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Sommer–Allibert Industries, USA, Inc.
Kansas City, Missouri

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PREFACE

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This report was prepared by Gregory M. Kinnes and Vincent D. Mortimer, HETAB, Division of Surveillance, Hazard Evaluations, and Field Studies (DSHEFS). Analytical support was provided by Ardith A. Grote and Data Chem Laboratories, Inc. Desktop publishing was performed by Denise Ratliff. Review and preparation for printing was performed by Penny Arthur.

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SUMMARY

On February 12, 1997, the National Institute for Occupational Safety and Health (NIOSH) received a confidential request for a health hazard evaluation (HHE) from employees of Sommer–Allibert Industries, USA, Inc. (SAI) in Kansas City, Missouri. The request was prompted by the reported occurrence of adverse health effects that employees associated with exposures to airborne contaminants from the paints and coatings used during the manufacture of automotive fascia (plastic front and rear bumpers). On April 28–29, 1997, investigators from NIOSH visited the SAI facility to conduct environmental sampling and evaluate the existing ventilation systems in the paint kitchen. Environmental air samples were collected for acetone, butyl alcohol, isopropanol, isobutanol, naphtha, toluene, butyl acetate, ethylbenzene, aromatic naphtha, xylenes, methanol, methyl ethyl ketone (MEK), and formaldehyde.

Formaldehyde concentrations determined for four area air samples ranged from 0.03 to 0.11 parts per million (ppm). These concentrations were above the NIOSH Recommended Exposure Limit (REL) of 0.016 ppm as a time–weighted average (TWA). In addition, one area sample collected in the distribution area had an airborne formaldehyde concentration (0.11 ppm) which equaled the NIOSH ceiling limit of 0.1 ppm. Although NIOSH has established numerical RELs for formaldehyde, it also considers formaldehyde to be a suspected human carcinogen and recommends that exposures be reduced to the lowest feasible concentration. All of the TWA concentrations for the remaining analytes calculated for each of the three areas in the paint kitchen and the paint mixers were well below their relevant evaluation criteria. In addition, all of the short–term exposures determined during this investigation were well below the relevant evaluation criteria for all the analytes, where applicable. The potential additive effects of exposure to these solvents on the central nervous and respiratory systems was also assessed. Three samples collected from the paint mixers and the average area concentrations for the distribution area indicated the potential for excessive solvent exposures. Although half–mask air–purifying respirators, which reduced worker exposures to these solvents, were required in the distribution area, these respirators did not protect against exposure to formaldehyde. The ventilation assessment and the environmental sampling results indicated that the ventilation system for the paint kitchen was not adequate and that improvements to the existing system were needed.

The NIOSH investigators determined that paint mixers can be exposed to airborne formaldehyde in excess of the NIOSH REL while working in the paint kitchen. Airborne concentrations of acetone, methanol, butyl alcohol, isobutanol, isopropanol, butyl acetate, MEK, ethylbenzene, toluene, naphtha, aromatic naphtha, and xylenes were all below their relevant individual evaluation criteria. Even though half–mask air–purifying respirators were utilized by the paint mixers while working in the distribution area, their use did not reduce the potential for exposure to formaldehyde, and the respiratory protection program needs to be reviewed to correct other reported deficiencies. The ventilation assessment and environmental sampling indicated that the ventilation system was not adequate in the distribution area and that improvements to the existing system were needed.

Keywords: SIC 3714 (Motor Vehicle Parts and Accessories) acetone, methanol, butyl alcohol, isobutanol, isopropanol, butyl acetate, methyl ethyl ketone, MEK, ethylbenzene, toluene, naphtha, aromatic naphtha, xylenes, formaldehyde, painting, automotive fascia, bumpers, pneumatic spray painting.

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INTRODUCTION

On February 12, 1997, the National Institute for Occupational Safety and Health (NIOSH) received a confidential request for a health hazard evaluation (HHE) from employees of Sommer–Allibert Industries, USA, Inc. (SAI) in Kansas City, Missouri. The request was prompted by the reported occurrence of adverse health effects that employees associated with exposures to airborne contaminants from the paints and coatings used during the manufacture of plastic automotive fascia (front and rear bumpers). The request stated that employees in the paint kitchen were experiencing headaches, dizziness, skin rashes, drowsiness, eye irritation, and dry mouth. The request also indicated that previous environmental monitoring found excessive air concentrations of aromatic naphtha (previously reported as coal tar naphtha) and that employees were provided half–face air–purifying respirators to protect against exposure to this solvent. However, employees reported that they were concerned because replacement cartridges for the respirators were frequently not available.

A NIOSH investigator contacted the requestor and the SAI official responsible for health and safety to gather information concerning the request and to discuss the scope of the NIOSH investigation. Information on the operation of the paint kitchen, results from previous industrial hygiene surveys, and the material safety data sheets (MSDS) for the paints, coatings, and solvents used in the paint kitchen was requested and reviewed. During these discussions, the SAI contact also requested that the NIOSH investigators conduct an evaluation of the existing ventilation systems operating in the paint kitchen.

On April 28–29, 1997, investigators from NIOSH visited the SAI facility to conduct environmental sampling and evaluate the ventilation systems in the paint kitchen. On April 28, 1997, an opening conference was held with SAI and employee representatives to discuss the request and conduct a walk–through inspection of the facility to familiarize the NIOSH investigators with the manufacturing process, worker responsibilities, and the operation of the ventilation systems in the paint kitchen. On April 29, 1997, the NIOSH investigators evaluated potential employee exposures to the paints, coatings, and various solvents in the paint kitchen and conducted an assessment of the existing ventilation systems. Preliminary recommendations based on initial observations were provided during both the April 1997 site visit and subsequent conversations with the SAI health and safety representative.

BACKGROUND

Facility Information

SAI is a manufacturing facility that utilizes injection molding of thermoset plastics to produce plastic automotive fascia (front and rear bumpers). At the time of the NIOSH investigation, the facility employed approximately 120 full–time employees and a varying number of temporary employees on three shifts at their Kansas City, Missouri facility. During full production, the plant capacity is 3,000 fascia (painted parts) per day. The fascia are manufactured in one of four injection molding machines (300 ton presses) that can produce parts at the rate of 45 parts per hour each for a total facility capability of 180 parts per hour. Each of the parts weigh approximately ten pounds. Bumpers that do not meet production criteria can be recycled by grinding and then remelting before introduction back into the injection molding process. After being molded, the fascia are placed on a robotic paint line. The robotic paint line sprays the parts with three different coats. The first coat applied is an adhesive promoter, which increases the surface area on the part to promote adhesion of the subsequent coats. The second coat is the base coat which provides the coloring to the fascia. The paint line can apply one of 26 different colors which are all mixed in the paint kitchen. The third coat is a clear coating that provides the finish to the parts. After the bumpers are painted, they are cured in an oven, allowed to cool, and then prepared for shipment to an automotive assembly facility.

