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Growth International  
Bennett Industries Division  
Peotone, Illinois**

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## **I. SUMMARY**

On March 13, 1989, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from the International Chemical Workers Union (ICWU) on behalf of its Local 194 members. NIOSH was asked to evaluate potential exposures during the manufacture of various specialized metal and plastic containers at Growth International, Bennett Industries Division in Peotone, Illinois.

NIOSH investigators initially visited the facility on June 6-7, 1989, at which time a ventilation survey was conducted. Return visits were made on February 15-16 and March 7, 1990, to conduct environmental air sampling for naphthas, methyl ethyl ketone (MEK), toluene, oil mists, butyl cellosolve (ethylene glycol monobutyl ether), perchloroethylene, formaldehyde, and other hydrocarbons and aldehydes.

The ventilation survey found that there were deficiencies with the local exhaust systems on several paint booths and drying ovens. The environmental air sampling indicated potential employee exposures to several contaminants. During the manufacture of metal containers, airborne concentrations of naphtha ranged from 21 to 126 milligrams per cubic meter of air ( $\text{mg}/\text{m}^3$ ), while toluene concentrations ranged from 0.18 to 6.7 parts per million of air (ppm). Airborne MEK concentrations ranged from 0.8 to 37 ppm. Samples with the highest concentrations of MEK were collected from the small parts painting, roller-coat, and litho operations. Oil mist concentrations in the stamping areas ranged from 0.04 to 0.10  $\text{mg}/\text{m}^3$ , while only three samples for butyl cellosolve had detectable concentrations. One sample of butyl cellosolve, collected from the roller-coat operation, indicated an airborne concentration of 19  $\text{mg}/\text{m}^3$ . These concentrations are below the relevant evaluation criteria; however, the sample for butyl cellosolve (19  $\text{mg}/\text{m}^3$ ) approached the NIOSH Recommended Exposure Limit (REL) of 24  $\text{mg}/\text{m}^3$ .

During the manufacture and silkscreening of plastic containers, airborne formaldehyde concentrations ranged 0.02 to 0.28 ppm. Several of these samples exceeded the NIOSH REL of 0.016 ppm. NIOSH recommends that exposure to formaldehyde be reduced to the lowest feasible concentration. Three of the samples were also above the 0.1 ppm OSHA limit that requires worker training. The highest formaldehyde concentrations were detected during the automatic (offset) silkscreening operation. Airborne concentrations of naphtha and perchloroethylene ranged from 3.5 to 3.6  $\text{mg}/\text{m}^3$  and 0.08 to 0.1 ppm, respectively. Butyl cellosolve concentrations measured during the manufacture of plastic containers ranged from non-detected to 3.3  $\text{mg}/\text{m}^3$ . A hydrocarbon screen performed during the molding of the plastic containers identified hexanes, 1,1,1-trichloroethane, toluene, perchloroethylene, xylenes, *t*-butyl isothiocyanate, and several aliphatic and aromatic hydrocarbons. Airborne concentrations for various hydrocarbons ranged from non-detected to 0.22 ppm for 1,1,1-trichloroethane, 0.03 to 0.23 ppm for perchloroethylene, and 0.48 to 3.5  $\text{mg}/\text{m}^3$  for total hydrocarbons.

Based upon the environmental air sampling results, employees performing the silkscreen operations are exposed to formaldehyde in excess of the NIOSH REL. These exposures should be reduced to the lowest feasible concentrations. Employees working at the paint booths, litho, and roller-coat are not overexposed to naphthas, toluene, MEK, or butyl cellosolve. However, improvements in the existing ventilation controls, elaborated in Section VIII, will reduce these employee exposures.

**KEYWORDS:** SIC 3411 (metal cans) and 3089 (plastics products, not elsewhere classified), naphthas, methyl ethyl ketone, toluene, oil mist, butyl cellosolve, formaldehyde, perchloroethylene, lithographic coatings, and silkscreen.

## II. INTRODUCTION

On March 13, 1989, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from the International Chemical Workers Union (ICWU) on behalf of its Local 194 members. NIOSH was asked to evaluate potential exposures during the manufacture of various specialized metal and plastic containers at Growth International, Bennett Industries Division in Peotone, Illinois. The request stated that employees were concerned with the painting and/or printing of logos and labels on containers and the poor ventilation in the facility.

An initial site visit was conducted by a team of NIOSH investigators on June 6-7, 1989, to evaluate chemical hazards with a concurrent HHE request to evaluate ergonomic hazards.<sup>1</sup> An opening conference was held on June 6, 1989, with the NIOSH, Bennett Industries, and ICWU, Local 194 representatives. After the opening conference and during the following day, NIOSH investigators conducted a walk-through investigation, which consisted of observing work practices, obtaining Material Safety Data Sheets (MSDS), collecting other background information, and performing measurements with various direct-reading instruments. Informal, private discussions were held with employees to document their concerns, and a general ventilation survey was conducted by NIOSH engineers.

