exposure to DMIPA and DMAE separately, and when looking at each eye individually. Median corneal thickness increased with increasing grades of corneal opacity (Table 5).

There was a statistically significant relationship between total amine concentration and increased risk of reductions in bilateral visual acuity and contrast sensitivity at 2.5% contrast over a shift (OR=1.2, 95% CI=1.001,1.43; OR=1.28, 95% CI=1.14,1.43, respectively). Similar results were found for DMIPA and DMAE separately, but were not statistically significant for DMAE. There was not a significant association between reduced contrast sensitivity at 1.25% contrast and concentrations of total amines, DMAE, or DMIPA. The prevalence of decrements in visual acuity and contrast sensitivity at 2.5% and 1.25% contrast by concentration of total amines is depicted in Table 6.

DISCUSSION

There have been case reports of blurry, halo, and/or blue grey vision in workers exposed to a variety of amines. Experimental exposure to TEA and DMEA produced visual symptoms, increased corneal thickness, corneal edema, and decrements in visual acuity and contrast sensitivity in study subjects.[8,10,12] In contrast, industrial studies have failed to associate these findings with average exposures to DMEA and TEA.[7,9,11,12] It has been postulated that this is because visual findings may be due to high peak exposures to amines as opposed to average exposures.

We documented an association between symptoms of blurry, halo, and blue-grey vision, corneal opacity, decrements in visual acuity and contrast sensitivity at 2.5% contrast and TWA exposure to two tertiary amines, DMAE and DMIPA. Neither DMAE nor DMIPA have previously been reported to cause visual disturbances in humans. Concentrations of DMAE and DMIPA were highly correlated, making it difficult to separate the effects of each amine. In addition, the two compounds are very similar, and it would be expected that they would produce similar health effects. However, DMIPA is the amine most likely to be causing visual changes in this group of workers for several reasons. Visual symptoms were much more common in the line division, where concentrations of DMAE were significantly lower than in the prime division. In contrast, DMIPA concentrations were significantly higher in the line division. Overall, DMIPA was present at levels approximately 3-4 times higher than DMAE. DMIPA is more volatile than DMAE, with a vapor pressure of 14.7 torr compared to 4.0 torr for DMAE.[18] SLS Management reports that they have been diluting the pH adjuster with water since discovering it may be the cause of employees visual disturbances, and that there have been no complaints since taking this action. On August 30, 2001, NIOSH investigators interviewed 27 of the 36 line workers who participated in the study (the other 9 were not at work at the time of the interviews) to confirm the cessation of visual disturbances. All 27 employees reported they had not experienced any visual disturbances since the process of diluting the pH adjuster had been in place, and had not heard any other employees report visual disturbances.

The mechanism of action of these visual disturbances appears to be a direct effect or local deposition of the amines on the epithelial layer of the cornea, producing opacity and thickening of the cornea. Previous studies have noted edema of the corneal epithelium after exposure to certain other tertiary amines without involvement of the endothelial cells of the cornea.[8,10] There was no evidence of endothelial cell disruption in this study either. Other studies have noted that these changes are usually limited to the directly exposed portion of the cornea supporting the hypothesis that there is a direct local effect on the cornea.[8,12] However, one study of experimental exposure to TEA found concentrations of TEA in the lacrimal fluid to be an average of 41 times higher than serum levels and postulated that systemic absorption may be of importance.[10]

Re-entry of air exhausted from the printing machines was not determined to be a problem on the day of the tracer gas testing as the amount of SF_6 re-entering the building was so small as to be barely detectable. However, on that day, the wind blowing from the north would have carried exhausted SF_6 away from the outdoor air intakes and entry points to the building. On the day the aerosol "fog" was used to visualize the movement of air around the exhaust discharges and building air intakes, the wind was out of the south; and, although most of the smoke was carried away from the building, some "fog" was observed circulating into the area of the outdoor air intakes. For this reason, it is expected that re-entry would be more of a problem with prevailing winds from the south, which is typical for this area of the country.

