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JAMES RIVER CORPORATION,
PACKAGING BUSINESS
GREENSBURG, INDIANA**

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SUMMARY

In February 1993, representatives of the James River Corporation and the Graphic Communications International Union jointly requested the National Institute for Occupational Safety and Health (NIOSH) to conduct a health hazard evaluation (HHE) of four specific operations at the company's Packaging Business facility in Greensburg, Indiana. This facility manufactures polyethylene plastic films, prints labels onto plastic films, and manufactures bags from plastic films, for use in packaging. The four specified operations are: polyethylene-film extrusion; extruder-die cleaning; bag-making; and, the making of "K-6 mat boards" in the Printing Department pre-press area. Synthetic materials are heated in each of these operations, and the requesting parties related concerns about potential health hazards to employees exposed to possible decomposition products, from pyrolysis of the materials, that might be released into the workroom air. To address these concerns, NIOSH investigators conducted an initial environmental survey on May 28, 1993, and follow-up environmental surveys on February 23 and 24 and April 5, 1994.

Qualitative air monitoring was conducted, and bulk material samples were collected and analyzed. Numerous aldehydes, alcohols, and other organic compounds were qualitatively detected. Samples for *quantitative* analyses of 24 different airborne contaminants (which measure the contaminants' concentration levels in the air) were collected and analyzed using nine different methods (many of which were used to measure more than one substance). These 24 analytes were selected after an assessment of process materials and their possible decomposition and/or pyrolysis products to select the most prominent and hazardous air contaminants likely to be present during the four relevant operations. This assessment was based upon a review of material-safety data sheets, air- and bulk-sampling qualitative analytical results, and other relevant sources of information. A total of 175 quantitative samples were collected and analyzed.

Full-shift exposures to carbon monoxide measured in the Bag Department ranged up to 7.7 parts per million (ppm) — 31% of the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Value (TLV) of 25 ppm for an 8-hour time-weighted average (TWA) exposure. Also, "spot" concentrations of up to 15 ppm were measured in some parts of this Department, exceeding the measured personal, full-shift exposures, but no data were collected suggesting full-shift personal exposures to concentrations in this range. These results suggest that hazardous CO concentrations are not likely to occur in this Department under the operating and ventilation conditions that were present during the first follow-up survey. Quantifiable concentrations of formaldehyde, ranging from 0.021 to 0.061 ppm, were measured in the Bag Department and the Printing Department pre-press area; these levels are well below the numerical evaluation criteria (i.e., the ACGIH ceiling TLV of 0.3 ppm and the Occupational Safety and Health Administration's Permissible Exposure Limits of 0.75 ppm for an 8-hr TWA exposure and 2 ppm for a short-term exposure). However, NIOSH recommends treating formaldehyde as a potential occupational carcinogen, and reducing exposures to the lowest feasible concentration, while ACGIH has designated this compound a suspected human carcinogen and therefore recommends that "worker exposure by all routes should be carefully controlled to levels as low as possible below the TLV." Trace concentrations of formaldehyde are common in ambient outdoor air, especially in urbanized areas, and reducing workplace exposure concentrations that are not greatly

elevated above the outdoor background concentration may not always be feasible. No other substances in these two areas, and no substances in the Extrusion Department or the Maintenance Department die shop, were measured in the air in concentrations above or approaching their respective evaluation criteria.

The results of qualitative air sampling indicate the presence of a variety of substances in the departments studied. However, quantitative measurements indicate that the airborne concentration levels of these substances are below those believed to pose hazards to human health. (The special case of formaldehyde may be an exception to this statement; see text). Recommendations include the following: (1) If ventilation or operational changes are made in the Bag Department, exposures to carbon monoxide in this Department air should be monitored to ensure continued compliance with the relevant evaluation criteria. (2) Formaldehyde concentrations in the Bag Department and the Printing Department pre-press area should be monitored again and compared with the outdoor ambient concentration to help determine if lower levels are feasible.

Keywords: SIC 3081 (Manufacturing of Unsupported Plastics Film and Sheet); ammonia; carbon monoxide; ethyl alcohol; formaldehyde; nitric oxide; n-propyl alcohol; n-propyl acetate.

INTRODUCTION AND BACKGROUND

On February 8, 1993, representatives of the James River Corporation and the Greensburg, Indiana, local chapter of the Graphic Communications International Union (GCIU) jointly requested the National Institute for Occupational Safety and Health (NIOSH) to conduct a health hazard evaluation (HHE) at the company's Packaging Business facility in Greensburg. This facility manufactures polyethylene plastic films, prints labels onto plastic films, and manufactures bags from plastic films, for use in packaging. Company and union representatives expressed concern about potential health hazards to employees from exposures to airborne chemical substances that are released during specific operations at the facility. Reportedly of particular concern were possible contaminants resulting from the decomposition and/or pyrolysis of process materials, due to high temperatures employed in these operations. The operations, substances, and reported concerns are the following:

- (1) Some employees in the Extrusion Department reportedly experience nausea during polyethylene-film extrusion (particularly during film "break-off" and "re-threading") when the film being produced includes as additives NAUGARD® BHT, "white concentrate," or nylon resin. (Subsequently, union representatives also expressed similar concerns about the extrusion of thick-gauge films in general, "white opaque" films, and "clear-choice" films [which are combinations of white and clear].) Metal dies used in the film-extrusion process are maintained at high temperatures.
- (2) Reportedly, an offensive smoke is generated during the cleaning of hot, metal extruder dies in the Maintenance Department die shop. Maintenance operators clean residues of plastic-film ingredients and possible decomposition products out of die assemblies, often using "E-Finishing Buffing Composition" to perform this job.
- (3) In the plate/proofing portion of the Printing Department pre-press area, occasional employee complaints of headache and nausea reportedly result from the high-temperature curing, sometimes called "Vulcanization," of "K-6 Mat Boards" into hardened molds for the plate-making process.

Additionally, on February 18, 1993, the Director of Safety and Health at the GCIU headquarters in Washington requested that the HHE address similar concerns about the following operation:

- (4) Bag Department operations, primarily the heat-sealing of plastic films in the manufacture of plastic bags, reportedly result in the formation, and evolution into the workroom air, of acrolein and/or "other by-products."

NIOSH investigators conducted an initial environmental survey on May 28, 1993, and follow-up environmental surveys on February 22 through 24 and April 5, 1994.

Facility and Operations

This facility is a moderately large (a few hundred feet on each side), roughly rectangular complex of connected buildings. Most of the facility consists of single-level, "high-bay" areas (perhaps 30 feet [ft]

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high), although some areas are lower and others have two levels. The facility operates 24 hours (hr) per day using a variety of shift schedules that generally differ between departments.

Extrusion. Polyethylene and other ingredients are together extruded — forced under high pressure through a hot, metal die — in a continuous stream, and the resulting plastic film proceeds continuously through an array of rollers to a cutter and onto large rollers or spools. Occasionally, due to operational requirements or film breakage, an extruder is stopped and the operators must "take down" the film, then "re-thread" it to restart the process. During these tasks, operators are in closer proximity to the extruder — the point of emission of airborne contaminants — than at other times. Local exhaust ventilation is not used in the vicinity of the extruders because excessive air circulation will affect the air temperature around the emerging plastic films, adversely affecting their quality. Some extruders are actually located inside of an enclosure the size of a small room to minimize temperature variations. Over 10 employees work in the Extrusion Department during each of two 12-hr shifts.

Extruder–die cleaning. Residues from the ingredients of the plastic films build up in the extruder assemblies over time, and periodically the assemblies are removed and taken to the Maintenance Department die shop for cleaning. To facilitate removal of the residues, these assemblies are heated. When a heated assembly is first opened, a visible, acrid smoke is released into the workroom air; this is referred to as the "initial burn-off" phase. Maintenance operators use hand tools to scrape the residues from the metal parts; they also use a special cleaning product called "E-Finishing Buffing Composition," which, according to its material safety data sheet (MSDS), contains abrasive powder mixed with various greases. A forklift truck, powered by a liquified petroleum gas–fueled (LPG–fueled) engine, is used in this operation to lift large parts of the die assembly off of lower parts. This engine type emits carbon monoxide (CO) and other contaminants in its exhaust stream. Local exhaust ventilation is not available for this operation. Approximately four employees work in the Maintenance Department die shop.