On February 15-16, 1990, NIOSH industrial hygienists evaluated potential employee exposures during the manufacture of both metal and plastic containers. Environmental air sampling for oil mists, butyl cellosolve (ethylene glycol monobutyl ether), MEK, naphthas, and toluene was conducted throughout the metal container manufacturing plant, including the stamping, painting, roller coat, and litho areas. Environmental air sampling was also conducted in two areas of the plastic container plant. Samples were collected for butyl cellosolve, naphthas, perchloroethylene, and formaldehyde in the silkscreening area. Hydrocarbon and aldehyde screening samples were obtained in the blow molding area. A return visit was made on March 7, 1990, to conduct environmental sampling during a silkscreening operation which was not observed during the previous survey.

### **III. BACKGROUND**

Growth International, Bennett Industries Division manufactures small to medium sized plastic and metal containers. The plastic and metal divisions of the plant are located in separate buildings and managed as separate entities. The metal division plant occupies 124,026 square feet (sq. ft.), while the plastic division plant occupies 72,431 sq. ft. At the time of this investigation, Bennett Industries employed 181 people at Growth International, 86 in the plastic container division, 77 in the metal container division, and 18 in general machine maintenance.

#### **A. Metal Container Division**

Metal for the containers is received in coils of long, thin sheets. The type of metal used depends on customer specifications, but is mainly steel or aluminum. The coils are unrolled and cleaned to remove any rust preventatives or other treatments used in shipment. The metal is then cut to specific-sized sheets that are used for either the container bottoms, lids, or walls. For the bottoms and lids, stacks of the cut sheet metal are transported by a forklift to the stamping areas. Several metal stamping machines (punch presses) are used to make the ends of the containers. Typically, four pieces are stamped from each metal sheet, with the edges crimped to allow proper attachment to the container walls. The lids also have holes stamped by another punch press. The container walls are made by welding the ends of the specifically sized sheets together, forming a tube. The process is conducted on a conveyor line where the containers are partially assembled by attaching the bottoms. The partially assembled containers are transported by the conveyor to automatic paint booths where both the inside and outside of the container are spray painted. The lids are spray painted in booths on a separate conveyor. After painting, both the lids and the containers are baked in an oven before final assembly.

Metal containers with specialized company logos are manufactured in a different manner. The metal sheets making the container walls are roller-coated a customer specified color and lithographed with company logos. This process does not involve spray painting. Once this coating is applied, the metal sheets are baked. The company logos are then lithographed on the outer surface with various inks and are again baked. Once the painting process is completed, the sheets are welded into tubes and assembled.

#### **B. Plastic Container Division**

Plastic containers are manufactured from polyethylene. Two molding processes are used to make the containers from the raw plastic pellets. Injection molding is used to make most of the containers that require covers, while blow molding is used to make containers with special shapes and specifications. Several container molding machines, including machines that mold the covers, are located throughout the facility. Before molding, the plastic pellets are melted and color dyes can be added. The molded containers are processed by trimming, shrinking, or attaching handles. Many of the containers also require silkscreening to apply customer logos and special labels. The silkscreening operations are performed on a manually operated machine or an automatic (offset) machine. Similar silkscreening inks are used in

both areas. For containers being silkscreened by the offset machine, handles are attached after the logos are allowed to dry. The finished plastic containers are inspected and prepared for shipment.

#### **IV. METHODS**

During the initial site visit, a general ventilation survey was performed using smoke tubes and an Alnor® thermoanemometer to determine the overall effectiveness of the current exhaust ventilation systems. Short-term, direct-reading measurements of airborne contaminants were made in suspected problem areas with Drager colorimetric detector tubes and an HNu® Photoionization Detector (PID). Informal, private discussions were held with employees to document their concerns.

During the return visits, personal breathing zone and general area samples were collected in both the metal and plastic divisions. Environmental air samples for oil mists, butyl cellosolve, MEK, naphthas, and toluene were collected in the metal container division. Samples for formaldehyde, naphthas, butyl cellosolve, and perchloroethylene were collected in the plastic container division. Samples for a hydrocarbon and aldehyde qualitative screening analysis were also collected during the manufacture of plastic containers.