Inside the building, the tracer gas spread quickly throughout the line-side production area when released from a central point in that area. It also dispersed quickly from the sampling locations. For 25 to 30 workers per shift on the line side, the ventilation rate was approximately 200 CFM per person; suggesting an adequate amount of outside air. There are no specific standards for general ventilation in a manufacturing plant such as this other than a guideline minimum of 15 CFM per person of outdoor air. It is, however, essential that the incoming outdoor air does not contain high concentrations of environmental contaminants, including those previously exhausted from the building. If the chemicals containing the tertiary amines cannot be reformulated, the local exhaust ventilation will need to be improved and the exhaust discharges and air intakes will need to be repositioned to prevent or reduce entry of exhausted contaminants back into the building. The open locations in the equipment where the amines are used should be enclosed as much as practicable, and the enclosures should be exhausted by local exhaust ventilation ducted to discharges on the outside of the building as close to the northeast corner of the building as practicable. If more that one discharge duct exits the building, the exhaust discharges should be grouped tightly together to take advantage of the larger effective diameter of the combined jet to achieve greater plume height. The discharge ductwork should extend at least 6 feet above the edge of the roof on the north side of the building and have a diameter such that the exhaust exits the end of each duct at a velocity not less than 2000 feet per minute ft/min and not greater than 3000 ft/min. The outdoor air intakes should be located as far to the west of the exhaust discharge point as practicable.[19]

CONCLUSIONS

Exposure to tertiary amines at SLS has been associated with blurry, halo, and blue-grey vision, corneal opacity, and decrements in visual acuity and contrast sensitivity at 2.5% contrast. While this appears to be a reversible phenomena, the visual changes pose a safety hazard, both on the job and when driving home. Dilution of the pH adjuster, which decreases the concentration of DMIPA and thus employee exposure, has eliminated employee reports of visual disturbances.

The re-entry of exhausted air is a potential problem, and the ventilation in the line division is not adequate under current work practices. Although increasing the general ventilation may provide some reduction in exposure, a more cost-effective solution would be to improve the local exhaust ventilation controlling the sources of tertiary amines associated with the printing machines, and then to also reposition the outdoor air intakes and exhaust dischage locations.

RECOMMENDATIONS

The following recommendations are made in order to reduce employee's exposure to DMIPA, DMAE, and other chemicals present in the work environment.

1. Continue to dilute the pH adjuster. Alternatively, contact the chemical manufacturer to discuss reformulating the pH adjuster.

2. Cover all 5-gallon ink pails and improve local exhaust ventilation at printing presses in order to reduce the amount of chemicals vaporizing into the work environment.

3. Ensure that air intake grilles are upwind of (i.e., to the west of) and at least 25 feet from exhaust discharges.

4. Do not use latex gloves to protect hands from chemical exposures. Instead, workers should be provided with and instructed to wear gloves made of materials that are impermeable to specific chemicals used. Butyl rubber gloves are appropriate for use with the amine compounds,as well as isopropyl alcohol, ammonia, and 2-butoxyethanol.[20]

5. Conduct industrial hygiene monitoring following process changes and when new chemical products (i.e., inks and additives) are introduced.

REFERENCES

1. Zabriske NA, Olson RJ [2000]. Occupational eye disorders. Chapter 50. In: Rom WN, ed. Environmental and Occupational Medicine. 3rd rev. ed. Philadelphia, PA: Lippincott-Raven Publishers, pp. 743-754.

2. Hyvarinen L [1994]. Ophthalmologic disorders. Chapter 12.1. In: Rosenstock L, Cullen M, eds. Textbook of clinical occupational and environmental medicine. Philadelphia, PA:W.R. Saunders Co, pp. 297-305.

3. Fay A, Jakobiec FA [2000]. Diseases of the visual system. Chapter 512. In: Goldman L, Bennett JC, eds. Cecil textbook of medicine. Philadelphia, PA: W.B. Saunders Company, pp. 2224-2235.

4. Colenbrander A. Low vision test chart. In: Precision Vision instruction manual for vision testing products. La Salle, IL:Precision Vision. p. 43.

5. Rosenberg, J, Cone JE, Katz EA [1997]. Solvents. Chapter 29. In: LaDou J, ed. Occupational and environmental medicine. 2nd rev. ed. Stamford, CT: Appleton and Lange, pp. 483-513.