The paint kitchen is a separate rectangular building attached to the main facility where the various coatings are stored, prepared, and distributed to the robotic paint line. All the coating materials are pneumatically conveyed and continuously recycled to the robotic paint line through carrier lines from pneumatic mixing totes located in the paint kitchen. The paint kitchen is physically separated by walls and automatic fire doors into three areas: storage, preparation, and distribution. The largest of these three areas is the storage area. Many of the various coatings and numerous solvents for the coatings are shipped in 55 gallon drums and are stored in this area. The second or middle area is the preparation area where drums of the various coatings and solvents are kept for easy access. Many of these drums are tapped, electrically grounded, and kept on horizontal racks. The third area is the distribution area which houses all of the pneumatic mixing totes and components of the recirculation system. All the coating carrier lines are connected to the main facility in this area. There are approximately 26 pneumatic mixing totes for the various colored base coats, adhesive promoter, and finishing clear coat.

There are typically one or two paint mixers who work in the paint kitchen per shift. All of the various colored base coats, the adhesive promoter, and the finishing coat have specific formulas and viscosities which have to be maintained for the pneumatic distribution system to properly supply the robotic paint line. The main task of the paint mixers is to periodically check the viscosity of all the mixing totes, and, based on the formulation for the individual coating, either manually add solvents or raw coating to keep the liquid at the specified viscosity. The paint mixers also refill the totes as needed. The solvents and raw coatings are obtained in the preparation area and carted into the distribution area by the paint mixers. The paint mixers are also responsible for moving the 55 gallon drums of solvents or raw coatings to and from the storage area as needed.

Approximately 75% of the paint mixer's time is spent in the distribution area checking the mixing totes. The remaining 25% of their work time is split between the preparation and storage areas. All of the mixing totes are covered, but are not hermetically sealed. Therefore, the volatilization of the solvents and coatings continuously occurs from the mixing totes. Because the mixing process generates most of the airborne contaminants, the paint mixers are required to wear half–mask air–purifying respirators when working in this distribution area. No respiratory protection is required in the other two areas. The paint mixers also use various types of protective gloves when handling the solvents and coatings.

At the time of this investigation, this facility was operating near full–capacity. However, several months after this investigation, SAI was in the process of downsizing and shutting down the painting processes at this facility. The plant went through a period of running at less than 30% capacity while operating only one shift. In February 1998 the facility ceased its painting operations entirely. In discussions with the SAI health and safety representative, it was indicated that the painting operations were transferred to another SAI facility and that SAI was considering the conversion to either a water–based or isocyanate–based coating system instead of the present solvent–based system. This representative also indicated that, if this plant reopens for the purposes of resuming painting operations, it would be equipped with additional emission control devices.

Ventilation System Description

Ventilation for the 70–foot (ft)–long by 55–ft–wide paint–room is provided by a continuous–flow, non–recirculating system. Outside air (100 percent) is supplied by a roof–top air–handling unit located midway along and just north of the longitudinal axis of the building projection which houses the paint processing. The supply air handler is situated with the 7–ft by 2–ft outside air intake opening at the bottom of a rain shroud, 18 inches above the roof surface, on the west end of the unit. A separate axial fan, located in the northwest quadrant of the roof area, exhausts air from building. The 36–inch–diameter exhaust fan discharge is 45 inches above the roof surface, 16 feet west and 3 feet north of the closest corner of the outside air intake of the supply air handler.

Inside the structure, the supply ductwork consists of three branches, one for each room (storage, preparation and distribution), located just below the 14–ft high ceiling. The supply diffusers are located on either the bottom or side surface of the 18–inch by 12–inch supply ductwork, which branches from the main 18–inch square trunk.

Three updraft exhaust vents, located at floor level in each room, are the inlet openings of the exhaust ductwork. The duct and opening in the storage room was 30 inches by 10 inches; in the preparation room, 15 inches by 10 inches; and in the distribution room, 14 inches by 12 inches.

METHODS

Environmental Assessment

Environmental sampling was conducted for several of the possible contaminants present in the paint kitchen. Since the painting and coating processes employed by SAI utilized several different solvents, a review of the MSDSs for the products used in the paint kitchen was conducted to develop an environmental sampling protocol. Based on the variety of solvents potentially present and the need to limit the number of analytical methods employed, a flexible sampling protocol was developed. Since many of the solvents could be adequately collected on activated charcoal sorbent tubes, air samples utilizing this sorbent media were collected using two different flowrates (50 & 200 millimeters [mm] of air per minute) to ensure the presence of adequate analyte and prevent analyte breakthrough. These samples were collected in conjunction with samples collected using thermal desorption tubes. The thermal desorption tubes would be qualitatively analyzed prior to the analysis of the other samples to identify the predominant compounds present in the paint kitchen. Once the predominant compounds were identified, the analytical conditions could be optimized during the subsequent analysis of the charcoal sorbent tubes to ensure adequate separation and quantification. Additional samples were collected for the various compounds that could not be adequately collected and analyzed using charcoal sorbent tubes. These samples were collected using other sampling media. Table 1 summarizes all of the air sampling and analytical methods used in this evaluation.[1] Utilizing this flexible protocol, air concentrations were determined for acetone, butyl alcohol, isopropanol, isobutanol, naphtha, toluene, butyl acetate, ethylbenzene, aromatic naphtha, xylenes, methanol, methyl ethyl ketone (MEK), and formaldehyde.

All air samples were collected with the appropriate sorbent tube media or impinger solution connected via Tygon® tubing to calibrated battery–operated sampling pumps. Sequential sampling, i.e., periodically changing the sample media throughout the shift, was utilized for several of the area and personal breathing zone (PBZ) samples to minimize the potential for analyte breakthrough. The area and PBZ sample concentrations were calculated with the actual monitoring time. Calibration of the air sampling pumps with the appropriate sampling media was performed before and after each monitoring period. Field blanks were submitted to the laboratory for each analytical method.

The thermal desorption tube samples, used for the qualitative analysis to identify the airborne contaminants, were collected from four locations throughout the facility. These four locations included the distribution area, preparation area, and storage area in the paint kitchen, and the main plant. Both area and PBZ samples were collected to determine employee exposures to the airborne contaminants identified by the qualitative sampling using the thermal desorption tubes. Area air samples were collected in all three areas of the paint kitchen. Area air samples utilizing charcoal sorbent tubes were collected from four area locations throughout the distribution area. One of these locations included a sample collected with ORBO 90 (for MEK) sorbent tubes while another location included a sample collected with silica gel (for methanol) sorbent tubes. Area air samples utilizing charcoal sorbent tubes were collected from three locations in the preparation area including one location where ORBO 90 and silica gel samples were also collected. Area air samples were also collected from three locations in the storage area utilizing the same methodology as in the preparation area. Four sequential samples were collected to prevent sample breakthrough from each location in both the distribution and preparation areas. The four sequential samples were then utilized to determine the time–weighted average over the sampling period. Because the contaminant concentrations were expected to be much lower in the storage area than the other two areas, only one sorbent tube was used for each of the area samples collected in the storage area. In addition to the area samples collected with the sorbent tube media, four area air samples for formaldehyde were collected utilizing impingers from four separate locations in the paint kitchen. These included two locations in the distribution area, and one location each in the preparation and storage areas.