A. Metal Container Division

The air samples for oil mist were collected during stamping operations using 37 millimeter (mm), binderless glass fiber filters. The filters were attached via Tygon® tubing to Gilian®, Model No. HFS 513A, hi-flow personal sampling pumps calibrated at a flow rate of 2.0 liters per minute (lpm). The filters were analyzed for oil mist by infrared spectrophotometry following NIOSH Method 5026.<sup>2</sup>

Air samples for naphtha and toluene were collected during the painting operations using standard 150 milligram (mg) activated charcoal tubes. These sorbent tubes were attached via Tygon® tubing to Gilian®, Model No. LFS 113 DC, low-flow personal sampling pumps calibrated at a flow rate of 200 milliliters per minute (ml/min). These sorbent tubes were then analyzed by gas chromatography with a flame ionization detector (GC/FID) according to NIOSH Methods 1550 and 1501.<sup>2</sup>

The air samples for butyl cellosolve from the stamping, roller coat, and litho operations were also collected using standard 150 mg activated charcoal tubes, attached to low-flow personal sampling pumps calibrated at a flow rate of 50 ml/min. The samples were analyzed by GC/FID according to NIOSH Method 1403.<sup>2</sup>

MEK samples were collected during the painting, roller coat, and litho operations on 240 mg Amborsorb XE-347 sorbent tubes attached to low-flow personal sampling pumps calibrated at a flow rate of 100 ml/min. The samples were analyzed by GC/FID according to NIOSH Method 2500.<sup>2</sup>

B. Plastic Container Division

Air samples for formaldehyde were collected using 20 ml of 1% sodium bisulfite solution in miniature impingers. The impingers were attached via Tygon® tubing to MSA personal sampling pumps calibrated at a flowrate of 0.5 lpm, for samples collected on February 16, or 1.0 lpm, for samples collected on March 7. The samples were analyzed for formaldehyde using visible spectroscopy according to NIOSH Method 3500.<sup>2</sup>

Air samples for naphtha and perchloroethylene were collected during the silkscreen operation and analyzed according to NIOSH Methods 1003 and 1550<sup>2</sup> in an identical manner as the samples collected in the metal container division for naphtha and toluene. Samples for butyl cellosolve were also collected during the silkscreening according to the method described above.

Air samples for hydrocarbons and aldehydes were collected during the molding operations on 150 mg activated charcoal and ORBO®-23 sorbent tubes, respectively. Two of the charcoal tube samples were attached via Tygon® tubing to the Gilian® hi-flow personal sampling pumps calibrated at 1.0 lpm, while the remaining charcoal tubes samples were collected at a flow rate of 200 ml/min using the Gilian® low-flow personal sampling pumps. The ORBO®-23 samples were collected using the low-flow pumps calibrated at 80 ml/min. The two high volume charcoal tube samples were screened by GC/FID and then analyzed with a Mass

Selective Detector (MSD) to identify contaminants. The remaining charcoal tubes were then analyzed by GC/FID to quantitate 1,1,1-trichloroethane, perchloroethylene, and total hydrocarbons, which were identified as contaminants by GC/MSD. The ORBO®-23 tubes were also screened by GC/FID and analyzed according to NIOSH Method 2539.<sup>2</sup>

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

The primary sources of environmental evaluation criteria for the workplace are: 1) NIOSH Recommended Exposure Limits (RELs),<sup>3</sup> 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs),<sup>4</sup> and 3) the U.S. Department of Labor, OSHA Permissible Exposure Limits (PELs).<sup>5</sup> The OSHA PELs may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH RELs, by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in the report, it should be noted that the most stringent standard was used; however, industry is legally required to meet those levels specified by the OSHA standard.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a chemical 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 high, short-term exposures.

### A. Petroleum Distillates (Naphtha)

Petroleum naphtha is comprised mainly of aliphatic hydrocarbons.<sup>6</sup> Effects from exposure to these solvents are primarily acute, unless significant amounts of substances that have chronic toxicity are present, such as benzene or glycol ethers. Epidemiologic studies have shown that exposure to similarly refined petroleum solvents (i.e., mineral spirits, Stoddard solvent) can cause dry throat, burning or

tearing of the eyes, mild headaches, dizziness, respiratory irritation, and dermatitis.<sup>7</sup> Some of the refined petroleum solvents have also been shown to cause transient central nervous system depression and that chronic intoxication may lead to polyneuropathy. The onset of these symptoms can be associated with the presence of C<sub>5</sub>-C<sub>8</sub> alkanes and their isomers.<sup>8,9</sup>

Petroleum naphtha appears to have weak skin cancer causing potential in laboratory mice.<sup>10</sup> The International Agency for Research on Cancer (IARC) has determined that there is only limited evidence implicating petroleum naphtha as a carcinogen in animals and insufficient evidence associating exposure to petroleum naphtha and the development of cancer in humans.<sup>11</sup> However, depending upon the manufacturing process, petroleum naphtha may sometimes contain varying amounts of aromatic hydrocarbons such as benzene. Benzene is classified by IARC as a known human carcinogen and has been associated with the development of leukemia and some lymphomas in humans.<sup>11</sup>