6. Albrecht WN, Stephenson RL [1988]. Health hazards of tertiary amine catalysts. Scand J Work Environ Health. 14:209-219.

7. Reilly MJ, Rosenman KD, Abrams JH, Zhu Z, Tsend C, Hertzberg V, Rice C [1995]. Ocular effects of exposure to triethylamine in the sand core cold box of a foundry. Occup Environ Med. 52(5):337-343.

8. Åkesson B, Florén I, Skerfving S [1985]. Visual disturbances after experimental human exposure to triethylamine. Br J Ind Med. 42:848-50.

9. Åkesson B, Bengtsson M, Florén I [1986]. Visual disturbances after industrial triethylamine exposure. Int Arch Occup Environ Health. 57:297-302.

10. Jarvinen P. Engstrom K, Riihmaki V, Ruusuvaara P, Setala K [1999]. Effects of experimental exposure to triethylamine on vision and the eye. Occup Environ Med. 56(1):1-5.

11. Jarvinen P, Hyvärinen L [1997]. Contrast sensitivity measurement in evaluations of visual symptoms caused by exposure to triethylamine. Occup Environ Med. 54(7):483-486.

12. Stählbom B, Lundh T, Florén I, Åkesson B [1991]. Visual disturbances in man as a result of experimental and occupational exposure to dimethylamine. Br J Ind Med. 48:26-29.

13. NIOSH [1987]. Request for assistance in preventing vision disturbances and acute physical distress due to dimethylethylamine (DMEA) exposure. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 88-103.

14. Klonne DR, Dodd DE, Pritts IM, Nachreiner DJ, Fowler EH, Troup CM.et. al. [1987]. Dimethylethanolamine: acute, 2-week, and 13-week inhalation toxicity studies in rats. Fundam Appl Toxicol. 9:512-521.

15. 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.

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

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

18. Ballantyne B, Leung H [1996]. Acute toxicity and primary irritancy of alkylalkanolamines. Vet Human Toxicol. 38(6):422-426.

19. ASHRAE [1997]. Air Flow Around Buildings. In: Fundamentals, 1997 ASHRAE Handbook.. Atlanta, GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., Chap 15.

20. Forsberg K, Mansdorf SZ [1997]. Quick selction guide to chemical protective clothing, 3rd. rev. edition. New York, NY: John Wiley and Sons, Inc.

Table 1. Full-shift Personal Breathing-zone Concentrations for Amines by Location (in mg/m^3)

	Line (n=93)		Prime (n=15)	
	Mean	Range	Mean	Range
Dimethylaminoethanol (DMAE)*	2.27	0.18-3.39	3.47	1.71-5.16
Dimethylisopropanolamine (DMIPA)*	7.70	0.66-17.08	2.08	0.86-3.31
Total Amines*	9.96	0.84-20.34	5.56	2.71-8.47

**mean amine concentrations differ by location* (*p<0.01*)

Table 2. Fifteen-minute Short-term Personal Breathing-zone Concentrations for Amines (in mg/m^3)

	Line (n=30)	
	Median	Range
Dimethylaminoethanol (DMAE)	3.7	0-86.7
Dimethylisopropanolamine (DMIPA)	9.3	0-48.7
Total Amines	12.0	0-135.3

Table 3. Prevalence of Reported Visual Symptoms by Total Amine Concentrations

Full-shift Total Amine Concentrations	n	Blurry Vision	Halo Vision	Blue-grey Vision
0.84-7.30 mg/m^3	26	3 (12%)	1 (4%)	0 (0%)
7.31-13.80 mg/m^3	57	26 (46%)	11 (19%)	7 (12%)
13.81-20.33 mg/m^3	13	12 (92%)	7 (54%)	8 (62%)