Printing–plate–mold making. Mat boards, which are resin-coated matrix boards, are cured in five mold-making machines at elevated temperatures, and thereby are hardened. Once hardened, the molds can be used to make rubber printing plates, which are affixed to the rollers of printing presses and used to print labels onto plastic films used in packaging. The "K-6 Mat Boards," which are primarily composed of phenolic resin and paper, are cured in one particular mold-making machine. One plate maker operates this machine. All four machines are equipped with local exhaust ventilation, but contaminants are emitted into the workroom air when the cured K-6 Mat Boards are removed from the machine by the plate maker. Approximately 13 employees work in the Printing Department pre-press area.

Bag making. Plastic films are heat-sealed on 58 automated bag machines to make plastic bags for packaging. This process creates air contaminants, including a visible smoke, during normal operation. During the initial NIOSH survey, only a few of the bag machines were equipped with local exhaust ventilation. In early 1994, between the initial survey and the first follow-up visit, the remaining machines were equipped with local-exhaust enclosures constructed of transparent plastic plates fastened together. These new local exhaust systems, similar to those observed during the initial survey, were operational during the follow-up surveys, and workers reported that conditions in the department were improved since their installation. The Bag Department is located in a large (approximately 200 ft x100 ft) high-bay room and employs approximately 54 people during each of three 8-hr shifts.

EVALUATION METHODS

Initial environmental survey (May 28, 1993). NIOSH investigators performed the following activities:

1. Visual inspection and evaluation of the facility and the four relevant departments and operations (extrusion, extruder-die cleaning, printing-plate-mold making, and bag making), and a review of relevant MSDSs;
2. Collection of general-area (GA) workroom air samples for subsequent "qualitative" chemical analyses (which identify many of the chemical compounds that are present, but do not indicate their concentrations in the air);
3. Collection of "bulk-material" samples of relevant solid or liquid materials, such as the K-6 Mat Board, for subsequent, qualitative chemical analyses for organic compounds (to characterize the compositions of these materials themselves, and of their decomposition and/or pyrolysis products when heated to reported process temperatures).

GA air samples were collected near the extrusion and printing-plate mold-making operations. Each of these samples was qualitatively analyzed for either general volatile organic compounds (VOCs) or for aldehydes, based upon an assessment of the air contaminants likely to result, considering the preliminary information received with the original HHE request about these processes and the substances used in them. Two samples for VOCs and one for aldehydes were collected in the plate/proofing portion of the Printing Department pre-press area, while five for VOCs and four for aldehydes were collected in the Extrusion Department. In general, these air samples were collected using portable, battery-powered air-sampling pumps to draw air at measured rates through suitable collecting media, with the latter then submitted for subsequent analyses; specific details about each sampling and analytical method used are summarized in Table 1. (The air samples for VOCs were collected and qualitatively analyzed using the "thermal-desorption" method summarized in this Table.) No air samples were collected in the Maintenance Department die shop since no extruder dies were cleaned on the day of the survey. Information about the Bag Department operations was not received with the original HHE request, so air sampling was not conducted in that Department during the initial survey.

A bulk-material sample of each of the following four materials were collected and submitted for subsequent qualitative analyses: K-6 Mat Board (before curing); K-6 Mat Board (after curing); E-Finishing Buffing Composition; and, residue found inside a Bag Department ventilation enclosure. A portion of each bulk sample was heated to the appropriate process temperature, and the effluent gas mixture was then qualitatively analyzed for general organic compounds using a method similar to the analytical portion of the "thermal-desorption" method for air samples summarized in Table 1. Additionally, a portion of the bulk sample of E-Finishing Buffing Composition was extracted with carbon disulfide, and the extract then was qualitatively analyzed for organic compounds using a method similar to the analytical portion of the "organics/qualitative/CT" method for air samples summarized in Table 1, but excluding the "GC-FID screening" step.

Follow-up environmental surveys (February 23 and 24, and April 5, 1994). The follow-up environmental surveys were conducted to characterize *levels of worker exposure* to airborne chemical contaminants known or suspected to be present in the four work areas previously discussed. To

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accomplish this, both personal-breathing-zone (PBZ) and GA air sampling, for qualitative and quantitative chemical analyses, was conducted. During the February 23 and 24, 1994, follow-up survey, monitoring of worker exposures to airborne contaminants during the "initial burn-off" phase of an extruder-die cleaning operation was not possible due to scheduling requirements, so the second follow-up survey was conducted on April 5, 1994, solely to perform this monitoring.

For reasons similar to those explained for the initial-survey sampling, air samples for *qualitative* analyses were collected, predominately in the Bag Department and in the Maintenance Department die shop during the "initial burn-off" phase of an extruder-die cleaning operation, where air sampling was not conducted during the initial survey. A total of 15 qualitative air samples were collected during the follow-up surveys and subsequently analyzed — 14 for general VOCs (8 with the "thermal-desorption" method and 6 with the "qualitative/CT" method; see Table 1), and 1 for aldehydes.

Samples for *quantitative* analyses of 24 different airborne contaminants (to measure the contaminants' concentrations in the air) were collected and analyzed using 11 different methods (many of which were used to measure more than one substance). These 24 analytes were selected after an assessment of the most prominent and hazardous air contaminants likely to be present during the four relevant operations, considering the constituents of the materials that are used in the areas and the likely decomposition and/or pyrolysis products of these materials. This assessment was based upon a review of MSDSs, air- and bulk-sampling qualitative analytical results, and other relevant sources of information. A total of 175 quantitative samples were collected and analyzed.

Most of these air samples were collected using battery-powered air-sampling pumps and suitable collecting media, with the latter submitted for subsequent analyses, as described for the air samples collected during the initial survey. However, some of the methods used during the follow-up surveys rely upon different collection methods (such as passive, diffusional collection, or the use of a hand-powered air pump to draw an air sample of measured total volume) and/or a different analytical approach (i.e., some of the methods provide direct indication of analyte concentration, without the need for subsequent laboratory analysis). Specific details about each sampling and analytical method used are summarized in Table 1, including method-specific information indicating the collection method and analytical approach for each method that utilizes one of the different types mentioned.

Each PBZ air sample was collected by attaching a portable air-sampling assembly to a worker's clothing, with the air inlet positioned on or near the collar so as to be within the breathing zone. Each GA air sample was collected by placing a sampler in a stationary location in the workroom.

Many of the samples were collected for long durations to approximate the time-weighted average (TWA) exposure levels during an entire work shift; others were collected for short periods of time during and immediately following specific, short operations, such as mat-board curing, or film take-down and re-thread at an extruder, to assess the exposures during those operations only.

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);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 In July 1992, the 11th U.S. Circuit Court of Appeals vacated the 1989 OSHA PEL Air Contaminants Standard. OSHA is currently enforcing the 1971 standards which are listed as transitional values in the current Code of Federal Regulations; however, some states operating their own OSHA approved job safety and health programs continue to enforce the 1989 limits. NIOSH encourages employers to follow the 1989 OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion. The OSHA PELs reflect the feasibility of controlling exposures in various industries where the agents are used, whereas NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required to meet those levels specified by an OSHA standard and that the OSHA PELs included in this report reflect the 1971 values.

A TWA exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limits (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short term.

NIOSH RELs, OSHA PELs, and ACGIH TLVs relevant to this evaluation are provided in Table 2. In addition, the following information explains the bases for the evaluation criteria for several of the air contaminants that were detected at quantifiable levels during this evaluation.

Ammonia

Ammonia is a severe irritant of the eyes, respiratory tract, and skin. It may cause coughing, burning, and tearing of the eyes; runny nose; chest pain; cessation of respiration; and death. Symptoms may be delayed in onset. Exposure of the eyes to high gas concentrations may produce temporary blindness and

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severe eye damage. Exposure of the skin to high concentrations of the gas may cause burning and blistering. Repeated exposure to ammonia gas may cause chronic irritation of the eyes and upper respiratory tract.^{4,5} The NIOSH REL for airborne ammonia is 25 parts per million parts of air (ppm) for a 10-hour TWA. The NIOSH STEL for ammonia is 35 ppm. ACGIH recommends a limit of 25 ppm for an 8-hour TWA, and a STEL of 35 ppm. The OSHA PEL for ammonia is 50 ppm for an 8-hour TWA.

Carbon Monoxide

Carbon monoxide (CO) is a colorless, odorless, tasteless gas which can be a product of the incomplete combustion of organic compounds. CO combines with hemoglobin and interferes with the oxygen carrying capacity of blood. Symptoms include headache, drowsiness, dizziness, nausea, vomiting, collapse, myocardial ischemia, and death.⁴ The NIOSH REL for CO in workroom air is 35 ppm for an 8-hour TWA. NIOSH also recommends a ceiling limit of 200 ppm which should not be exceeded at any time during the workday. The OSHA PEL for CO is 50 ppm for an 8-hour TWA. The ACGIH TLV for CO is 25 ppm as an 8-hour TWA.