Since naphthas are mixtures of aliphatic hydrocarbons, the evaluation criteria are based upon the most commonly available varieties (petroleum ether, rubber solvent, varnish makers' and painters' (VM&P) naphtha, mineral spirits, and Stoddard solvent). The NIOSH REL for VM&P naphtha (refined petroleum solvents) is 350 mg/m<sup>3</sup> as a TWA exposure. In addition, a ceiling concentration limit (15 minutes duration) of 1800 mg/m<sup>3</sup> is stipulated.<sup>3</sup> The OSHA PEL for VM&P naphtha is 1350 mg/m<sup>3</sup> TWA, and 525 mg/m<sup>3</sup> for Stoddard solvents.<sup>5</sup> The ACGIH has also established TLVs of 1370 mg/m<sup>3</sup> for VM&P naphtha and 525 mg/m<sup>3</sup> for Stoddard solvent.<sup>4</sup> The NIOSH REL for benzene is 0.1 ppm of air and classifies it as a human carcinogen<sup>3</sup>; the OSHA PEL is 1 ppm<sup>5</sup>; and the current ACGIH TLV is 10 ppm as a suspected human carcinogen. ACGIH has proposed to lower the TLV to 0.1 ppm and classify benzene as a proven human carcinogen.<sup>4</sup>

## B. MEK

MEK is in a group of organic solvents classified as ketones.<sup>12</sup> MEK is absorbed primarily through inhalation and causes irritation of the eyes, mucous membranes, and skin; and at high concentrations may cause central nervous system (CNS) depression. In humans, exposure to 100 ppm of MEK caused mild nose and throat irritation; 200 ppm caused mild eye irritation; and 300 ppm was associated with headaches.<sup>13</sup> Exposure of laboratory animals to 10,000 ppm produced CNS depression after five hours.<sup>13</sup> Additional studies indicate that MEK by itself does not cause neurologic toxicity of the extremities (peripheral neuropathy), but rather, may potentiate the toxic effects of substances known to cause peripheral neuropathy, such as *n*-hexane.<sup>14</sup> The National Toxicology Program, in conjunction with other governmental agencies, has found no evidence supporting an association between MEK exposure and the development of cancer in humans or experimental animals.<sup>15</sup>

The NIOSH REL, ACGIH TLV, and OSHA PEL for MEK is 200 ppm as an 8-hour TWA, while a 15-minute STEL of 300 ppm has also been established.<sup>3,4,5</sup>



C. Toluene

Toluene is a CNS depressant. Subjects exposed to 100 ppm of toluene for 6 hours in an environmental chamber complained of eye and nose irritation and in some instances, headache, dizziness, and a feeling of intoxication.<sup>16</sup> However, no significant differences were noted in performance on a battery of neurobehavioral tests. Symptoms were not noted at 10 or 40 ppm. Repeated or prolonged contact with liquid toluene defats the skin, causing fissuring, drying, and dermatitis.<sup>13</sup> The NIOSH REL, ACGIH TLV, and OSHA PEL for toluene is 100 ppm as an 8-hour TWA, with a 15-minute STEL of 150 ppm.<sup>3,4,5</sup>

D. Oil Mists

The evaluation criteria for oil mists are based primarily on studies conducted with a petroleum based, white mineral oil containing no additives.<sup>8,17</sup> Mineral oils, as well as other lubricating or cutting oils, can contain a complex mixture of aromatic, naphthenic, and straight- or branched-chain paraffinic hydrocarbons. The composition of a given oil depends upon the way in which the oil was processed, and the degree to which it was processed. Many mineral oils in use today vary in composition, and can contain various additives and impurities.

Mineral oil mist is of low toxicity.<sup>13</sup> Inhalation of mineral oil mist in high concentrations may cause pulmonary effects, although this has rarely been reported. A single case of lipoid pneumonitis suspected to have been caused by exposure to very high concentrations of oil mist was reported in 1950; this occurred in a cash register serviceman whose heavy exposure occurred over 17 years of employment.<sup>18</sup> Early epidemiological studies linked cancers of the skin and scrotum with exposure to mineral oils.<sup>19</sup> These effects have been attributed to contaminants such as polycyclic aromatic hydrocarbons (PAHs) and/or additives with carcinogenic properties present in the oil. IARC determined that there is sufficient evidence for carcinogenicity to humans, based on epidemiologic studies of uncharacterized mineral oils containing additives and impurities. There is, however, inadequate evidence for carcinogenicity to humans for highly refined oils.<sup>20</sup> Prolonged exposure to mineral oil mist may also cause dermatitis, particularly in persons with pre-existing skin disorders.