PBZ samples were collected from one paint mixer who was working during the first shift and from both the paint mixers who worked the second shift. During the first shift, PBZ samples utilizing both charcoal and ORBO 90 sorbent tubes were collected. Six sequential samples were collected from this paint mixer to determine the full–shift time–weighted average. Two of the sequential samples were collected for short durations (17 & 20 minutes), so that the results could be compared to the applicable short–term exposure limit (STEL) criteria. These STEL samples were collected when the paint mixer manually changed tote drums. Due to the expected battery life of the sampling pumps, the PBZ samples for the paint mixers working the second shift were only collected during the first part of the shift. Samples utilizing both charcoal and ORBO 90 sorbent tubes were collected from one of the paint mixers, while charcoal sorbent tubes utilizing both flowrates (50 & 200 mm of air per minute) were collected from the other paint mixer on the second shift. Two sequential samples were collected from the paint mixer who wore both the charcoal and ORBO 90 sorbent media. However, the second sequential sample was a STEL sample of only a short duration (15 minutes) collected during the change of tote drums. PBZ samples for methanol were not collected during this investigation.

Ventilation Assessment

The ventilation was evaluated by measuring the air flow exhausted from the paint kitchen. The airflow was first estimated by measuring the velocity of the air exiting the exhaust fan on the roof. Then a pitot tube was used to traverse the exhaust branch ducts inside the paint kitchen. More than one set of readings was obtained, and the average was used to calculate the amount of air exhausted from each room. Due to the location and configuration of the make–up air supply fan and ductwork, the supply airflow was not measured.

A micromanometer was used to measure the difference in pressure of the various rooms of the paint kitchen with respect to the outside of the building. The direction of the pressure differential was confirmed using a smoke tube.

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 increases the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs),[2] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[3] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[4] Employers are encouraged to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion.

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

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

A brief toxicity review and the exposure criteria for several of the contaminants that were identified during this investigation are included in Table 2. This list is not inclusive to all contaminants that may be present in the paint kitchen, but represent the contaminants of particular concern due to their toxicity.

Mixtures (Equivalent exposure criterion)

Concurrent exposure to two or more hazardous substances which act upon the same target organ system may be considered as additive exposures. In the absence of information to the contrary, the combined effect, rather than that of either individually, should be given primary consideration when evaluating worker exposure to substances with similar physiologic effects.

To evaluate the additive effect, the exposure level of each substance is computed as a fraction of the evaluation criterion for that substance. If the sum of these fractions exceeds unity (1.0), employee exposure to that mixture of substances is excessive. This concept is described by the following formula:

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

where Cn indicates the observed atmospheric concentration of an air contaminant and Tn refers to the corresponding occupational health exposure criterion.[2,3,4] (The underlying assumption is that each of the relevant exposure criteria used for this computation was established to prevent the same "additive effects" and not for control of some other health effect unique to one of the substances.)

When evaluating exposure to chemical mixtures, it is important to note that synergistic action or potentiation may occur with some combinations of atmospheric contaminants. A synergistic effect is where the combined effect of two (or more) chemicals is much greater than the sum of the effect from separate exposure to the chemicals.[5] Potentiation is when a chemical agent does not have a toxic effect on an organ system, but when present with exposure to another chemical agent, it makes that agent much more toxic.[6] Applying the equivalent exposure evaluation criteria for synergistic or potentiating cases may underestimate the true impairment to the workers' health as a result of exposure to chemical mixtures.

Ventilation

There are no OSHA standards for ventilation other than the performance standards that ventilation should be adequate to maintain worker exposures to the workplace contaminants below the permissible exposure limit. However, other organizations acknowledged as authorities in industrial ventilation have published recommendations.

The American Society of Heating, Refrigerating and Air–Conditioning Engineers (ASHRAE) states that humidity is important in reducing static electricity, which is extremely dangerous in explosive atmospheres, and recommends a minimum value of 35% relative humidity.[6]

ASHRAE, citing a National Fire Protection Association code, cautions that combustible vapor–air mixtures should be diluted to less than 25% of the lower explosive limit (LEL) of the vapor.[7] The ACGIH concurs that fire and explosion can be prevented if concentrations of combustible vapors are kept below 25% of the LEL; however, they remind the reader that such atmospheres may be hazardous to health, as occupational health exposure limit concentrations are always more restrictive. They both give procedures and equations for calculating the amount of ventilation needed.[8]

In another reference, ASHRAE recommends that the exhaust stack be designed and located to prevent reentrainment of exhausted air into supply air inlets. Many factors such as building design, surrounding topography, prevailing wind direction and speed, and exhaust air temperature must be considered in designing the exhaust stack; however, the exhaust stack location should always be downwind of any air intakes. ASHRAE also recommends that the stack discharge velocity be greater than 2500 feet per minute (ft/min).[9]

Make–up or replacement air is necessary in almost all mechanical ventilation applications to replace air being exhausted through the exhaust system or discharged from the building as excess return air. Not only does the provision of make–up air prevent outside air which hasn't been filtered and heated or cooled (depending on the season) from infiltrating through cracks around windows and doors and other openings, but also providing the proper amount of make–up air controls building pressure and airflow from space to space, enabling contaminant concentrations, temperature, humidity and air movement to be controlled.[10]

RESULTS

Environmental Assessment

The results of the environmental monitoring are summarized in Tables 3, 4, and 5. Trace concentrations are defined as being between the analytical limit of detection (LOD) and limit of quantitation (LOQ). The analytical LODs and LOQs for the environmental sampling methods used during this investigation were used to determine the minimum detectable concentrations (MDCs) and minimum quantifiable concentrations (MQCs) which are calculated based on representative sample volumes. The MDCs and MQCs are also presented in these tables where required. The results for each of the analytes are described in detail below.

The results for each of the individual sequential area samples, along with the TWA calculated over the entire sampling period, are summarized in Table 3. The highest concentrations for each of the analytes, except acetone, were found in the distribution room. The highest concentrations for acetone were found in the preparation room. Several of the sequential samples had greater than 30% of the total amount of acetone on the sorbent tube back–up sections indicating that sample breakthrough had occurred. Therefore, the concentrations presented for these samples are most likely underestimations. All of these sequential samples where acetone breakthrough occurred were at the higher flowrate (200 mm per minute) and are noted in Table 3. In addition, all of the samples collected for methanol indicated that sample breakthrough occurred.

Formaldehyde concentrations determined from area samples ranged from 0.03 to 0.11 parts per million (ppm). The two samples collected in the distribution area had concentrations of 0.07 and 0.11 while the preparation and storage areas had concentrations of 0.08 and 0.03 ppm, respectively. As with the other analytes, the highest formaldehyde concentration was found in the distribution area.

The results for each of the individual sequential PBZ samples, along with the TWA and STEL concentrations, are summarized in Table 4. A majority of the highest contaminant concentrations were encountered during the short periods when the tote drums were changed. The range of STEL concentrations in ppm for each of the analytes, except methanol, determined during these tasks included: acetone, 32–168; butyl alcohol, non–detected–8.6; isobutanol, non–detected–4.5; isopropanol, 19–47; butyl acetate, non–detected–8.0; MEK, 20–33; ethylbenzene, non–detected–10; toluene, non–detected–5.3; naphtha, non–detected–21; aromatic naphtha, non–detected–16; and xylenes, trace–38. All of the non–detected or trace values, except those for butyl acetate, were determined on the same single STEL sample, while the higher concentrations were found on the other two STEL samples.