Ethyl alcohol

Upon inhalation, absorbed ethyl alcohol, or ethanol, vapor causes slight symptoms of poisoning when air concentrations are about 1000 ppm, and strong stupor and morbid sleeplessness at 5000 ppm. According to ACGIH, "The inhalation of alcohol vapor causes local irritating effects on the eyes, headaches, sensation of heat, intraocular vision, stupor, fatigue, and a great need for sleep."⁹ Ethyl alcohol, even in low concentrations in the air, is irritating to the eyes and upper respiratory tract, and this feature "is more important in setting the limits for exposure than the secondary toxic effects from the absorbed alcohol." The NIOSH REL, OSHA PEL, and ACGIH TLV are all 1000 ppm for an 8-hour TWA exposure.^{1,2,3}

Formaldehyde

Formaldehyde is a colorless gas with a strong odor. Exposure can occur through inhalation and skin absorption. The acute effects associated with airborne formaldehyde exposure are irritation of the eyes and respiratory tract and sensitization of the skin. The first acute symptoms associated with formaldehyde exposure, at concentrations ranging from 0.1 to 5 ppm, are burning of the eyes, tearing, and general irritation of the upper respiratory tract. There is variation among individuals, in terms of their tolerance and susceptibility to acute exposures of the compound.⁶

In two separate studies, formaldehyde has induced a rare form of nasal cancer in rodents. Formaldehyde exposure has been identified as a possible causative factor in cancer of the upper respiratory tract in a proportionate mortality study of workers in the garment industry.⁷ NIOSH recommends treating formaldehyde as a potential occupational carcinogen, and reducing exposures to the lowest feasible concentration. The OSHA PEL is 0.75 ppm for an 8-hour TWA and 2 ppm for a STEL.⁸ ACGIH has designated formaldehyde a suspected human carcinogen and therefore recommends that "worker exposure by all routes should be carefully controlled to levels as low as possible below the TLV," which is a ceiling limit of 0.3 ppm.²

Nitric oxide

Animal studies indicate that nitric oxide (NO) has an affinity for ferrous hemoglobin, which normally transports oxygen in the blood; the two substances react to form nitrosyl hemoglobin, a compound that is incapable of oxygen transport. This toxic action resembles that of carbon monoxide. However, no effects have been reported from human exposure to NO alone. ACGIH indicates that its basis for a TLV is the relative toxicity in animal studies of NO to that of nitrogen dioxide.⁹ The NIOSH REL, OSHA PEL, and ACGIH TLV are all 25 ppm for an 8-hour TWA exposure.^{1,2,3}

n-Propyl Acetate

According to ACGIH, "There are few data upon which to base a TLV for n-propyl acetate. From the acute animal inhalation studies, n-propyl acetate appears to be more toxic than isopropyl acetate or ethyl acetate, but less toxic than n-butyl acetate."⁹ At high concentrations, animal studies show narcotic effects; salivation and eye irritation were also noted. The NIOSH REL, OSHA PEL, and ACGIH TLV are all 200 ppm for an 8-hour TWA exposure. NIOSH and ACGIH also recommend STELs of 250 ppm.^{1,2,3}

n-Propyl Alcohol

Vapors of n-propyl alcohol, or n-propanol, are irritating to the eyes and upper respiratory tract. Ingestion of the liquid has reportedly led to one fatality. In animal studies, narcotic effects have been noted. In two small chronic animal studies, increased rates of malignant tumors were reported in rats directly injected with n-propanol, compared with control groups.⁹ The NIOSH REL, OSHA PEL, and ACGIH TLV are all 200 ppm for an 8-hour TWA exposure. NIOSH and ACGIH also recommend STELs of 250 ppm, and add the "skin" designation to their criteria to indicate the possibility of sufficient absorption through the skin, upon direct contact, to induce systemic effects.^{1,2,3}

RESULTS AND DISCUSSION

Results for the *qualitative* analyses of the air and bulk samples collected during this evaluation are summarized in Table 3. The results of all qualitative air samples collected in a given department, during any of the surveys, are combined in this Table; each compound detected in *any* air sample from the given department is denoted (by the symbol "XX") in the Table. Similarly, the results of the bulk-material-sample qualitative analyses are combined in this Table.

The qualitative results were used to help determine an effective quantitative sampling and analytical strategy. The remaining discussion focusses on the results of the air samples analyzed quantitatively. In general, the quantitative analytical methods are less sensitive than the qualitative ones, so, in the following discussion, some substances are reported as "not detected" even though the qualitative methods may have detected traces of the same substances in the same areas. Throughout the following discussion, the concentrations of many of the substances are reported as "less than the minimum detectable concentration" for the method used and the sample involved. In all cases except a few involving the results of formaldehyde analyses, the minimum detectable concentrations are below — usually well

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below — the relevant evaluation criteria provided in Table 2. (The few exceptions to this statement, regarding certain formaldehyde results, are explained at the appropriate locations in the following discussion.)

Bag Department

The results of full-shift air samples analyzed for a group of seven specific organic compounds are provided in Table 4. As noted in the Table, perchloroethylene, 1,2-dichloroethylene, hexane, and xylenes were not detected. Toluene, n-propyl acetate, and 1,1,1-trichloroethane were detected in "trace" concentrations, far below all relevant evaluation criteria (see Table 2 and the previous section of this report). The results of full-shift air samples analyzed for a group of four specific alcohols are provided in Table 5. As noted in the Table, isopropanol was not detected. Although n-propanol (1.6 to 11 ppm), ethanol (in "trace" concentrations), and 1-methoxy-2-propanol (in "trace" concentrations) were detected, the concentrations of each were well below all relevant evaluation criteria.

The results of full-shift breathing-zone diffusion-tube air samples for CO are provided in Table 6; exposure concentrations in this department ranged from 1.4 ppm to 7.7 ppm. The latter exposure is 31% of the ACGIH TLV of 25 ppm for an 8-hour TWA exposure. The results of "spot test" general-area detector-tube samples for CO are provided in Table 7; concentrations ranged from less than the minimum detectable concentration to 15 ppm, suggesting that "spot" concentrations in some parts of the Department exceed the personal, full-shift exposures. If these "spot-test" samples represented personal exposures for full shifts, the latter concentration would be 60% of the 25 ppm 8-hour-TWA TLV; however, no data were collected suggesting full-shift personal exposures to concentrations in this range.

Full-shift breathing-zone samples were collected in this department and analyzed for four aldehydes: acrolein, acetaldehyde, formaldehyde, and propanal. None were detected; the minimum detectable concentrations are, respectively, 0.05 ppm or less, 0.06 ppm or less, 0.3 ppm or less, and 0.1 ppm or less, which (except in the case of formaldehyde, discussed below) are all well below the relevant evaluation criteria. (*The minimum detectable concentration for a given substance may differ from sample to sample in the same set because it is partly dependent upon the total volume of air sampled, which may vary among the samples.*) These samples were collected "side-by-side" (i.e., at the same locations and during the same time periods) with the full-shift CO samples summarized in Table 6. Separate long-term general-area air samples for formaldehyde only were also collected; the results are provided in Table 8. Concentrations ranged from 0.021 to 0.061 ppm, which is consistent with the breathing-zone sampling results (for which all results were below the minimum detectable concentrations of 0.3 ppm or less). These concentrations are below the *numerical* evaluation criteria (e.g., the 0.75-ppm OSHA TWA-PEL and the 0.3-ppm ACGIH ceiling TLV). However, NIOSH recommends treating formaldehyde as a potential occupational carcinogen, and reducing exposures to the lowest feasible concentration, while ACGIH has designated this compound a suspected human carcinogen and therefore recommends that "worker exposure by all routes should be carefully controlled to levels as low as possible below the TLV."

Extrusion Department

The results of full-shift air samples analyzed for a *different* group of seven specific organic compounds and mixtures are provided in Table 9. As noted in the Table, toluene, n-propyl acetate, perchloroethylene, 1,2-dichloroethylene, hexane, and ethyl acetate were not detected. Aliphatic

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hydrocarbons (approximately C₁₀ to C₁₂) were detected in "trace" concentrations, well below all relevant evaluation criteria. The results of full-shift air samples analyzed for a group of four specific alcohols are provided in Table 5. As noted in the Table, isopropanol, ethanol, and 1-methoxy-2-propanol were not detected. n-Propanol was detected, in concentrations ranging from "trace" levels up to 3.3 ppm; however, these levels are well below all relevant evaluation criteria.