Environmental evaluation criteria for mineral oil mist have been established by ACGIH and OSHA, at 5 mg/m<sup>3</sup> as an eight-hour TWA.<sup>4,5</sup> The criteria were established to minimize respiratory irritation and pulmonary effects. The NIOSH REL for oil mist is also 5 mg/m<sup>3</sup>, with a 10 mg/m<sup>3</sup> STEL.<sup>3</sup> However, since the role of additives and oil fume from partial heat-decomposition have yet to be completely evaluated experimentally, NIOSH suggests that these criteria may not be applicable to all forms of oil mists.<sup>8</sup>

#### E. Formaldehyde

Formaldehyde is a colorless gas with a pungent and irritating odor at ambient temperatures;<sup>21</sup> its odor threshold is approximately 0.8 ppm.<sup>21,22</sup> Formaldehyde may cause adverse health effects following exposure via inhalation, ingestion, or dermal or eye contact.<sup>21</sup> Mild to unpleasant eye irritation occurs in acclimated workers at 2 to 10 ppm, and intolerable irritation with possible tissue damage occurs at levels above 25 ppm.<sup>21</sup> While the term "formaldehyde" is also used to describe various mixtures of formaldehyde, water, and alcohol, the term "formalin" more precisely describes aqueous solutions, particularly those containing 37 to 50 percent formaldehyde and 6 to 15 percent alcohol stabilizer. Paraformaldehyde, a solid, also serves as a source of formaldehyde gas.<sup>23</sup>

Based upon the results of laboratory tests which have demonstrated the carcinogenic and mutagenic activity of formaldehyde in animals, NIOSH and OSHA recommend that formaldehyde be handled in the workplace as a potential occupational carcinogen.<sup>23,24</sup> NIOSH recommends that occupational exposures to formaldehyde be controlled to the lowest feasible concentration.<sup>24</sup> On December 4, 1987, OSHA issued a comprehensive regulation covering occupational exposure to formaldehyde (29 CFR 1910.1048). This rule reduced the 8-hour TWA PEL to 1 ppm and established a 2 ppm 15-minute STEL. The comprehensive standard also included an "action level" of 0.5 ppm, measured as an 8-hour TWA, with provisions for employee exposure monitoring, medical surveillance, recordkeeping, regulated areas, emergency procedures, preferred methods to control exposure, maintenance and selection of personal protective equipment, and hazard communication. OSHA's rule was based on the consideration of a wide range of new evidence including animal bioassays and epidemiological evidence. It was based in part on OSHA's recognition of formaldehyde as a potential occupational carcinogen as well as its irritating and sensitizing effects.<sup>23</sup>

On May 27, 1992, OSHA amended its existing regulation for occupational exposure to formaldehyde to take effect on June 26, 1992. The final amendments lowered the 8-hour PEL for formaldehyde from 1 ppm to an 8-hour TWA of 0.75 ppm. The amendments also added medical removal protection provisions to supplement the existing medical surveillance requirements for those employees suffering significant eye, nose, or throat irritation; and for those suffering from dermal irritation or sensitization from occupational exposure to formaldehyde. Additional hazard labeling, including a warning that formaldehyde presents a potential cancer hazard, is required where formaldehyde levels, under reasonably foreseeable conditions of use, may potentially exceed 0.5 ppm. The final

amendments also provided for annual training of all employees exposed to formaldehyde at levels of 0.1 ppm or higher.<sup>23</sup>

ACGIH classifies formaldehyde as a Suspected Human Carcinogen (i.e., a chemical substance associated with industrial processes, which is suspected of inducing cancer, based on either limited epidemiological evidence or demonstration of carcinogenesis in one or more animal species by appropriate methods).<sup>4</sup> The recommendation of ACGIH concerning a Suspected Human Carcinogen is that worker exposures by all routes be carefully controlled to levels as low as reasonably achievable below its TLV.<sup>4</sup> On June 2, 1992, ACGIH adopted a ceiling limit TLV of 0.3 ppm. A ceiling limit is a concentration that should not be exceeded during any part of the working exposure. ACGIH formerly recommended an 8-hour TLV-TWA of 1 ppm and a 15-minute STEL of 2 ppm for formaldehyde. The revised TLV was adopted to further reduce sensory irritation for workers handling formaldehyde or formaldehyde-containing products. Moreover, ACGIH stated that because the reported dose-dependent carcinogenic effect in the rat and mouse and the inadequate epidemiologic data on the cancer risk in man, it was advisable to reduce formaldehyde workplace exposure to the lowest possible level.<sup>25</sup>