Average TWA concentrations were calculated for each of three areas in the paint kitchen and each of paint mixers. These averages are summarized in Table 5. The average concentrations were used to calculate the cumulative exposures to the mixture of chemicals present in the paint kitchen.

Ventilation Assessment

The exhaust flowrate for the paint kitchen was determined to be approximately 4000 cubic feet per minute (CFM). Roughly half of this was exhausted from the storage room, with the other two rooms splitting the remainder. The actual flowrates for each room, along with the approximate area and volume of the rooms, are presented in Table 6.

While making the measurements, it was noticed that pieces of paper, packing material, and other debris had accumulated on the screens which cover the exhaust duct openings a few inches above the floor in each of the rooms.

On the roof, the exhaust stack was neither located downwind, based on the predominant westerly winds, of the outside air intake, nor terminated high enough above the roof to be above the recirculation region. Also, the discharge velocity was approximately 1200 ft/min, less than half the recommended value.

Overall, the paint kitchen was positively pressurized with respect to outside, that is, air left the paint kitchen any time a door was opened. This means that adequate make–up air was provided to the interior space, preventing unfiltered, unconditioned infiltration air.

DISCUSSION

Environmental Assessment

The environmental sampling conducted in the paint kitchen indicated that the paint mixers who worked in this area are exposed to numerous chemical solvents. These included formaldehyde, acetone, methanol, butyl alcohol, isobutanol, isopropanol, butyl acetate, MEK, ethylbenzene, toluene, naphtha, aromatic naphtha, and xylenes. The area air samples for formaldehyde indicated that the paint mixers encountered airborne formaldehyde concentrations in all three areas of the paint kitchen which were above the NIOSH REL of 0.016 ppm as an 8–hour TWA. In addition, one area sample collected in the distribution area had an airborne formaldehyde concentration (0.11 ppm) which equaled the NIOSH ceiling limit of 0.1 ppm. Although NIOSH has established numerical RELs for formaldehyde, it also considers formaldehyde to be a suspected human carcinogen and recommends that exposures be reduced to the lowest feasible concentration. All of these formaldehyde concentrations were below the ACGIH TLV and OSHA PEL of 0.3 and 0.75 ppm, respectively, for an 8–hour TWA. Since the paint mixers spend most of their time in the paint kitchen where they are potentially exposed to these airborne concentrations, the use of some type of engineering control to reduce exposures or the substitution with coatings which do not contain formaldehyde should be implemented.

As summarized in Table 5, all of the average solvent concentrations calculated for each of the three areas in the paint kitchen and the average PBZ solvent concentrations determined for the paint mixers were well below the evaluation criteria for each of the individual analytes. In addition, all of the STEL concentrations determined during this investigation were well below the relevant evaluation criteria for all the analytes where applicable. According to the NIOSH "Pocket Guide to Chemical Hazards," the central nervous and respiratory systems were listed as target organs for all of the compounds listed in Table 5.[11] Therefore, TLV values for mixtures were determined using the formula for additive effects and the ACGIH TLVs for the individual compounds. The additive effect of the airborne concentrations for all the analytes, except formaldehyde, for the three PBZ samples collected from the paint mixers were less than 1 (0.8, 0.7, & 0.7). A value of 1 or above would indicate an exposure that exceeded the evaluation criteria based on the additive effects. When the average concentrations of the area samples were used to determine the additive effect of the contaminants, a value exceeding 1 was calculated for the distribution area (1.5). The preparation (0.4) and storage (0.1) areas had calculated values which were well below 1. All of these calculations made for the additive effects do not account for the respiratory protection provided by the use of respiratory protection which was required in the distribution area.

All of the potential exposures encountered by the paint mixers discussed above would be reduced due to the appropriate use of the half–mask air–purifying respirators in the distribution area. These respirators utilized activated charcoal cartridges which protect against volatile organic compounds (VOCs). However, these cartridges are not rated for protection against formaldehyde vapors. In addition, one paint mixer working the 2nd shift had to go into the main plant to perform a maintenance check on acid and base tanks. This paint mixer reported that this activity is periodically performed and that he uses the same respirator and cartridges given to him for use in the distribution area of the paint kitchen. These VOC cartridges do not provide adequate protection against acid mists. It was also reported that replacement cartridges for the respirators were frequently not available. Therefore, these reports and observations indicated that SAI needs to review their respiratory protection program. In addition, NIOSH recommends that respiratory protection be used only as an interim control until appropriate engineering controls can be implemented to reduce employee exposures.

Ventilation Assessment

The ventilation appears inadequate considering that the calculated additive effect value from full– and partial–shift personal samples for the two workers in the paint kitchen approached 1.0 even when the effects of formaldehyde were not included. From the area samples, the additive concentration in the distribution room of the paint kitchen exceeded 1.5 without considering formaldehyde, while the concentrations for the other two rooms were well below 1.0. The highest airborne concentration of formaldehyde (0.11 ppm) was also found in the distribution room. This indicates that the distribution room should be the initial focus of improved ventilation.

One alternative would be to increase the ventilation flowrate for the distribution room to not less than 2000 CFM, which would theoretically reduce the additive concentrations to below 1.0. To enact this alternative, the existing exhaust fan and supply fan might need to be replaced, or a new separate supply/exhaust system could be installed for the distribution room. Although this may be the simplest alternative to implement, the drawbacks are the lack of certainty that the installed increase would be adequate, especially considering the possible switch to paints containing isocyanate compounds.

Another alternative would be to install local exhaust ventilation around each of the “totes”. Of course, additional ventilation exhaust and supply capacity would have to be installed also, but the likelihood of achieving effective control of solvent emissions is high. Although this may be the most effective control, the drawback of this alternative is the difficulty finding room around the tote stations for properly placed exhaust hoods. A third alternative would be to switch to hermetically sealed totes. This would minimize the emission of solvent vapors.

CONCLUSIONS

Based on the environmental sampling results, it was determined that paint mixers can be exposed to airborne formaldehyde concentrations in excess of the NIOSH REL while they are working in the paint kitchen. Area air concentrations of formaldehyde were above the NIOSH REL for formaldehyde of 0.016 ppm in all three areas of the paint kitchen, with one concentration which equaled the NIOSH ceiling limit of 0.1 ppm. Athough the environmental sampling results also indicated that the airborne concentrations of acetone, methanol, butyl alcohol, isobutanol, isopropanol, butyl acetate, MEK, ethylbenzene, toluene, naphtha, aromatic naphtha, and xylenes were all below their relevant individual evaluation criteria, the additive effects of these solvents is of concern due to both central nervous system and respiratory effects. The PBZ samples collected from the paint mixers all had cumulative exposures, calculated using the ACGIH TLVs and formula for additive effects, which approached 1, while the distribution room had a cumulative concentration which exceeded 1. Even though half–mask air–purifying respirators were utilized by the paint mixers while working in the distribution area to reduce their exposure potential, their use did not reduce the exposure potential to formaldehyde. In addition, the respiratory protection program needs to be reviewed to correct other reported deficiencies. The ventilation assessment and environmental sampling indicated that this system was not adequately reducing the solvent concentrations in the distribution area and that improvements to the existing system were needed. Although the painting operations at this facility have ceased, the findings from this investigation may still be generally applicable to similar painting operations at other SAI facilities.