The results of full-shift diffusion-tube air samples for carbon monoxide are provided in Table 6; concentrations ranged from "trace" levels up to 8.6 ppm. These concentrations are below all relevant criteria.

Full-shift samples were collected and analyzed for four aldehydes: acrolein, acetaldehyde, formaldehyde, and propanal. None were detected; the minimum detectable concentrations were, respectively, 0.02 ppm or less, 0.03 ppm or less, 0.1 ppm or less, and 0.06 ppm or less, which are all below the relevant evaluation criteria. These samples were collected "side-by-side" with most of the full-shift CO samples summarized in Table 6.

Short-term general-area samples (17 minutes in duration on February 23, 1994, and 10 minutes on February 24) were collected at the film take-down and re-thread operation, and analyzed for the same organic compounds, alcohols, and aldehydes as the long term samples collected in this department. None were detected, except for a "trace" concentration of n-propanol on the first day (indicating that the concentration of this compound was between the minimum detectable and minimum quantifiable concentrations for this sample of 1 and 4.0 ppm, respectively, which is well below the relevant evaluation criteria). A "spot check" general-area detector-tube sample for CO was also collected during each of these sampling periods, and none was detected.

Printing Department pre-press area

The results of full-shift air samples analyzed for a group of seven specific organic compounds and mixtures are provided in Table 9. As noted in the Table, toluene, perchloroethylene, 1,2-dichloroethylene, hexane, and ethyl acetate were not detected. Aliphatic hydrocarbons (approximately C₁₀ to C₁₂) were detected in "trace" concentrations, and n-propyl acetate was detected at concentrations ranging from 2.7 to 6.9 ppm; these levels are well below all relevant evaluation criteria. The results of full-shift air samples analyzed for a group of four specific alcohols are provided in Table 5. Isopropanol, and 1-methoxy-2-propanol were not detected. However, n-propanol was detected, in concentrations ranging from 14 to 28 ppm, as was ethanol, in concentrations ranging from 2.7 to 4.9 ppm. These levels are below all relevant evaluation criteria. Measured full-shift concentrations of n-propyl acetate, n-propanol, and ethanol were greater in this department than elsewhere in the facility, yet the highest levels measured were, respectively, just 3.5%, 14%, and 0.49% of the relevant 8-hour TWA criteria.

The results of full-shift air samples for ammonia are provided in Table 10; concentrations ranged from 1.4 to 2.2 ppm. These concentrations are below all relevant evaluation criteria.

Full-shift samples were collected and analyzed for four aldehydes: acrolein, acetaldehyde, formaldehyde, and propanal. None were detected; the minimum detectable concentrations were, respectively, 0.02 ppm or less, 0.02 ppm or less, 0.09 ppm or less, and 0.05 ppm or less, which are all below the relevant evaluation criteria. These samples were collected "side-by-side" with

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organic-compounds samples CT-37, CT-36, CT-76, and CT-74 (summarized in Table 9), and ammonia sample NH3-12 (summarized in Table 10).

Short-term, general-area samples were collected during and after the "K-6 Mat Board" curing process for 44 minutes on February 23, 1994, and for 34 minutes on February 24, for the same seven organic compounds, four alcohols, and four aldehydes as the full-shift samples collected in this department. Similar samples were collected for methylene chloride, two phthalate compounds, and formaldehyde alone (first day only). Two "spot check" general-area detector-tube samples each for nitrogen dioxide (NO₂), and for the total of NO₂ and nitric oxide (NO), were also collected during each of these sampling periods; considered together, results of these samples were used to estimate the concentration of NO alone. The sampling period on each day included two mat-board curing-and-removal cycles.

Analyses of the short-term samples detected the following substances at the air concentrations listed:

1. n-propanol, 22 ppm (first day) and 20 ppm (second day);
2. ethanol, 3.6 ppm (first day) and 4.1 ppm (second day);
3. n-propyl acetate, 3.8 ppm (first day) and 3.1 ppm (second day);
4. aliphatic hydrocarbons (C₁₀₋₁₂), "trace" concentration (first day only);
5. formaldehyde (alone), 0.029 ppm;
6. nitric oxide, 0.5 and 0.4 ppm (first day), 0.5 and 0.5 ppm (second day);
7. nitrogen dioxide, "trace" concentration for the second sample on the first day and both samples on the second day.

These concentrations were below all relevant evaluation criteria. In the case of formaldehyde, the measured concentration was below the *numerical* evaluation criteria, but NIOSH recommends treating formaldehyde as a potential occupational carcinogen, and reducing exposures to the lowest feasible concentration; ACGIH similarly recommends that formaldehyde exposures be minimized. The above substances were not detected in the samples not itemized. No other substances were detected.

Maintenance Department die shop

On February 24, 1994, one long-term, personal-breathing-zone air sample for aldehydes was collected during part of an extruder-die-cleaning operation. A maintenance mechanic wore the sampler during a 4-hour, 48-minute period that began well after the "initial burn-off" phase of the operation had been completed. This sample was analyzed for four aldehydes: acrolein, acetaldehyde, formaldehyde, and propanal. None were detected; the minimum detectable concentrations were, respectively, 0.02 ppm, 0.03 ppm, 0.1 ppm, and 0.06 ppm, which are all below the relevant evaluation criteria. A "spot check" general-area detector-tube sample for carbon monoxide was also collected during this sampling period, and none was detected.

Two sets of short-term air samples were collected on April 5, 1994, and analyzed for three alcohols, the four aldehydes mentioned above, and a (*different*) group of seven organic substances. One set was collected during an approximately 90-minute period that included the initial burn-off phase of a die-cleaning operation, and the other set was collected during the subsequent 80-minute period. In each set were both personal-breathing-zone and general-area samples.

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Analyses of the short-term samples detected the following substances at the air concentrations listed:

1. n-propanol (breathing-zone), 1.1 ppm ("initial burn-off" phase) and "trace" concentration (period subsequent to "initial burn-off" phase); n-propanol (general-area), "trace" concentrations (both periods);
2. n-propyl acetate (breathing-zone), "trace" concentration ("initial burn-off" phase);
3. aliphatic hydrocarbons (C₁₀₋₁₂), "trace" concentration (subsequent period);

The detected concentrations were below all relevant evaluation criteria. The above substances were not detected in the samples not itemized. No other substances were detected.

Three long-term, diffusion-tube samples for CO were also collected during the entire 170-minute period. The results are summarized in Table 6. Concentrations ranged from "trace" levels to 6.7 ppm. The largest source of CO during this operation is likely the LPG-fueled forklift truck, used throughout the operation. Therefore, the 8-hour TWA exposures for this operation may be similar to the measured concentrations. The measured concentrations are below all relevant evaluation criteria.

CONCLUSIONS

Although *qualitative* air sampling indicates the presence of a variety of substances in the departments studied, *quantitative* measurements indicate that the airborne concentration levels of these substances are below those believed to pose hazards to human health. (The special case of formaldehyde may be an exception to this statement, as explained in two of the following subsections). Specific conclusions follow regarding each department investigated.

Bag Department

Full-shift exposures to CO of up to 31% of the ACGIH TLV of 25 ppm for an 8-hour TWA exposure were measured in this department. Also, "spot" concentrations of up to 15 ppm were measured in some parts of the Department, exceeding the measured personal, full-shift exposures, but no data were collected suggesting full-shift personal exposures to concentrations in this range. These results suggest that hazardous CO concentrations are not likely to occur in this Department under the operating and ventilation conditions that were present during the first follow-up survey.

Quantifiable concentrations of formaldehyde were measured, although they were below the *numerical* evaluation criteria (i.e., the ACGIH ceiling TLV of 0.3 ppm and the OSHA PELs of 0.75 ppm for an 8-hr TWA exposure and 2 ppm for a short-term exposure). However, NIOSH recommends treating formaldehyde as a potential occupational carcinogen, and reducing exposures to the lowest feasible concentration, while ACGIH has designated this compound a suspected human carcinogen and therefore recommends that "worker exposure by all routes should be carefully controlled to levels as low as possible below the TLV." Trace concentrations of formaldehyde are common in ambient outdoor air, especially in urbanized areas, and reducing workplace exposure concentrations that are not greatly elevated above the outdoor background concentration may not always be feasible.

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Other substances were not present in notable concentrations.

Extrusion Department

No substances were present in notable concentrations.