#### F. Threshold Limit Values for Mixtures

When two or more hazardous substances which act upon the same organ system are present, their combined effect, rather than that of either individually, should be given primary consideration. If the sum of the following fractions, where  $C_n$  indicates the observed atmospheric concentration and  $T_n$  the corresponding threshold limits, exceeds unity, then the threshold limit of the mixture should be considered as being exceeded.<sup>4</sup>

$$C_1/T_1 + C_2/T_2 + \cdots C_n/T_n$$

In the absence of information to the contrary, the effects of the different hazards should be considered as additive. Synergistic action or potentiation may, however, occur with some combinations of atmospheric contaminants. Such cases at present must be determined individually. Potentiating or synergistic agents are not necessarily harmful by themselves. Potentiating effects of exposure to such agents by routes other than that of inhalation are also possible, e.g., imbibed alcohol and inhaled narcotic (trichloroethylene). Potentiating effects are characteristically seen at higher exposure concentrations.<sup>4</sup>

## VI. RESULTS AND DISCUSSION

### A. Metal Container Division

The ventilation survey showed that the ventilation systems on the lithograph and roller-coat machines were not operating properly. The airflow at the openings on the roller-coat machine was actually escaping outwards instead of drawing inwards. Also, a section of the conveyor that transports the containers from the paint booths to the drying oven does not have any ventilation to control the escape of vapors. Vapors could be seen escaping from the containers, and organic vapors were

detected by the PID. The stamping machines were another area of concern. An oil mist was seen being sprayed in workers' breathing zones while the machines were in operation.

Air samples to determine potential employee exposures to solvents during the container painting operations were collected from several employees and areas. Four personal breathing zone and four general area air samples were collected during painting operations for naphtha, toluene, and MEK. General area air samples for the same contaminants were also collected during the roller-coat and litho operations. The results of the environmental air sampling for naphtha and toluene are included in Table I, while the results for the MEK samples are included in Table II. The mean airborne concentration of naphtha was 63 mg/m<sup>3</sup> (range: 21 to 126 mg/m<sup>3</sup>), and the mean toluene concentration was 2.1 ppm (range: 0.18 to 6.7 ppm). The mean MEK concentration was 17 ppm (range: 0.8 to 37 ppm). All of the concentrations were below their individual evaluation criteria. Two of the highest naphtha concentrations (126 and 72 mg/m<sup>3</sup>) were collected from the roller-coat and litho machines. The MEK concentrations (25 and 15 ppm) in these two areas were also among the highest concentrations detected for this contaminant. Samples collected from two small parts painters also had among the highest concentrations of these three contaminants. One of these painters was exposed to 68 mg/m<sup>3</sup> naphtha, 4.5 ppm toluene, and 28 ppm MEK; the other painter's breathing zone concentrations were 83 mg/m<sup>3</sup>, 6.7 ppm, and 37 ppm, respectively.

The effects of toluene, MEK, and naphthas were assumed to be additive for the purposes of this investigation. The TLV for mixtures was calculated by incorporating the most stringent evaluation criterion for each of these compounds into the sum of fractions presented previously. Therefore, if the resulting sum of the following fractions,

$$C_t/100 + C_m/200 + C_n/350$$

(where  $C_t$ ,  $C_m$ , and  $C_n$  are the airborne concentrations of toluene, MEK, and naphtha, respectively)

exceeded unity (1), then the threshold limit of this mixture would be exceeded. The resulting sum of these fractions ranged from 0.08 to 0.50, indicating that none of the samples exceeded the threshold limit for a mixture of toluene, MEK, and naphtha. The highest combined exposures occurred during the roller-coat operation (0.50) and small parts painting (0.49 and 0.38).

Oil mist and butyl cellosolve samples were collected to determine potential exposures during the metal stamping operations. Two general area air samples for butyl cellosolve were also collected during the roller-coat and litho operations. The results of the oil mist samples are included in Table III. The airborne oil mist concentrations ranged from 0.04 to 0.10 mg/m<sup>3</sup>. However, the amount of oil mist collected on 7 of these 10 samples was between the limit of detection (LOD) and the limit of quantitation (LOQ). Therefore, the oil mist concentrations for these samples are only estimates. Both the LODs and the LOQs are values determined by the procedures used to analyze the field samples. They are not dependent on the amount of air volume collected during sampling. Minimum detectable

concentrations (MDCs) and minimum quantifiable concentrations (MQCs), however, are dependent on sample air volume. They are determined by dividing respective LODs and LOQs by air sample volumes appropriate for a given set of field samples. The LOD for oil mist was 20 micrograms ( $\mu\text{g}$ ) per sample, which equates to a MDC of  $0.02 \text{ mg/m}^3$ , assuming a sampling volume of 905 liters. The LOQ was  $69 \mu\text{g/sample}$ , which equates to a MQC of  $0.08 \text{ mg/m}^3$ , assuming the same air sampling volume.