Table 4. Corneal Changes Across Shift by Total Amine Concentration

Full-shift Total Amine Concentrations	n	Presence of Corneal Opacity in Either Eye[#]	Prevalence of Increased Corneal Thickness Either Eye	Mean Change in Corneal Thickness* (standard deviation)	Median Change in Corneal Thickness	Range of Change in Corneal Thickness
0.84-7.30 mg/m^3	26	3 (12%)	17 (65%)	-0.0015 (0.0073)	0.0003	-0.0250 to 0.0055
7.31-13.80 mg/m^3	57	13 (23%)	39 (68%)	0.0004 (0.0060)	0.0010	-0.0155 to 0.0200
13.81-20.33 mg/m^3	13	8 (62%)	12 (92%)	0.0065 (0.0087)	0.0050	-0.0055 to 0.0285

* *in millimeters*
[#] *either grade 1, 2, or 3*

Table 5. Corneal Thickness Changes Across Shift by Corneal Opacity

	Change in Corneal Thickness Left Eye				Change in Corneal Thickness Right Eye			
Corneal Opacity Grade	n	Mean	Median	Range	n	Mean	Median	Range
0	77	-0.0006	0.001	-0.028 to 0.013	76	-0.0005	0.0005	-0.022 to 0.015
1	16	0.003	0.003	-0.008 to 0.017	13	0.004	0.001	-0.004 to 0.017
2	5	0.007	0.010	-0.005 to 0.018	9	0.004	0.005	-0.006 to 0.022
3	2	0.022	0.022	0.018 to 0.026	2	0.021	0.021	0.011 to 0.031

Table 6. Prevalence of Across Shift Decrements in Vision by Total Amine Concentration

Full-shift Total Amine Concentrations	n	Decreased Bilateral Visual Acuity	Decreased Bilateral Contrast Sensitivity at 2.5% Contrast	Decreased Bilateral Contrast Sensitivity at 1.25% Contrast
0.84-7.30 mg/m^3	26	2 (8%)	1 (4%)	9 (35%)
7.31-13.80 mg/m^3	57	7 (12%)	11 (19%)	19 (33%)
13.81-20.33 mg/m^3	13	6 (46%)	8 (62%)	6 (46%)

Appendix A
Air Sampling Results for Amines
Superior Labels System, Inc.
April 23, 2001

Sample Type and Location	Sampling Time (minutes)	Sample Flow Rate (cubic centimeters per minute)	Sample Volume (liters)	Concentration, milligrams per cubic meter (mg/m^3)		
				DMAE	DMIPA	Total Amines
Line Division						
Press Operator #1	547	100	54.7	3.01	11.02	14.03
Press Operator #5	524	100	52.4	2.44	8.59	11.03
Press Operator #9	508	100	50.8	2.32	8.46	10.79
Press Operator #15	504	100	50.4	2.76	8.53	11.29
Press Operator #17	596	100	59.6	2.62	8.05	10.67
Press Operator #19	455	100	45.5	2.84	10.33	13.16
Press Operator #20	516	100	51.6	1.30	4.84	6.14
Press Operator Assistant	578	100	57.8	2.13	7.44	9.57
Press Operator Assistant	533	100	53.3	1.82	6.75	8.57
Rewinder Operator	534	100	53.4	2.19	8.05	10.24
Rewinder Operator	569	100	56.9	2.18	8.08	10.26
Rewinder Operator	575	100	57.5	2.19	8.17	10.37
Rewinder Operator	480	100	48.0	2.00	7.29	9.29
Shift Supervisor	529	100	52.9	1.83	6.99	8.83
Prime Division						
Press Operator #14	575	100	57.5	2.90	1.77	4.68
Rewinder Operator	401	100	40.1	2.37	1.40	3.77
Background Areas						
Office area	470	100	47.0	0.43	1.17	1.60
Outdoors	266	100	26.6	ND	ND	ND
Minimum Detectable Concentration (MDC)*				0.07	0.07	
Minimum Quantifiable Concentration (MQC)*				0.17	0.17	

Abbreviations: DMAE = dimethylaminoethanol   ND = none detected (concentration less than the MDC)
DMIPA = dimethylisopropanolamine   * = assuming a 60 liter sample

Appendix A (continued)
Air Sampling Results for Amines
Superior Labels System, Inc.
April 24, 2001