RECOMMENDATIONS

The following recommendations are based on the environmental sampling results, ventilation system evaluation results, and observations made during this investigation and are offered in the interest of improving health and safety conditions for employees if the painting operations at this facility are eventually resumed. These recommendations may also be generally applicable to similar painting operations at other SAI facilities.

1. Improve the ventilation of the Paint Distribution room by either increasing the ventilation flowrate for the Distribution Room to not less than 2000 CFM, installing local exhaust ventilation around each of the

"totes," or replacing the existing totes with hermetically sealed totes. Note that, even if hermetically sealed totes are installed, the existing ventilation should be retained.

2. Develop and follow a schedule of routine maintenance and cleaning of the ventilation system, especially the screens at the updraft openings a few inches above the floor in each of the rooms. These screens become obstructed with debris, and the flow into the exhaust ventilation system is reduced.

3. Increase the stack height of the exhaust from the paint kitchen. Given the adjacent wall of the main portion of the plant, the stack should terminate at least 10 feet above the top of that wall. The velocity of the exhaust discharge should be increased to be greater than 2500 ft/min. The exhaust can be augmented with air supplied by a separate fan on the roof for this purpose.

4. SAI should establish an appropriate schedule for replacement of the respirator cartridges and ensure that an adequate supply is readily available. SAI should also ensure that appropriate cartridges to protect against all the airborne contaminants, including VOCs, formaldehyde, and acid mists, are used. Several manufacturers currently offer respirator cartridges that are rated as providing adequate protection to these types of contaminants.

5. SAI should review its current respiratory protection program to ensure that it complies with all the requirements described in 29 CFR 1910.134.[12] Publications developed by NIOSH which should also be referenced, include the NIOSH Guide to Industrial Respiratory Protection and NIOSH Respirator Decision Logic.[13,14] The written program should designate one individual with the responsibility for administering the respiratory protection program. The written respirator program should also contain information on the following topics: (a) the departments/operations which require respiratory protection; (b) the correct respirators required for each job/operation; (c) specifications that only NIOSH/Mining Safety and Health Administration (MSHA) approved respiratory devices shall be used; and (d) the criteria used for the proper selection, use, storage and maintenance of respirators, including limitations. A respiratory protection program should include the following elements:

a. written operating procedures
b. appropriate respirator selection
c. employee training
d. effective cleaning of respirators
e. proper storage
f. routine inspection and repair
g. exposure surveillance
h. program review
i. medical approval
j. use of approved respirators

All of these elements are discussed in more detail in the referenced materials.

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Table 1
Summary of Sampling and Analytical Methods
SAI Automotive USA–Kansas City, Inc., Kansas City, MO (HETA 97–0106–2770)

Analyte(s)	Flow Rate (cc/min)	Sample Media	Analytical Method(s)	Comments
Qualitative Volatile Organic Compound (VOC) Screen	50	Thermal desorption tubes	Samples analyzed using the Tekmar thermal desorber interfaced directly to a gas chromatograph and a mass spectrometry detector (GC/MS)	Each thermal desorption (TD) tube contains three beds of sorbent materials: (1) a front layer of Carbotrap C; (2) a middle layer of Carbotrap; and (3) a back section of Carbosieve S–III.
Acetone, Butyl alcohol, Isopropanol, Isobutanol, Naphtha, Toluene, Butyl acetate, Ethylbenzene, Aromatic naphtha, Xylenes, and MEK*	200 & 50	Activated charcoal sorbent tubes (100 mg front section / 50 mg back section)	Combination of NIOSH Method Nos. 1300, 1401, 2500, 1550, 1501, and 1450; analysis by GC–FID with modifications	Samples were desorbed for 30 minutes in 1 mL of carbon disulfide. Two capillary columns with two different oven conditions were utilized: 30 m x 0.25 mm fused silica coated internally with 0.25 µm of DB–1 followed by 30 m x 0.32 mm fused silica coated internally with 0.5 µm of DBWAX. Naphtha was quantatited against heptane standards while the aromatic naphtha was quantatited against 1,3,5–trimethylbenzene standards.
MEK and Acetone[†]	200	ORBO 90 sorbent tube (160 mg front section / 80 mg back section of Carboxen™–564 carbon molecular sieve)	NIOSH Method Nos 1300 and 2500, analysis by GC–FID with modifications	Samples were desorbed for 30 minutes in 1 mL carbon disulfide containing 1 µL of benzene as an internal standard. Capillary column used was 30 m x 0.32 mm fused silica coated internally with 1.0 µm of DB–5ms. Although acetone was also analyzed using this method, no acetone concentrations determined with this method were reported due to analyte break–through. All reported acetone concentrations were determined using the charcoal tube method.
Methanol	200	Silica gel sorbent tube	NIOSH Method No. 2000, analysis by GC–FID with modifications.	Samples were desorbed for 4 hours in 1 mL of DDI water. Capillary column used was 30 m x 0.52 mm fused silica coated internally with 7.0 µm of Rtx–1.
Formaldehyde	1000	Impinger with 20 mL of 1% sodium bisulfite solution	NIOSH Method No. 3500, analysis by visible spectroscopy	Color was developed by adding 0.1 mL of 1% chromotropic acid and 6 mL concentrated sulfuric acid to each sample.

cc/min = cubic centimeters or milliliters of air per minute
mg = milligram
GC–FID = Gas chromatography–flame ionization detector
m = meter
µm = micrometer
MEK = Methyl ethyl ketone
mL = milliliter
mm = millimeter
µL = microliter
DDI = distilled deionized

*Although MEK analysis was also conducted on these samples, these values were not reported, unless noted. Reported MEK concentrations were determined using the validated NIOSH method for MEK.

[†] Although analysis for acetone was also conducted on these samples, these values were not reported. Most of these samples had analyte breakthrough; therefore, reported acetone concentrations were determined using the other analytical method listed for acetone.