Printing Department pre–press area

Quantifiable concentrations of formaldehyde were measured, although they were below the *numerical* evaluation criteria (i.e., the ACGIH ceiling TLV of 0.3 ppm and the OSHA PELs of 0.75 ppm for an 8–hr TWA exposure and 2 ppm for a short–term exposure). However, NIOSH recommends treating formaldehyde as a potential occupational carcinogen, and reducing exposures to the lowest feasible concentration, while ACGIH has designated this compound a suspected human carcinogen and therefore recommends that "worker exposure by all routes should be carefully controlled to levels as low as possible below the TLV." Trace concentrations of formaldehyde are common in ambient outdoor air, especially in urbanized areas, and reducing workplace exposure concentrations that are not greatly elevated above the outdoor background concentration may not always be feasible.

Other substances were not present in notable concentrations.

Maintenance Department die shop

No substances were present in notable concentrations.

RECOMMENDATIONS

Bag Department

If changes are made in ventilation systems, production, or operations that may affect the airborne concentrations of CO in this Department, exposures to this gas should be monitored to ensure continued compliance with the relevant evaluation criteria.

Formaldehyde concentrations should be monitored again and compared with the outdoor ambient concentration to help determine if lower levels are feasible. More specifically, the concentrations and existing ventilation rates at various locations, along with the outdoor background concentrations at various times, can be considered to determine whether substantial reductions in exposure levels are likely attainable if realistically achievable increases in ventilation rates were to be provided.

Printing Department pre–press area

Formaldehyde concentrations should be monitored again and compared with the outdoor ambient concentration to help determine if lower levels are feasible. More specifically, the concentrations and existing ventilation rates at various locations, along with the outdoor background concentrations at

various times, can be considered to determine whether substantial reductions in exposure levels are likely attainable if realistically achievable increases in ventilation rates were to be provided.

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TABLE 1. Air Sampling and Analytical Methods Used

Analyte(s)	NIOSH Method No.	Air Sampling Medium	Nominal Air-Sampling Flowrate	Sample Preparation and Analytical Techniques	Comments
General volatile organic compounds (VOCs), for qualitative (screening) analyses (" <u>thermal-desorption</u> " method)	---	"TD tube"	20 mL/min	Thermal desorption; GC-MSD	
General volatile organic compounds (VOCs), for qualitative (screening) analyses (" <u>CT</u> " method)	---	CT	200 mL/min	CS ₂ extraction; GC-FID screening; GC-MSD confirmation	GC column used was 30-meter fused-silica capillary column internally coated with DB-1.
Aldehydes, for qualitative (screening) analyses	2539	Glass tube packed with 2-HMP-coated XAD-2 Resin	50 mL/min	Toluene extraction; GC-NPD for initial-survey samples and GC-FID for second followup-survey samples	Modifications to NIOSH Method 2539 included: variations in GC columns and temperatures; and, different column/detector configurations (the Method calls for GC-FID followed by GC-MSD).
Specified general organic compounds and/or mixtures (quantitative analyses)	1003/1300/1450/1501/1550	CT	20 mL/min for full-shift samples; 200 mL/min for short-term samples	CS ₂ extraction; GC-FID	The five NIOSH Methods listed are similar, and the methods used were similar to all five. GC column used was a 30-meter fused-silica capillary column internally coated with DB-5, and column-temperature programming varied from that specified in the cited methods.
Alcohols	1400/1402	CT	20 mL/min for full-shift samples; 200 mL/min for short-term samples	Extraction with 2% or 5% isobutanol in CS ₂ ; GC-FID	The two NIOSH Methods listed are similar, and the methods used were similar to both. GC column used was a 30-meter fused-silica capillary column internally coated with DB-WAX, and column-temperature programming varied from that specified in the cited methods.
Aldehydes, specified (quantitative analyses)	2539	Glass tube packed with 2-HMP-coated XAD-2 Resin	20 mL/min for full-shift samples; 50 mL/min for short-term samples	Toluene extraction (of the oxazolidine derivative of each aldehyde); GC-FID measurement (of each oxazolidine derivative)	Modifications to NIOSH Method 2539 included: variations in GC columns and temperatures; and, a different column/detector configuration (the Method calls for GC-FID followed by GC-MSD).
Formaldehyde (only)	3500	Aqueous 1% sodium bisulfite solution in midget impinger	1.0 L/min or 1.2 L/min	Reaction with hydrochloric acid and chromotropic acid to form a purple chromagen; colorimetric determination (visible-light spectroscopy)	

TABLE 1. (continued) Air Sampling and Analytical Methods Used

Analyte(s)	NIOSH Method No.	Air Sampling Medium	Nominal Air-Sampling Flowrate	Sample Preparation and Analytical Techniques	Comments
Methylene chloride	1005	2 CTs in series	20 mL/min	CS ₂ extraction; GC/FID	Analytical technique modified as follows: GC column (a 30-meter fused-silica capillary column internally coated with DB-WAX was used) and column-temperature programming varied from those specified in the cited method.
Ammonia	6701	Aqueous 0.01N H ₂ SO ₄ solution in "badge" sampler	Not applicable; passive collection by diffusion	Ion chromatography/conductivity detection	
Phthalates	5020	0.8- μ m-pore MCE-membrane filter in plastic cassette	1.5 L/min or 3.0 L/min	CS ₂ extraction; GC/FID	Analytical technique modified as follows: GC column (a 30-meter fused-silica capillary column internally coated with DB-5 was used) and column temperature varied from those specified in the cited method.
Carbon monoxide (long-term diffusion-tube method)	---	Reagent-impregnated granules packed in glass tube	Not applicable; passive collection by diffusion	Reaction with reagent (a palladium compound) to form a greyish-black compound; colorimetric length-of-stain determination	Dräger® Diffusion Tube "Carbon Monoxide 50/a-D"
Carbon monoxide ("spot-test" detector-tube method)	---	Reagent-impregnated granules packed in glass tube	Not measured; proper total air volume sampled with Dräger® pump	Reaction with reagent (iodine pentoxide in the presence of selenium dioxide and fuming sulfuric acid) to cause color change; colorimetric length-of-stain determination	Dräger® Tube "Carbon Monoxide 5/c"
Nitrogen dioxide (NO ₂)	---	Reagent-impregnated granules packed in glass tube	Not measured; proper total air volume sampled with Dräger® pump	Reaction with reagent (N,N'-diphenylbenzidine) to form bluish-grey compound; colorimetric length-of-stain determination	Dräger® Tube "Nitrogen Dioxide 0.5/c"
Oxides of nitrogen (total of NO ₂ and nitric oxide [NO])	---	Reagent-impregnated granules packed in glass tube	Not measured; proper total air volume sampled with Dräger® pump	Oxidation with chromium VI reagent compound, then reaction with reagent (N,N'-diphenylbenzidine) to cause color change; colorimetric length-of-stain determination	Dräger® Tube "Nitrous Fumes 0.5/a (NO+NO ₂)"

CT = Charcoal tube (glass tube packed with activatedcoconut-shell charcoal).
 GC = Gas chromatography
 MSD = Mass-selective detector
 NPD = Nitrogen-phosphorus detector

CS₂ = Carbon disulfide
 FID = Flame-ionization detector
 TD tube = "Thermal-desorption" tube (metal tube packed with three synthetic adsorbents)
 2-HMP = 2-(Hydroxymethyl)piperidine

TABLE 2. Evaluation Criteria for Occupational Exposures to Air Contaminants

Substance	NIOSH RELs	OSHA PELs		ACGIH TLVs
		1989 Standard (not enforceable)	"Transitional" (enforceable)	
Toluene	100 ppm TWA 150 ppm STEL	100 ppm TWA 150 ppm STEL	200 ppm TWA 300 ppm ceiling 500 ppm peak (10-minute maximum per 8-hour shift)	50 ppm TWA ("skin")
n-propyl acetate	200 ppm TWA 250 ppm STEL	200 ppm TWA 250 ppm STEL	200 ppm TWA	200 ppm TWA 250 ppm STEL
1,1,1-Trichloroethane (Methyl chloroform)	350 ppm (15-min ceiling)	350 ppm TWA 450 ppm STEL	350 ppm TWA	350 ppm TWA 450 ppm STEL
Formaldehyde	"Lowest feasible concentration," treat as potential occupational carcinogen (see text)	----	0.75 ppm TWA 2 ppm STEL	0.3 ppm ceiling ("suspected human carcinogen")
Ethanol (Ethyl alcohol)	1000 ppm TWA	1000 ppm TWA	1000 ppm TWA	1000 ppm TWA
1-Methoxy-2-propanol (Propylene glycol monomethyl ether)	100 ppm TWA 150 ppm STEL	100 ppm TWA 150 ppm STEL	----	100 ppm TWA 150 ppm STEL
n-Propanol (n-Propyl alcohol)	200 ppm TWA ("skin") 250 ppm STEL	200 ppm TWA 250 ppm STEL	200 ppm TWA	200 ppm TWA ("skin") 250 ppm STEL
Aliphatic hydrocarbons, approximately C ₁₀ to C ₁₂ (as Petroleum distillates)	350 mg/m ³ TWA 1800 mg/m ³ ceiling (15-minute)	1600 mg/m ³ TWA	2000 mg/m ³ TWA	525 mg/m ³ TWA (as Stoddard solvent)
Carbon monoxide	35 ppm TWA 200 ppm ceiling	35 ppm TWA 200 ppm 5-minute STEL 1500 ppm peak (instantaneous)	50 ppm TWA	25 ppm TWA
Ammonia	25 ppm TWA 35 ppm STEL	35 ppm STEL	50 ppm TWA	25 ppm TWA 35 ppm STEL
Nitrogen dioxide	1 ppm STEL	1 ppm STEL	5 ppm ceiling	3 ppm TWA 5 ppm STEL
Nitric oxide	25 ppm TWA	25 ppm TWA	25 ppm TWA	25 ppm TWA