Twelve samples were collected for butyl cellosolve, but only 3 had detectable concentrations. The analytical LOD was  $0.01 \text{ mg/sample}$ , while the LOQ was  $0.03 \text{ mg/sample}$ , which equates to a MDC of  $0.5 \text{ mg/m}^3$  and a MQC of  $1.4 \text{ mg/m}^3$ , assuming a sampling volume of 22 liters. Two of the three samples had airborne concentrations between the MDC and MQC, with the one sample having a concentration ( $19 \text{ mg/m}^3$ ) greater than the MQC (roller-coat operation). The two samples with detectable concentrations between the MDC and MQC were collected from the litho operation and a press operator in the stamping area. The butyl cellosolve concentrations were  $1.6$  and  $0.9 \text{ mg/m}^3$ , respectively. The airborne concentrations for both oil mist and butyl cellosolve were below their relevant evaluation criteria. However, the airborne concentration of  $19 \text{ mg/m}^3$  for butyl cellosolve collected from the roller-coat machine approached the NIOSH REL. The NIOSH REL for ethylene glycol monobutyl ether (butyl cellosolve, EGBE, 2-butoxyethanol) is  $24 \text{ mg/m}^3$  as an 8-hour TWA.<sup>3</sup> The OSHA PEL is  $240 \text{ mg/m}^3$  as an 8-hour TWA established for the construction industry, while the ACGIH TLV is  $121 \text{ mg/m}^3$  with a skin notation.<sup>4,5</sup>

#### B. Plastic Container Division

The silkscreening operations in the plastic container division were an area of concern because they were not equipped with any exhaust ventilation systems. Detector tube measurements for monostyrene were taken in several areas of the plastics production area. The levels of monostyrene ranged from not detected to approximately 5 ppm. However, these detector tubes are not very accurate ( $\pm 15$  to 20%) and were only used to identify areas where exposures could occur.

During the survey on February 16, 1990, environmental air samples were collected for potential contaminants from the manual silkscreen, injection molding, and blow molding. The automatic (offset) silkscreen was not operating. Samples for butyl cellosolve, naphthas, perchloroethylene, and formaldehyde were collected during the manual silkscreen operation. Neither of the two personal breathing zone samples for butyl cellosolve collected during the operation had detectable amounts. The MDC and MQC were the same as those described previously. Four additional personal breathing zone samples were collected for naphthas and perchloroethylene. The airborne naphtha concentrations are included in Table I. The naphtha concentrations ranged from  $3.5$  to  $3.6 \text{ mg/m}^3$ . However, none of the concentrations were above the MQC of  $5.3 \text{ mg/m}^3$ . The analytical LOD for these samples was  $0.1 \text{ mg/sample}$ , with a MDC of  $1.8 \text{ mg/m}^3$ , assuming a sampling volume of 56.5 liters, while the LOQ was  $0.3 \text{ mg/sample}$ . The airborne concentrations of perchloroethylene ranged from  $0.08$  to  $0.1 \text{ ppm}$ . One sample was between the MDC and MQC of  $0.03$  and  $0.08 \text{ ppm}$ , respectively. The MDC and MQC were determined from the analytical LOD of  $0.01 \text{ mg/sample}$  and the LOQ of

0.03 mg/sample, assuming a sampling volume of 56.5 liters. The concentrations for all of the contaminants were below their relevant evaluation criteria.

Two general area air samples for formaldehyde were collected during the manual silkscreen operation (Table IV). The concentrations for both these samples was determined to be 0.02 ppm; between the MDC and MQC of 0.01 and 0.02 ppm, respectively, assuming a sampling volume of 138 liters. The analytical LOD and LOQ for these samples were 1.0 and 3.4  $\mu\text{g}/\text{sample}$ , respectively. The two sample concentrations were above the NIOSH REL of 0.016 ppm, which is based on the lowest, reliable detection limit. However, NIOSH recommends that potential exposures to formaldehyde be reduced to the lowest feasible concentration.