Table 2
Toxicity and Exposure Criteria Information
SAI Automotive USA–Kansas City, Inc., Kansas City, MO (HETA 97–0106–2770)

Compound	Toxicity Review*	NIOSH[†] REL	OSHA[†] PEL	ACGIH[†] TLV®
Acetone	Acetone is an irritant of the eyes and mucous membranes of the nose and throat; at very high concentrations it is a central nervous system (CNS) depressant. A recent control study found slight but statistically significant performance decrements on several neurobehavioral tests following 4–hour exposure to 250 ppm, suggesting mild CNS depression at this level.	250 ppm	1000 ppm	500 ppm 750 ppm STEL
***n*–Butyl alcohol**	*n*–Butyl alcohol is an irritant of the eyes and mucous membranes and may cause CNS depression at very high concentrations. Chronic exposure to concentrations above 50 to 200 ppm causes irritation of the eyes with lacrimation, blurring of vision, and photophobia. Contact dermatitis of the hands may occur due to defatting action of the liquid, and toxic amounts can be absorbed through the skin.	50 ppm ceiling (S)	100 ppm	50 ppm ceiling (S) *Notice of Intended Changes:25 ppm ceiling limit*
Toluene	Toluene causes CNS depression, and can cause acute irritation of the eyes, respiratory tract, and skin. Since it is a defatting solvent, repeated or prolonged skin contact will remove the natural lipids from the skin which can cause drying, fissuring, and dermatitis. Studies have shown that subjects exposed to 100 ppm of toluene for six hours complained of eye and nose irritation, and in some cases, headache, dizziness, and a feeling of intoxication (narcosis).	100 ppm 150 ppm STEL	200 ppm 300 ppm ceiling	50 ppm (S)
***n*–Butyl acetate**	Butyl acetate causes irritation of mucous membranes and the eyes; at high concentrations, it causes narcosis in animals and it is expected that severe exposure will cause the same effect in humans. In humans, *n*–butyl acetate affected the throat at 200 ppm; severe throat irritation occurred at 300 ppm, and the majority of the subjects also complained of eye and nose irritation.	150 ppm 200 ppm STEL	150 ppm	150 ppm 200 ppm STEL
Formaldehyde	Formaldehyde is an irritant of the eyes and the respiratory tract: it causes both primary irritation and sensitization dermatitis; and at high levels, it is carcinogenic in experimental animals and is considered a suspected human carcinogen. The first 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.	0.016 ppm 0.1 ppm ceiling[‡] **Ca**	0.75 ppm 2 ppm STEL	0.3 ppm ceiling **Ca** *Notice of Intended Changes: Sensitizer*
Ethyl benzene	Ethyl benzene is an irritant of the skin, eyes, and mucous membranes; at high concentrations, it causes neurological and respiratory depression. When chronic exposures exceed 100 ppm, complaints include fatigue, sleepiness, headache, and mild irritation of the eyes and respiratory tract. Animal studies have shown slight liver and kidney effects.	100 ppm 125 ppm STEL	100 ppm	100 ppm 125 ppm STEL *Notice of Intended Changes: confirmed animal carcinogen with unknown relevance to humans*
Isobutyl alcohol	At high concentrations, isobutyl alcohol causes narcosis in animals, and it is expected that severe exposure in humans would produce the same effect. Skin exposure can cause mild irritation and slight erythema and hyperemia.	50 ppm	100 ppm	50 ppm

Table 2 (continued)
Toxicity and Exposure Criteria Information
SAI Automotive USA–Kansas City, Inc., Kansas City, MO (HETA 97–0106–2770)

Compound	Toxicity Review*	NIOSH† REL	OSHA† PEL	ACGIH† TLV®
Isopropyl alcohol	Isopropyl alcohol is an irritant of the eyes and mucous membranes; at very high doses, it causes CNS depression. Human subjects exposed to 400 ppm for 3 to 5 minutes experienced mild irritation of the eyes, nose, and throat; at 800 ppm, the irritation was not severe, but the majority of subjects considered the atmosphere uncomfortable.	400 ppm 500 ppm STEL	400 ppm	400 ppm 500 ppm STEL *Notice of Intended Changes:* 200 ppm 400 ppm STEL *not classifiable as a human carcinogen*
Methyl ethyl ketone (MEK)	MEK is an irritant of the eyes, mucous membranes, and skin; at high concentrations, it causes narcosis in animals, and it is expected that severe exposure in humans will produce the same effect. 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. Although not highly neurotoxic itself, MEK may potentiate substances known to cause neuropathy.	200 ppm 300 ppm STEL	200 ppm	200 ppm 300 ppm STEL
Methanol	Methanol causes optic neuropathy, metabolic acidosis, and respiratory depression. Although methanol poisoning has occurred primarily from the ingestion of adulterated alcoholic beverages, symptoms also can occur from inhalation or absorption through the skin. Exposure to vapor concentrations ranging from 365 to 3080 ppm may result in blurred vision, headache, dizziness, and nausea.	200 ppm 250 ppm STEL (S)	200 ppm	200 ppm 250 ppm STEL (S)
VM&P naphtha (as heptane)	VM&P naphtha, or petroleum naphtha, is a petroleum distillate containing mainly C_5 to C_{11} aliphatic hydrocarbons (as distinguished from coal tar naphtha which is mixture composed primarily of aromatic hydrocarbons). 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. VM&P naphtha is a CNS depressant and a mild irritant of the eyes and upper respiratory tract. 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.	75 ppm✦ 390 ppm✦ ceiling	500 ppm stoddard solvent	300 ppm *confirmed animal carcinogen with unknown relevance to humans*
Coal tar naphtha / Aromatic naphtha (as trimethyl benzene)	Aromatic naphtha, or coal tar naphtha, is primarily a mixture of toluene, xylene, cumene, benzene, and other aromatic hydrocarbons (as distinguished from petroleum naphtha which is constituted mainly of aliphatic hydrocarbons). Coal tar naphtha is a CNS depressant. Severe exposure is expected to cause light–headedness, drowsiness, and possibly irritation of the eyes, nose, throat. Renal toxicity of naphtha was suggested in one study of newspaper pressroom workers with low levels of exposure. As with VM&P naphtha, the degree of toxicity may be dependant on differences in the formulations of the naphtha. Skin contact with the liquid may result in drying and cracking due to defatting action.	100 ppm	100 ppm	*Coal tar naphtha has been deleted from the ACGIH listing of TLVs in favor of references to its individual chemical components*

Table 2 (continued)
Toxicity and Exposure Criteria Information
SAI Automotive USA–Kansas City, Inc., Kansas City, MO (HETA 97–0106–2770)

Compound	Toxicity Review*	NIOSH† REL	OSHA† PEL	ACGIH† TLV®
Xylene	Xylene vapor is an irritant of the eyes, mucous membranes, and skin; at high concentrations, it causes narcosis. Volunteers exposed to 460 ppm for 15 minutes had slight tearing and light–headedness. A level of 230 ppm was not considered objectionable by most of these subjects. However, an earlier study, the majority of subjects found 200 ppm irritating to the eyes, nose, and throat and judged 100 ppm to be the highest concentration subjectively satisfactory for an 8–hour exposure. At high concentrations, exposure to xylene has a narcotic effect on the CNS, and minor reversible effects on the liver and kidneys. Both human and animal data suggest that mixed xylene, *m*–xylene, *o*–xylene, and *p*–xylene, all produce similar effects although the potency with regard to a given effect may vary with individual isomers.	100 ppm 150 ppm STEL	100 ppm	100 ppm 150 ppm STEL

Abbreviations:

REL = Recommended Exposure Limit (NIOSH)
TLV® = Threshold Limit Value (ACGIH)
ppm = parts per million
(S) = significant exposure can occur through skin contact

PEL = permissible exposure limit (OSHA)
CNS = central nervous system
STEL = Short–term exposure limit
Ca = carcinogen

***Sources: Hathaway GJ, Proctor NH, Hughes JP, Fischman ML [1996]. Proctor and Hughes' chemical hazards of the workplace. 4th ed. New York, NY: Van Nostrand Reinhold.**

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†The OSHA PELs and ACGIH TLVs are based on 8–hour time–weighted average concentrations while the NIOSH RELs are based on time–weighted average concentrations of up to 10–hours. All criteria listed are time–weighted averages unless otherwise noted.