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NIOSH REL	=	National Institute for Occupational Safety and Health -- Recommended Exposure Limit
OSHA PEL	=	Occupational Safety and Health Administration -- Permissible Exposure Limit
ACGIH TLV	=	American Conference of Governmental Industrial Hygienists -- Threshold Limit Value
TWA	=	Time-weighted average, full-shift (10-hr for NIOSH RELs and 8-hr for OSHA PELs and ACGIH TLVs, unless noted)
STEL	=	Short-term exposure limit (15-min sampling period, unless noted)
ppm	=	parts (of contaminant) per million (parts of air)
"skin"	=	substance may be absorbed by direct contact, in addition to inhalation exposure
mg/m ³	=	milligrams (of contaminant) per cubic meter (of air)

TABLE 3. Summary of results, qualitative (screening) analyses of air and bulk-material samples, May 1993 and February and April 1994.

Substance Detected	Air-sampling Locations (Department)				Bulk-material Samples (Material, and Department where Used or Found)		
	Extrusion	Bag	Maintenance	Printing (pre-press area)	“K-6 Mat Board” (Printing pre-press area)	“E-Finishing Buffing Composition” (Maintenance Department)	Residue found inside Bag Department ventilation enclosure
Sulfur dioxide and/or propane	XX	XX	XX	XX			
Propene	XX			XX			
Acetaldehyde	XX	XX	XX	XX			
Methanol and/or isobutane	XX	XX	XX	XX			
Butane			XX				
Butene	XX						
Butane and/or butenes				XX			
Ethylenimine and methyl amine compound (possibly)					XX		
Bromochlorodifluoromethane		XX	XX				
Ethanol	XX	XX	XX	XX	XX		
Acrolein	XX	XX		XX			
Propanal	XX	XX	XX	XX		XX	
Isopropanol	XX	XX		XX	XX		
Methylene chloride				XX			
Dichloroethylene isomer		XX	XX				

TABLE 3. Summary of results, qualitative (screening) analyses of air and bulk-material samples, May 1993 and February and April 1994 (continued)

Substance Detected	Air-sampling Locations (Department)				Bulk-material Samples (Material, and Department where Used or Found)		
	Extrusion	Bag	Maintenance	Printing (pre-press area)	“K-6 Mat Board” (Printing pre-press area)	“E-Finishing Buffing Composition” (Maintenance Department)	Residue found inside Bag Department ventilation enclosure
Carbon disulfide				XX			
Acetone			XX				
Pentane	XX					XX	
Formic acid						XX	
Butanal						XX	
Pentanal						XX	XX
n-Propanol	XX	XX	XX	XX			
Methyl ethyl ketone				XX			
Ethyl acetate				XX	XX		
M.W. 86 compound (possibly vinyl acetate)	XX						
Acetic acid				XX		XX	
Hexane	XX	XX	XX	XX		XX	
1,1,1-Trichloroethane	XX	XX	XX	XX			
Benzene	XX			XX			
Isopropyl acetate				XX			

TABLE 3. Summary of results, qualitative (screening) analyses of air and bulk-material samples, May 1993 and February and April 1994 (continued)

Substance Detected	Air-sampling Locations (Department)				Bulk-material Samples (Material, and Department where Used or Found)		
	Extrusion	Bag	Maintenance	Printing (pre-press area)	“K-6 Mat Board” (Printing pre-press area)	“E-Finishing Buffing Composition” (Maintenance Department)	Residue found inside Bag Department ventilation enclosure
Butanol		XX		XX			
1-Methoxy-2-propanol	XX		XX	XX			
Pentanol						XX	
Heptane						XX	
Trichloroethylene			XX	XX			
Octane						XX	
Isooctane	XX		XX	XX			
n-Propyl acetate	XX	XX	XX	XX			
Methyl isobutyl ketone				XX	XX		
Toluene	XX		XX	XX	XX		
Isobutyl acetate			XX				
Phenol				XX	XX		
Xylene and/or ethyl benzene isomers		XX	XX				
Hydroxybenzaldehyde					XX		
Cresol isomers	XX				XX		

TABLE 3. Summary of results, qualitative (screening) analyses of air and bulk-material samples, May 1993 and February and April 1994 (continued)

Substance Detected	Air-sampling Locations (Department)				Bulk-material Samples (Material, and Department where Used or Found)		
	Extrusion	Bag	Maintenance	Printing (pre-press area)	“K-6 Mat Board” (Printing pre-press area)	“E-Finishing Buffing Composition” (Maintenance Department)	Residue found inside Bag Department ventilation enclosure
Terpene (pinene)			XX				
M.W. 136 phenyl compound (possibly a methylpyridinecarboxamide)					XX		
Hexamethylenetetramine					XX		
M.W. 149 phenyl-nitrogen compound (possibly)					XX		
M.W. 152 methoxyethyl phenol compound (possibly)	XX						
M.W. 154 C ₁₀ H ₁₈ O compound (possibly cineole)	XX						
Dibutyl phthalate					XX		
Diocetyl phthalate					XX		
Cyclopentanone	XX						
Unidentified fatty acid							XX
Heptanone						XX	
Hexanal	XX			XX		XX	XX
Propoxy-ethanol				XX			

TABLE 3. Summary of results, qualitative (screening) analyses of air and bulk-material samples, May 1993 and February and April 1994 (continued)

Substance Detected	Air-sampling Locations (Department)				Bulk-material Samples (Material, and Department where Used or Found)		
	Extrusion	Bag	Maintenance	Printing (pre-press area)	"K-6 Mat Board" (Printing pre-press area)	"E-Finishing Buffing Composition" (Maintenance Department)	Residue found inside Bag Department ventilation enclosure
Propyl propionate				XX			
n-Butyl acetate				XX			
Perchloroethylene		XX	XX	XX			
Siloxane	XX			XX			
2-Ethoxyethyl acetate (Cellosolve acetate)	XX		XX	XX			
Butrolactone (possibly)							XX
Heptanal						XX	XX
Heptenal						XX	
Dihydromethylfuranone (possibly)							XX
Octanal						XX	XX
Octenal						XX	
Ethylidihydrofuranone (possibly)							XX
Aliphatic hydrocarbons (mixture)	XX			XX	XX		
C ₅ -C ₉ (and possibly C ₁₀) alkenes and/or cycloalkanes						XX	

TABLE 3. Summary of results, qualitative (screening) analyses of air and bulk-material samples, May 1993 and February and April 1994 (continued)

Substance Detected	Air-sampling Locations (Department)				Bulk-material Samples (Material, and Department where Used or Found)		
	Extrusion	Bag	Maintenance	Printing (pre-press area)	“K-6 Mat Board” (Printing pre-press area)	“E-Finishing Buffing Composition” (Maintenance Department)	Residue found inside Bag Department ventilation enclosure
n-Undecane			XX				
n-Dodecane			XX				
C ₁₀ -C ₁₂ branched alkanes	XX	XX	XX	XX			
Nonanal						XX	
Nonenal						XX	
Hydroxybenzoic acid, methyl ester						XX	
Aliphatic aldehydes (unspecified)			XX				
Decanal, unidentified branched aliphatic aldehyde, and undecanal (possibly)						XX	
Aliphatic aldehydes, C ₉ -C ₁₂	XX						XX
Aliphatic aldehydes, C ₁₃ -C ₁₅							XX
C ₁₉ -C ₃₁ n-alkanes						XX	
C ₂₀ -C ₂₇ alkanes						XX	
C ₁₈ -C ₂₄ alkanes and alkenes/cycloalkanes, and analogous aliphatic aldehydes							XX