Sample Type and Location	Sampling Time (minutes)	Sample Flow Rate (cubic centimeters per minute)	Sample Volume (liters)	Concentration, milligrams per cubic meter (mg/m^3)		
				DMAE	DMIPA	Total Amines
Line Division						
Press Operator #1	561	100	56.1	1.88	5.64	7.52
Press Operator #5	582	100	58.2	1.56	3.80	5.36
Press Operator #9	572	100	57.2	2.19	6.82	9.00
Press Operator #15	578	100	57.8	2.66	8.04	10.71
Press Operator #17	567	100	56.7	2.61	7.76	10.37
Press Operator #19	572	100	57.2	2.45	7.69	10.14
Press Operator #20	540	100	54.0	1.55	4.48	6.03
Press Operator Assistant	582	100	58.2	1.82	5.84	7.66
Press Operator Assistant	521	100	52.1	2.09	6.72	8.81
Rewinder Operator	548	100	54.8	1.42	4.45	5.88
Rewinder Operator	567	100	56.7	2.20	7.05	9.26
Rewinder Operator	586	100	58.6	2.15	7.17	9.32
Rewinder Operator	575	100	57.5	1.62	4.70	6.31
Prime Division						
Press Operator #3	565	100	56.5	3.03	2.76	5.79
Press Operator #14	568	100	56.8	5.16	3.31	8.47
Rewinder Operator	550	100	55.0	5.09	2.58	7.67
Minimum Detectable Concentration (MDC)*				0.07	0.07	
Minimum Quantifiable Concentration (MQC)*				0.17	0.17	

Abbreviations:
DMAE = dimethylaminoethanol
DMIPA = dimethylisopropanolamine
* = assuming a 60 liter sample

Appendix A (continued)
Air Sampling Results for Amines
Superior Labels System, Inc.
April 25, 2001

Sample Type and Location	Sampling Time (minutes)	Sample Flow Rate (cubic centimeters per minute)	Sample Volume (liters)	Concentration, milligrams per cubic meter (mg/m^3)		
				DMAE	DMIPA	Total Amines
Line Division						
Press Operator #1	553	100	55.3	3.13	9.95	13.07
Press Operator #5	434	100	43.4	3.20	8.76	11.96
Press Operator #9	552	100	55.2	2.59	8.15	10.74
Press Operator #15	345	100	34.5	3.15	9.19	12.34
Press Operator #17	572	100	57.2	2.83	8.57	11.40
Press Operator #19	573	100	57.3	2.41	7.50	9.91
Press Operator #20	599	100	59.9	2.42	5.68	8.10
Press Operator Assistant	593	100	59.3	3.63	6.75	10.37
Press Operator Assistant	556	100	55.6	2.14	6.47	8.62
Rewinder Operator	623	100	62.3	2.38	7.22	9.60
Rewinder Operator	552	100	55.2	2.50	7.79	10.29
Rewinder Operator	570	100	57.0	2.65	8.07	10.72
Rewinder Operator	424	100	42.4	2.29	6.37	8.66
Rewinder Operator	556	100	55.6	2.59	8.09	10.68
Shift Supervisor	578	100	57.8	2.21	6.75	8.96
Prime Division						
Press Operator #3	536	100	53.6	4.29	3.17	7.46
Press Operator #14	633	100	63.3	4.42	2.23	6.92
Minimum Detectable Concentration (MDC)*				0.07	0.07	
Minimum Quantifiable Concentration (MQC)*				0.17	0.17	

Abbreviations:
DMAE = dimethylaminoethanol
DMIPA = dimethylisopropanolamine
* = assuming a 60 liter sample

Appendix A (continued)
Air Sampling Results for Amines
Superior Labels System, Inc.
April 26, 2001