‡Values based on the lowest reliably quantifiable concentration of NIOSH analytical method 3500 during previous NIOSH testimony. At the present time, investigators should be aware that formaldehyde levels can currently be measured below 0.1 ppm for a 15–minute sampling period and 0.016 ppm for up to a 10–hour sampling period. It may be appropriate to refrain from using numerical limits and instead state that concentrations should be the lowest feasible (in some situations, this may be limited by the ambient background concentration).

✦The NIOSH REL for VM&P naphtha is currently listed in milligrams per cubic meter of air (350 mg/m^3 & 1800 mg/m^3 ceiling). These criteria were converted to parts per million at standard conditions utilizing a molecular weight of 114.

Table 3
Summary of Airborne Contaminant Concentrations – Area Samples (parts per million)
SAI Automotive USA–Kansas City, Inc., Kansas City, MO (HETA 97–0106–2770)

Description	Sample Time	Sample Volume (liters)	Acetone	Methanol	Butyl alcohol	Isobutanol	Isopropanol	Butyl acetate	MEK	Ethylbenzene	Toluene	Naphtha	Aromatic Naphtha	Xylenes
Distribution area (a) 50 cc/min	0655–0907	6.6	15	n/a	8.0	6.0	13	9.2	n/a	9.1	3.8	21	16	34
	0907–1117	6.5	15	n/a	8.6	6.1	25	11	n/a	12	4.5	26	18	46
	1117–1339	7.1	14	n/a	8.8	6.0	28	12	n/a	13	4.1	24	21	49
	1339–1548	6.4	39	n/a	11	7.2	39	15	n/a	ND	5.8	53	3.0	61
TWA			21	n/a	9.2	6.3	26	12	n/a	8.6	4.5	31	15	47
Distribution area (b) 50 cc/min	0655–0907	6.6	15	n/a	7.0	5.5	12	9.6	n/a	9.8	3.9	22	17	35
	0907–1117	6.5	14	n/a	8.6	6.1	24	10	n/a	11	4.0	24	18	43
	1117–1339	7.1	14	n/a	7.9	5.6	25	10	n/a	10	3.5	22	18	39
	1339–1548	6.4	28	n/a	0.6	0.8	20	trace	n/a	trace	ND	trace	ND	0.2
TWA			18	n/a	6.1	4.5	20	7.4	n/a	8.0	2.9	18	13	29
Distribution area (c) 200 cc/min	0655–0907	26.4	15*	29*	8.0	5.9	12	10	27	10	4.0	22	19	41
	0907–1117	26.0	11*	29*	7.1	5.1	19	8.9	27	9.7	3.3	19	16	37
	1117–1339	28.4	11*	25*	7.2	4.8	24	8.1	30	8.9	2.8	17	14	35
	1339–1548	25.8	28*	35*	9.3	5.9	30	9.0	34	9.8	3.3	20	16	37
TWA			16*	29*	7.9	5.4	21	9.1	30	10	3.3	19	16	38
Distribution area (d) 200 cc/min	0655–0907	26.4	14*	n/a	8.6	6.0	13	11	n/a	11	4.2	23	20	43
	0907–1117	26.0	15*	n/a	9.8	6.7	27	12	n/a	13	4.4	26	22	53
	1117–1339	28.4	15	n/a	11	7.2	33	11	n/a	11	3.8	22	19	47
	1339–1548	25.8	33*	n/a	11	7.3	32	11	n/a	12	4.1	26	18	45
TWA			19*	n/a	10	6.8	26	11	n/a	12	4.1	24	20	47

Table 3 (continued)
Summary of Airborne Contaminant Concentrations – Area Samples (parts per million)
SAI Automotive USA–Kansas City, Inc., Kansas City, MO (HETA 97–0106–2770)

Description	Sample Time	Sample Volume (liters)	Acetone	Methanol	Butyl alcohol	Isobutanol	Isopropanol	Butyl acetate	MEK	Ethylbenzene	Toluene	Naphtha	Aromatic Naphtha	Xylenes
Preparation area (a) 50 cc/min	0711–0915	6.2	31	n/a	1.1	0.85	14	1.4	n/a	1.7	0.94	3.5	2.8	5.9
	0915–1200	8.2	36	n/a	1.1	0.85	12	1.3	n/a	1.6	0.94	3.9	3.7	5.9
	1200–1353	5.6	29	n/a	0.88	0.71	12	0.86	n/a	1.0	0.85	2.8	ND	3.3
	1353–1600	6.4	36	n/a	1.0	0.77	24	1.0	n/a	1.3	1.2	3.1	1.7	4.0
TWA			33	n/a	1.0	0.80	15	1.2	n/a	1.4	1.0	3.4	2.2	4.9
Preparation area (b) 200 cc/min	0711–0915	24.8	39	5.8*	1.6	1.1	18	2.0	4.6	2.3	1.0	4.1	4.0	8.4
	0915–1200	33	47*	3.5*	1.6	1.2	18	1.4	5.0	ND	1.2	6.1	3.3	5.7
	1200–1353	22.6	48	6.4*	1.8	1.3	23	1.7	5.1	1.8	1.2	4.6	3.5	6.7
	1353–1600	25.4	58*	8.7*	2.2	1.6	40	2.3	6.9	2.8	2.0	6.0	6.2	11
TWA			48	5.9*	1.8	1.3	25	1.8	5.4	1.6	1.4	5.3	4.2	7.8
Preparation area (c) 200 cc/min	0711–0915	24.8	39	n/a	1.6	1.1	18	2.2	n/a	ND	1.2	7.2	5.2	9.2
	0915–1200	33	47*	n/a	1.7	1.3	18	1.9	n/a	ND	1.4	7.4	5.9	8.4
	1200–1353	22.6	48	n/a	1.6	1.2	22	1.6	n/a	1.8	1.1	4.4	3.5	6.5
	1353–1600	25.4	60*	n/a	2.2	1.6	1.9	2.3	n/a	2.6	1.9	5.7	5.6	10
TWA			49	n/a	1.8	1.3	15	2.0	n/a	1.0	1.4	6.3	5.2	8.6

Table 3 (continued)
Summary of Airborne Contaminant Concentrations – Area Samples (parts per million)
SAI Automotive USA–Kansas City, Inc., Kansas City, MO (HETA 97–0106–2770)

Description	Sample Time	Sample Volume (liters)	Acetone	Methanol	Butyl alcohol	Isobutanol	Isopropanol	Butyl acetate	MEK	Ethylbenzene	Toluene	Naphtha	Aromatic Naphtha	Xylenes
Storage area (a)† 50 cc/min	1619–2005	11.3	15	n/a	0.26	0.20	1.9	0.32	n/a	0.43	0.49	0.93	trace	1.3
Storage area (b)† 200 cc/min	1619–2005	45.2	28	0.80*	0.54	0.39	3.7	0.65	2.3	0.81	0.76	1.6	1.4	2.9
Storage area (c)† 200 cc/min	1619–2005	45.2	25	n/a	0.47	0.35	3.2	0.56	n/a	0.66	0.65	1.3	1.3	2.5

( )	–	denotes area sample location (a,b,c, or d)
n/a	–	not sampled
ND	–	not detected, value was below the minimum detectable concentration (MDC) listed below
cc/min	–	cubic centimeters (or milliliters) of air per minute
TWA	–	time weighted average of sequential area samples collected from one location
trace	–	detected value was between the MDC & minimum quantifiable concentration (MQC) listed below

The following MDCs and MQCs, listed respectively in parts per million for each analyte, were calculated assuming a sample volume of 6.4 liters: butyl acetate – 0.03, 0.12; ethyl benzene – 0.04, 0.12; toluene – 0.04, 0.14; naphtha – 0.32, 1.1; and aromatic naphtha – 0.32, 1.0.