TABLE 3. Summary of results, qualitative (screening) analyses of air and bulk-material samples, May 1993 and February and April 1994 (continued)

Substance Detected	Air-sampling Locations (Department)				Bulk-material Samples (Material, and Department where Used or Found)		
	Extrusion	Bag	Maintenance	Printing (pre-press area)	"K-6 Mat Board" (Printing pre-press area)	"E-Finishing Buffing Composition" (Maintenance Department)	Residue found inside Bag Department ventilation enclosure
Caprolactam	XX						
M.W. 212 (possibly a C ₁₃ H ₁₂ N ₂ O compound)					XX		
Methylene bisphenol isomers					XX		
Unidentified phenyl compounds (possibly benzoic acid esters)					XX		
tert-Butyl cresol	XX						
M.W. 220 2,6-di-tert-butylquinone	XX						
M.W. 218 C ₁₆ H ₂₈ compound			XX				
M.W. 218 phenyl compound (possibly a substituted naphthoquinone)	XX						
M.W. 218 di-tert-butyl alkyl cresol compound (possibly)	XX			XX			
Bis(dimethylethyl)phenol isomer	XX						
M.W. 196 compound (possibly thiophene)	XX						

TABLE 3. Summary of results, qualitative (screening) analyses of air and bulk-material samples, May 1993 and February and April 1994 (continued)

Substance Detected	Air-sampling Locations (Department)				Bulk-material Samples (Material, and Department where Used or Found)		
	Extrusion	Bag	Maintenance	Printing (pre-press area)	"K-6 Mat Board" (Printing pre-press area)	"E-Finishing Buffing Composition" (Maintenance Department)	Residue found inside Bag Department ventilation enclosure
M.W. 206 di-tert-butylphenol compound	XX						
4-Methyl-2,6-di-tert-butylphenol (BHT)	XX			XX			

XX -- Substance was qualitatively identified in at least one sample of air from the indicated Department or through at least one type of analysis (either solvent extract or heated effluent-gas) conducted on the indicated bulk-material sample. See text for details.

TABLE 4. Results: Full-shift, personal breathing-zone air samples collected in the bag department, and analyzed for seven organic compounds.*

Bag Department Job Title	Date 1994	Sample No.	Sampling Time		Air Concentration,* ppm		
			start (a.m.)	stop (p.m.)	n-propyl acetate	toluene	1,1,1- trichloroethane
Packer A	23 Feb.	CT-11	7:09	2:45	Trace ¹	ND ²	ND
Operator/Packer A	23 Feb.	CT-9	7:10	2:43	Trace	ND	ND
Packer B	23 Feb.	CT-5	7:13	2:37	Trace	Trace	ND
Packer C	23 Feb.	CT-17	7:14	2:53	Trace	Trace	Trace
Operator/Packer B	23 Feb.	CT-16	7:27	2:52	Trace	ND	Trace
Operator A	23 Feb.	CT-4	7:30	2:35	ND	ND	ND
Packer (roving relief)	23 Feb.	CT-13	7:33	2:47	Trace	ND	ND
Adjuster A	23 Feb.	CT-8	7:35	2:42	Trace	ND	ND
Packer H	24 Feb.	CT-57	7:12	2:40	ND	ND	ND
Packer J	24 Feb.	CT-52	7:13	2:46	ND	ND	Trace
Adjuster D	24 Feb.	CT-49	7:15	2:25	ND	ND	ND
Adjuster E	24 Feb.	CT-47	7:17	2:25	ND	ND	ND
Packer K	24 Feb.	CT-51	7:32	2:38	ND	ND	ND
Adjuster F	24 Feb.	CT-59	7:35	2:42	ND	ND	Trace
Packer L	24 Feb.	CT-53	7:37	2:35	ND	ND	ND

* Each sample was also analyzed for: perchloroethylene; 1,2-dichloroethylene; hexane; and, xylene (all isomers). These were not detected. The approximate minimum detectable concentrations for these four compounds in this sample set were, respectively: 0.2 parts per million (ppm); 0.3 ppm; 0.3 ppm; and, 0.3 ppm.

- 1 "Trace" indicates that the substance was detected, and the concentration was between the minimum detectable concentration and the minimum quantifiable concentration. This range is approximately 0.3 to 0.9 ppm for n-propyl acetate, 0.3 to 1 ppm for toluene, and 0.2 to 0.7 ppm for 1,1,1-trichloroethane, for this sample set.
- 2 "ND" indicates "not detected." For this sample set, the minimum detectable concentration for n-propyl acetate is approximately 0.3 ppm, for toluene approximately 0.3 ppm, and for 1,1,1-trichloroethane approximately 0.2 ppm.

TABLE 5. Results: Full-shift air samples for four alcohols.*

Job Title (or Area-sample Location)	Date 1994	Sample No.	Sampling Time		Air Concentration,* ppm		
			start (a.m.)	stop (p.m.)	n-propanol	1-methoxy- 2-propanol	ethanol
Bag Department							
Packer A	23 Feb.	CT-12	7:09	2:46	2.8	ND ¹	ND
Operator/Packer A	23 Feb.	CT-10	7:10	2:44	10	ND	Trace ²
Packer B	23 Feb.	CT-6	7:13	2:37	3.1	ND	ND
Packer C	23 Feb.	CT-18	7:14	2:54	4.0	ND	ND
Operator/Packer B	23 Feb.	CT-15	7:27	2:50	11	ND	Trace
Operator A	23 Feb.	CT-3	7:30	2:35	2.3	ND	ND
Packer (roving relief)	23 Feb.	CT-14	7:33	2:48	3.5	ND	Trace
Adjuster A	23 Feb.	CT-7	7:35	2:40	4.2	ND	Trace
Packer H	24 Feb.	CT-56	7:12	2:40	2.1	ND	ND
Packer J	24 Feb.	CT-60	7:13	2:46	3.3	Trace	Trace
Adjuster D	24 Feb.	CT-50	7:15	2:25	2.0	ND	ND
Adjuster E	24 Feb.	CT-48	7:17	2:25	1.7	ND	ND
Adjuster F	24 Feb.	CT-55	7:35	2:38	1.6	Trace	ND
Packer L	24 Feb.	CT-54	7:37	2:35	1.9	ND	ND
Extrusion Department							
Extruder Helper A	23 Feb.	CT-19	7:25	3:06	2.0	ND	ND
Extruder Helper B	23 Feb.	CT-21	7:36	3:06	1.5	ND	ND
Extruder Operator A	23 Feb.	CT-27	7:53	3:13	2.1	ND	ND
Extruder Operator B	23 Feb.	CT-23	7:56	3:11	Trace	ND	ND
Extruder Helper C	23 Feb.	CT-26	8:26	3:12	2.7	ND	ND
Extruder Operator F	24 Feb.	CT-71	8:16	3:54	3.1	ND	ND
Extruder Helper F	24 Feb.	CT-65	8:18	3:42	≥2.6†	ND	ND
Extruder Operator G	24 Feb.	CT-70	8:22	3:54	3.3	ND	ND

TABLE 5. Results: Full-shift air samples for four alcohols* (continued).

Job Title (or Area-sample Location)	Date 1994	Sample No.	Sampling Time		Air Concentration,* ppm		
			start (a.m.)	stop (p.m.)	n-propanol	1-methoxy- 2-propanol	ethanol
Printing Department pre-press area							
Plate Maker A	23 Feb.	CT-39	9:00	3:55	28	ND	4.9
AREA SAMPLE: near #4 mold-making machine	23 Feb.	CT-38	9:10	3:55	27	ND	4.5
Plate Maker B	24 Feb.	CT-73	9:46	4:12	≥20†	ND	≥4.2†
AREA SAMPLE: near #5 mold-making machine	24 Feb.	CT-75	9:52	4:15	14	ND	2.7

* Each sample was also analyzed for isopropanol. This was not detected. The approximate minimum detectable concentration for this compound in this sample set was 0.6 parts per million (ppm).

- 1 "ND" indicates "not detected." For this sample set, the minimum detectable concentration for 1-methoxy-2-propanol is approximately 0.4 ppm, and for ethanol approximately 0.7 ppm.
- 2 "Trace" indicates that the substance was detected, and the concentration was between the minimum detectable concentration and the minimum quantifiable concentration. This range is approximately 0.3 to 1 ppm for 1-methoxy-2-propanol and 0.6 to 2 ppm for ethanol, for this sample set.

† Actual concentration may be equal to or somewhat greater than reported value, due to possible analyte "breakthrough," during sampling, past the sampling media.

TABLE 6. Results: Full-shift, personal breathing-zone air samples for carbon monoxide (diffusion-tube samples).