Sample Type and Location	Sampling Time (minutes)	Sample Flow Rate (cubic centimeters per minute)	Sample Volume (liters)	Concentration, milligrams per cubic meter (mg/m^3)		
				DMAE	DMIPA	Total Amines
Line Division						
Press Operator #1	607	100	60.7	3.30	11.20	14.60
Press Operator #9	599	100	59.9	3.22	10.68	13.91
Press Operator #15	564	100	56.4	3.12	9.57	12.70
Press Operator #17	618	100	61.8	3.40	10.52	13.92
Press Operator #20	610	100	61.0	1.52	4.04	5.56
Press Operator Assistant	601	100	60.1	2.58	8.49	11.06
Press Operator Assistant	637	100	63.7	2.34	8.16	10.50
Rewinder Operator	634	100	63.4	1.88	5.36	7.24
Rewinder Operator	552	100	55.2	2.68	9.60	12.28
Rewinder Operator	581	100	58.1	2.13	7.23	9.36
Rewinder Operator	557	100	55.7	2.68	9.34	12.01
Rewinder Operator	517	100	51.7	2.79	9.86	12.65
Shift Supervisor	614	100	61.4	2.32	7.00	9.25
Prime Division						
Press Operator #3	552	100	55.2	2.36	1.25	4.89
Background Areas						
Office area	559	100	55.9	1.25	0.50	1.25
Minimum Detectable Concentration (MDC)*				0.08	0.07	
Minimum Quantifiable Concentration (MQC)*				0.33	0.17	

Abbreviations:
DMAE = dimethylaminoethanol
DMIPA = dimethylisopropanolamine
* = assuming a 60 liter sample

Appendix A (continued)
Air Sampling Results for Amines
Superior Labels System, Inc.
April 30, 2001

Sample Type and Location	Sampling Time (minutes)	Sample Flow Rate (cubic centimeters per minute)	Sample Volume (liters)	Concentration, milligrams per cubic meter (mg/m^3)		
				DMEA	DMIPA	Total Amines
Line Division						
Press Operator #1	560	100	56.0	3.89	10.54	14.43
Press Operator #5	611	100	61.1	3.01	7.86	10.87
Press Operator #15	316	100	31.6	3.04	8.86	11.90
Press Operator #17	611	100	61.1	3.70	9.98	13.68
Press Operator #19	651	100	65.1	4.50	12.75	17.25
Press Operator Assistant	535	100	53.5	2.43	6.17	8.60
Rewinder Operator	430	100	43.0	2.02	5.35	7.37
Prime Division						
Press Operator #6	579	100	57.9	4.15	1.07	5.22
Press Operator #14	520	100	52.0	3.83	2.90	6.73
Background Areas						
Office area	549	100	54.9	0.36	0.75	1.11
Minimum Detectable Concentration (MDC)*				0.08	0.07	
Minimum Quantifiable Concentration (MQC)*				0.33	0.17	

Abbreviations:
DMIPA = dimethylisopropanolamine
DMAE = dimethylaminoethanol
* = assuming a 60 liter sample

Appendix A (continued)
Air Sampling Results for Amines
Superior Labels System, Inc.
May 1, 2001

Sample Type and Location	Sampling Time (minutes)	Sample Flow Rate (cubic centimeters per minute)	Sample Volume (liters)	Concentration, milligrams per cubic meter (mg/m^3)		
				DMEA	DMIPA	Total Amines
Line Division						
Press Operator #1	526	100	52.6	2.51	8.75	11.25
Press Operator #5	531	100	53.1	2.52	8.66	11.19
Press Operator #7	568	100	56.8	1.85	6.16	8.01
Press Operator #12	522	100	52.2	1.76	6.03	7.80
Press Operator #15	562	100	56.2	2.28	7.83	10.11
Press Operator #17	499	100	49.9	2.81	10.02	12.83
Press Operator #19	591	100	59.1	2.30	7.45	9.75
Press Operator Assistant	586	100	58.6	2.12	6.66	8.77
Press Operator Assistant	577	100	57.7	2.01	6.59	8.60
Rewinder Operator	557	100	55.7	1.96	6.64	8.60
Rewinder Operator	281	100	28.1	2.63	8.08	10.71
Rewinder Operator	500	100	50.0	2.18	7.20	9.38
Shift Supervisor	507	100	50.7	1.16	3.69	4.85
Prime Division						
Press Operator #6	578	100	57.8	3.18	2.23	5.42
Press Operator #14	559	100	55.9	3.45	2.04	4.06
Background Areas						
Office/exam area	500	100	50.0	0.68	0.55	1.44
Minimum Detectable Concentration (MDC)*				0.08	0.07	0.15
Minimum Quantifiable Concentration (MQC)*				0.33	0.17	0.17