Eight general area air samples to screen for hydrocarbons and aldehydes were collected from the injection and blow molding processes, and two additional area samples were collected from the manual silkscreen. Several hydrocarbons were identified on two samples submitted for qualitative analysis including hexanes, 1,1,1-trichloroethane, toluene, perchloroethylene, xylenes, *t*-butyl isothiocyanate, and several aliphatic and aromatic hydrocarbons. A small benzene peak was identified on one of the sample chromatograms. The chromatograms for these two samples are included in the appendix. The remaining charcoal tubes were then analyzed quantitatively for 1,1,1-trichloroethane, perchloroethylene, and total hydrocarbons. Airborne concentrations ranged from non-detected to 0.22 ppm for 1,1,1-trichloroethane, 0.03 to 0.23 ppm for perchloroethylene, and 0.48 to 3.5  $\text{mg}/\text{m}^3$  for total hydrocarbons. The MDCs and MQCs for these samples were 0.03 and 0.1 ppm, 0.03 and 0.09 ppm, and 0.20 and 0.60  $\text{mg}/\text{m}^3$  for 1,1,1-trichloroethane, perchloroethylene, and total hydrocarbons, respectively. These were determined assuming a sampling volume of 50.4 liters. The LODs and LOQs for these contaminants were 0.01 and 0.03  $\text{mg}/\text{sample}$ , respectively. Formaldehyde was the only compound detected in the aldehyde screen. The levels of formaldehyde were estimated to be between 0.5 and 2  $\mu\text{g}/\text{sample}$ , which equates to estimated formaldehyde concentrations between 0.02 and 0.08 ppm, assuming a sampling volume of 20.1 liters.

Additional environmental air sampling was performed on March 7, 1990, when the automatic (offset) silkscreen was in operation. Five general area samples for formaldehyde and seven personal breathing zone samples for butyl cellosolve were collected. The airborne concentrations of formaldehyde are included in Table IV. The concentrations ranged from 0.067 to 0.28 ppm, with an average of 0.15 ppm. The highest concentrations were found on the silkscreener and at the entrance and exit of the curing oven. These concentrations are below the OSHA PEL of 0.75 ppm, but are above the 0.1 ppm limit where worker training is required. One of the concentrations approached the ACGIH TLV of 0.3 ppm, ceiling, which is not to be exceeded. NIOSH recommends that these concentrations be reduced to the lowest feasible concentration. The seven samples for butyl cellosolve had concentrations ranging from non-detected to 3.3  $\text{mg}/\text{m}^3$ . None of the samples with detectable amounts had concentrations above the MQC. The analytical LOD and LOQ were 0.01 and 0.03  $\text{mg}/\text{sample}$ , which equate to an MDC and MQC of 1.6 and 4.9  $\text{mg}/\text{m}^3$ , respectively, assuming a sampling volume of 6.1 liters.

## **VII. CONCLUSIONS**

Based upon the environmental sampling results, employees performing the silkscreen operations are exposed to formaldehyde in excess of the NIOSH REL which recommends reducing exposures to the lowest feasible concentrations. Employees working at the paint booths, litho, and roller-coat are not overexposed to naphthas, toluene, MEK, or butyl cellosolve. However, improving the existing ventilation controls and the installation of additional controls will further reduce employee exposures.

## VIII. RECOMMENDATIONS

Recommendations are based on the ventilation survey, environmental air sampling results, and observations made during the investigation. Original recommendations concerning the ventilation controls were reported in a letter dated July 10, 1989, from NIOSH engineers after the initial site visit (see appendix). Additional recommendations follow.

1. The feasibility of substituting formaldehyde-containing coatings and inks with products which do not contain formaldehyde should be investigated. Caution should be used so that substitution with a more toxic product does not occur.
2. The drying ovens in the painting, roller-coat, litho, and both silkscreen operations should be properly ventilated with local exhaust ventilation (see appendix). Upgrades to the paint booths and existing local exhaust ventilation systems should be implemented. These upgrades should include the control of exposures during the actual roller-coat, litho, and silkscreen application. A ventilation contractor, who is experienced with local exhaust ventilation systems, should be consulted to ensure proper design and operation.
3. Employees who may be exposed to formaldehyde at or above 0.1 ppm must receive hazard communication training in compliance with OSHA formaldehyde regulations (29 CFR 1910.1048). The products containing formaldehyde must be labeled if airborne concentrations are likely to reach 0.5 ppm. The label must state that the product contains HCHO, give the name and address of a responsible party, and a statement that the physical and health hazard information is available from the employer and from the MSDS. The regulation requirements would include both employees and products involved in the silkscreen operations. Additional employee exposure monitoring for formaldehyde should be conducted in response to employee complaints.
4. Employees who use products containing butyl cellosolve should use proper personal protective equipment (PPE) to prevent skin contact. The PPE should be made of material resistant to butyl cellosolve (i.e., butyl rubber or Saranex®).



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## **APPENDIX**

SAMPLE "A" CHROMATOGRAM FOR HYDROCARBON SCREEN

SAMPLE "B" CHROMATOGRAM FOR HYDROCARBON SCREEN

LETTER DETAILING VENTILATION RECOMMENDATIONS