Department	Job Title	Date 1994	Sample No.	Sampling Time		Air Concentration of Carbon Monoxide (ppm)
				start (a.m.)	stop (p.m.)	
Extrusion	Extruder Operator A	23 Feb.	CO-1	7:53	3:13	ND ¹
Extrusion	Extruder Operator B	23 Feb.	CO-2	7:56	3:11	Trace ²
Extrusion	Extruder Operator C	23 Feb.	CO-3	7:37	3:07	Trace
Bag	Operator/Adjuster A	23 Feb.	CO-4	7:36	2:53	4.8
Extrusion	Extruder Operator D	23 Feb.	CO-5	8:42	3:08	8.6
Extrusion	Extruder Helper D	23 Feb.	CO-6	8:36	3:23	Trace
Bag	Packer D	23 Feb.	CO-7	7:34	2:53	2.7
Bag	Packer E	23 Feb.	CO-8	7:32	2:53	3.4
Bag	Operator/Packer C	23 Feb.	CO-9	7:30	2:53	1.4
Extrusion	Extruder Helper E	23 Feb.	CO-10	7:26	3:14	Trace
Extrusion	Extruder Operator E	23 Feb.	CO-11	7:25	3:07	Trace
Bag	Packer F	23 Feb.	CO-12	7:16	2:53	2.6
Bag	Adjuster B	23 Feb.	CO-13	7:12	2:45	6.6
Bag	Packer G	23 Feb.	CO-14	7:13	12:15	2.0
Bag	Adjuster C	23 Feb.	CO-15	7:10	2:53	3.9
Bag	Packer N	24 Feb.	CO-16	7:12	2:40	4.7
Bag	Packer P	24 Feb.	CO-17	7:16	2:32	6.2
Bag	Adjuster G	24 Feb.	CO-18	7:13	2:43	4.7
Bag	Operator/Packer D	24 Feb.	CO-19	7:31	2:32	2.9
Bag	Packer Q	24 Feb.	CO-20	7:33	2:40	7.7
Bag	Packer R	24 Feb.	CO-21	7:35	2:40	6.3
Bag	Packer S	24 Feb.	CO-22	7:36	2:37	6.4
Extrusion	Extruder Helper G	24 Feb.	CO-23	8:19	3:30	Trace
Extrusion	Roll Doctor	24 Feb.	CO-24	8:20	4:07	3.2
Extrusion	Extruder Helper H	24 Feb.	CO-25	8:16	3:55	2.0

1 "ND" indicates "not detected." The minimum detectable concentration is approximately 0.7 ppm.

2 "Trace" indicates that carbon monoxide was detected, but a precise reading of the diffusion tube was difficult due to a small length-of-stain indication. This concentration is estimated to be about 1 ppm.

TABLE 7. Results: “Spot-check,” general-area air samples for *carbon monoxide* (detector-tube samples), collected in the bag department.

Bag Department Location	Date 1994	Sampling Time	Air Concentration of Carbon Monoxide (ppm)
Bag Machine #20 (outside hood)	23 Feb.	2:12	Trace ¹
Bag Machine #20 (inside hood)	23 Feb.	↓	5
Bag Machine #16 (outside hood)	23 Feb.	↓	15
Bag Machine #16 (inside hood)	23 Feb.	↓	15
Bag Machine #10	23 Feb.	↓	10
Bag Machine #35	23 Feb.	↓	5
Bag Machine #44	23 Feb.	↓	Trace
Bag Machine #46	23 Feb.	2:50	Trace
Bag Machine #15	24 Feb.	Approximately 1:40	Trace
Bag Machine #8	24 Feb.	↓	Trace
Bag Machine #16	24 Feb.	↓	Trace
Bag Machine #42	24 Feb.	↓	Trace
Bag Machine #28	24 Feb.	↓	Trace
Bag Machine #35	24 Feb.	↓	Trace
Employee Lunch Station	24 Feb.	Approximately 2:00	ND ²

- 1 “Trace” indicates that carbon monoxide was detected, but a precise reading of the detector tube was difficult due to a small length-of-stain indication. This concentration is estimated to be about 1 to 3 ppm.
- 2 “ND” indicates “not detected.” The minimum detectable concentration is approximately 1 ppm.

TABLE 8. Results: Partial-shift, general-area air samples for *formaldehyde*, collected in the bag department and analyzed by NIOSH Method 3500.

Bag Department Location	Date 1994	Air-Sampling Flow Rate (L/min)	Sample No.	Sampling Time		Airborne Formaldehyde Concentration (ppm)
				Start	Stop	
Bag Machine #17	23 Feb.	1.2	HCHO-3	2:01 p.m.	3:53 p.m.	0.031
Bag Machine #11	23 Feb.	1.2	HCHO-1	2:03 p.m.	3:54 p.m.	0.029
Bag Machine #29	23 Feb.	1.2	HCHO-2	2:05 p.m.	3:55 p.m.	0.024
Bag Machine #35	23 Feb.	1.2	HCHO-4	2:07 p.m.	3:57 p.m.	0.035
Bag Machine #14	24 Feb.	1.0	HCHO-10	9:38 a.m.	1:34 p.m.	0.021
Bag Machine #41	24 Feb.	1.0	HCHO-11	9:35 a.m.	1:31 p.m.	0.030
Bag Machine #47	24 Feb.	1.0	HCHO-8	10:01 a.m.	1:35 p.m.	0.061
Bag Machine #28	24 Feb.	1.0	HCHO-9	9:46 a.m.	1:32 p.m.	0.025

TABLE 9. Results: Full-shift air samples for seven organic compounds.*

Job Title (or Area Sample Location)	Date 1994	Sample No.	Sampling Time		Air Concentration*	
			start (a.m.)	stop (p.m.)	n-propyl acetate (ppm)	aliphatic hydrocarbons C ₁₀ to C ₁₂ (mg/m ³)
Extrusion Department						
Extruder Helper A	23 Feb.	CT-20	7:25	3:06	ND ¹	ND
Extruder Helper B	23 Feb.	CT-22	7:36	3:06	ND	ND
Extruder Operator A	23 Feb.	CT-28	7:53	3:13	ND	ND
Extruder Operator B	23 Feb.	CT-24	7:56	3:11	ND	ND
Extruder Helper C	23 Feb.	CT-25	8:26	3:12	ND	ND
Extruder Operator F	24 Feb.	CT-72	8:16	3:54	ND	ND
Extruder Helper F	24 Feb.	CT-66	8:18	3:42	ND	ND
Extruder Operator G	24 Feb.	CT-69	8:22	3:54	ND	ND
Towmotor Operator	24 Feb.	CT-58	8:48	2:36	ND	Trace ²
Printing Department pre-press area						
Plate Maker A	23 Feb.	CT-36	9:00	3:55	6.9	Trace
AREA SAMPLE: near #4 mold-making machine	23 Feb.	CT-37	11:23	3:55	6.2	Trace
Plate Maker B	24 Feb.	CT-76	9:46	4:12	4.0	Trace
AREA SAMPLE: near #5 mold-making machine	24 Feb.	CT-74	9:52	4:16	2.7	ND

* Each sample was also analyzed for: perchloroethylene, 1,2-dichloroethylene, hexane, ethyl acetate, and toluene. These were not detected. The approximate minimum detectable concentrations for these compounds in this sample set were, respectively: 0.2 parts per million (ppm); 0.4 ppm; 0.4 ppm; 0.4 ppm; and, 0.4 ppm.

- 1 "ND" indicates "not detected." For this sample set, the minimum detectable concentration for n-propyl acetate was approximately 0.3 ppm, and for aliphatic hydrocarbons (C₁₀ to C₁₂) approximately 10 milligrams per cubic meter (mg/m³).
- 2 "Trace" indicates that the substance was detected, and the concentration was between the minimum detectable concentration and the minimum quantifiable concentration. This range is approximately 10 to 61 mg/m³ for aliphatic hydrocarbons (C₁₀ to C₁₂), for this sample set.

TABLE 10. Results: Full-shift air samples for ammonia, collected in the Printing Department/pre-press area.

Job Title (or Area-sample Location)	Date 1994	Sample No.	Sampling Time		Airborne Ammonia Concentration (ppm)
			Start (a.m.)	Stop (p.m.)	
Platemaker A	23 Feb.	NH3—5	9:00	3:55	1.8
AREA SAMPLE, near #4 mold-making machine	23 Feb.	NH3—12	9:10	3:55	1.4
AREA SAMPLE, near #5 mold-making machine	24 Feb.	NH3—2	9:52	4:15	2.2