Abbreviations:
DMAE = dimethylaminoethanol
DMIPA = dimethylisopropanolamine
* = assuming a 60 liter sample

Appendix A (continued)
Air Sampling Results for Amines
Superior Labels System, Inc.
May 2, 2001

Sample Type and Location	Sampling Time (minutes)	Sample Flow Rate (cubic centimeters per minute)	Sample Volume (liters)	Concentration, milligrams per cubic meter (mg/m^3)		
				DMEA	DMIPA	Total Amines
Line Division						
Press Operator #1	554	100	55.4	2.72	13.85	16.57
Press Operator #5	563	100	56.3	2.72	15.16	18.03
Press Operator #12	477	100	47.7	2.01	10.69	12.70
Press Operator #15	540	100	54.0	2.59	13.33	15.93
Press Operator #17	562	100	56.2	3.26	17.08	20.34
Press Operator #19	461	100	46.1	3.64	14.97	18.61
Press Operator Assistant	573	100	57.3	2.44	11.87	14.31
Press Operator Assistant	571	100	57.1	2.80	13.13	15.94
Rewinder Operator	592	100	59.2	1.99	10.64	12.64
Rewinder Operator	217	100	21.7	2.56	13.10	15.67
Shift Supervisor	510	100	51.0	1.29	6.08	7.37
Prime Division						
Press Operator #6	582	100	58.2	4.12	2.58	6.70
Press Operator #14	563	100	56.3	3.20	2.13	5.33
Background Areas						
Office/exam area	581	100	58.1	0.40	1.33	1.72
Outdoors	578	100	57.8	ND	ND	ND
Minimum Detectable Concentration (MDC)*				0.07	0.05	
Minimum Quantifiable Concentration (MQC)*				0.17	0.17	

Abbreviations:
DMIPA = dimethylisopropanolamine
DMAE = dimethylaminoethanol
ND = none detected (concentration less than the MDC)
* = assuming a 60 liter sample

Appendix A (continued)
Air Sampling Results for Amines
Superior Labels System, Inc.
May 3, 2001

Sample Type and Location	Sampling Time (minutes)	Sample Flow Rate (cubic centimeters per minute)	Sample Volume (liters)	Concentration, milligrams per cubic meter (mg/m^3)		
				DMEA	DMIPA	Total Amines
Line Division						
Press Operator #12	507	100	50.7	0.51	1.83	2.35
Press Operator #15	515	100	51.5	0.93	3.73	4.66
Press Operator #17	318	100	31.8	0.18	0.66	0.84
Press Operator #19	545	100	54.5	0.97	3.28	4.26
Press Operator Assistant	357	100	35.7	1.48	3.92	5.41
Press Operator Assistant	416	100	41.6	1.18	3.56	4.74
Rewinder Operator	570	100	57.0	0.74	2.60	3.33
Rewinder Operator	486	100	48.6	0.78	2.90	3.68
Shift Supervisor	502	100	50.2	0.56	1.73	2.29
Shift Supervisor	548	100	54.8	0.82	2.92	3.74
Prime Division						
Press Operator #6	547	100	54.7	2.01	0.86	2.87
Press Operator #14	509	100	50.9	1.71	1.00	2.71
Background Areas						
Office/exam area	516	100	51.6	0.16	0.64	0.79
Outdoors	561	100	56.1	ND	ND	ND
Minimum Detectable Concentration (MDC)*				0.07	0.05	
Minimum Quantifiable Concentration (MQC)*				0.17	0.17	

Abbreviations:
DMIPA = dimethylisopropanolamine
DMAE = dimethylaminoethanol
ND = none detected (concentration less than the MDC)
* = assuming a 60 liter sample

To receive NIOSH documents or information about occupational safety and health topics contact NIOSH at:

1–800–35–NIOSH (356–4674)
Fax: 1-513-533-8573
E-mail: pubstaff@cdc.gov
or visit the NIOSH web site at:
www.cdc.gov/niosh