*The concentrations reported for these samples are estimated due to sample breakthrough: greater than 30% of the reported analyte amount was found on the back–up section of the sorbent tube.

†Due to the lower concentrations expected in this area, sequential sampling was not performed, and the sorbent tubes were not changed to minimize the potential for breakthrough. Therefore, the concentrations presented are TWAs for each of the three locations.

Table 4
Summary of Airborne Contaminant Concentrations – Personal Breathing Zone Samples (parts per million)
SAI Automotive USA–Kansas City, Inc., Kansas City, MO (HETA 97–0106–2770)

Description	Sample Time	Sample Volume (liters)	Acetone	Methanol	Butyl alcohol	Isobutanol	Isopropanol	Butyl acetate	MEK	Ethylbenzene	Toluene	Naphtha	Aromatic Naphtha	Xylenes
Paint Mixer 1st shift 200 cc/min	0618–0853	31	12	n/a	5.7	3.9	11	8.1	18	7.2	3.0	16	14	27
	0853–1128	31	16*	n/a	5.5	3.7	14	7.5	16	ND	3.2	23	12	25
	1128–1148 **STEL**	4.0	116	n/a	ND	ND	19	ND	25	ND	ND	ND	ND	trace
	1148–1314	17	10	n/a	2.9	2.1	8.0	2.4	8.3	3.9	1.9	7.8	7.3	15
	1314–1331 **STEL**	3.6	32	n/a	6.2	4.5	47	8.0	20	9.5	3.3	21	16	36
	1331–1644	39	52*	n/a	5.6	3.7	19	ND	18	6.0	2.6	12	11	23
TWA			29	n/a	5.1	3.4	15	4.4	16	4.4	2.7	15	11	23
Paint Mixer 2nd shift 200 cc/min	1641–1933	34	57	n/a	4.1	2.4	15	ND	14	4.5	2.2	8.5	7.7	17
	1933–1948 **STEL**	3	168	n/a	8.6	4.4	30	ND	33	10	5.3	18	16	38
TWA			66	n/a	4.5	2.6	17	ND	15	4.9	2.4	9.3	8.4	18
Paint Mixer 2nd shift 50 cc/min	1635–1957	10	18	n/a	4.9	3.6	19	8.3	9.4‡	7.1	2.5	13	11	25
Paint Mixer 2nd shift 200 cc/min	1635–1957	40	15	n/a	4.2	3.0	15	5.7	7.4‡	4.7	1.6	8.5	8.1	18

cc/min – cubic centimeters (or milliliters) of air per minute

n/a – not sampled

trace – detected value was between the MDC & minimum quantifiable concentration (MQC). For this STEL sample, the total amount of xylenes detected was between the MDC of 0.06 parts per million (ppm) and MQC of 0.19 ppm, calculated assuming a sample volume of 4.0 liters.

STEL – short–term exposure limit

ND – not detected, value was below the minimum detectable concentration (MDC) listed below

The following MDCs, listed respectively in ppm for each analyte, were calculated assuming a sample volume of 4.0 liters: butyl alcohol – 0.08; isobutanol – 0.08; butyl acetate – 0.05; ethyl benzene – 0.06; toluene – 0.07; naphtha – 0.6; and aromatic naphtha – 0.5.

Table 5
Summary of Airborne Contaminant Concentrations – Average of Area and Personal Breathing Zone Samples (parts per million)
SAI Automotive USA–Kansas City, Inc., Kansas City, MO (HETA 97–0106–2770)

Description	Acetone	Methanol	Butyl alcohol	Isobutanol	Isopropanol	Butyl acetate	MEK	Ethylbenzene	Toluene	Naphtha	Aromatic Naphtha	Xylenes	Mixture Additive effects[●]
Area Samples													
Distribution area	20[†]	29*	8.3	5.8	23	9.9	30	9.6	3.7	23	16	40	1.5
Preparation area	43	5.9*	1.5	1.1	18	1.7	5.4	1.3	1.3	5.0	3.9	7.1	0.4
Storage area	23	0.8*	0.42	0.31	2.9	0.51	2.3	0.63	0.63	1.3	1.1	2.2	0.1
Personal Breathing Zone Samples													
Paint Mixer–1st shift	29	n/a	5.1	3.4	15	4.4	16	4.4	2.7	15	11	23	0.8
Paint Mixer–2nd shift[★]	16	n/a	4.6	3.3	17	7.0	8.4[‡]	5.9	2.0	11	9.6	22	0.7
Paint Mixer–2nd shift[✦]	66	n/a	4.5	2.6	17	ND	15	4.9	2.4	9.3	8.4	18	0.7
Evaluation Criteria													
NIOSH REL OSHA PEL ACGIH TLV®	250 100 500	200 200 200	50 100 50	50 100 50	400 400 400	150 150 150	200 200 200	100 100 100	100 200 50	75 500 300	100 100 n/a	100 100 100	1

[●] These values were calculated using the ACGIH formula for determining the TLVs for Mixtures (see Evaluation Criteria). According to the NIOSH "Pocket Guide to Chemical Hazards," the central nervous and respiratory systems were listed as target organs for all of the compounds listed in this table. Therefore, this value was determined using the formula for additive effects and the ACGIH TLVs for the individual compounds.

[†] The two sets of sequential samples collected at the higher flowrate (200 cc/min) were not used to determine this value because they were estimated due to sample breakthrough: greater than 30% of the reported analyte amount was found on the back–up section of the sorbent tube.

* The concentrations reported for these samples are estimated due to sample breakthrough.

[★] One of two paint mixers who worker the 2nd shift. This paint mixer remained in the paint kitchen throughout the shift. The results from two separate charcoal tube samples (50 & 200 cc/min) were averaged to obtain the time weighted average.

[‡] Since a sample with an ORBO 90 sorbent tube (validated NIOSH method for MEK) was not collected from this individual, this value for MEK was obtained using the charcoal sorbent tube method listed in Table 1.

[✦] One of two paint mixers who worker the 2nd shift. This paint mixer performed tasks both in paint kitchen and on the plant floor. Two sequential samples were used to determine the time weighted average.

Table 6
Size and Exhaust Flow Rates for the Paint Kitchen
SAI Automotive USA–Kansas City, Inc., Kansas City, MO (HETA 97–0106–2770)

Room	Area (sq–ft)	Volume (cu–ft)	Flow rate (CFM)
Storage	2110	28000	1900
Preparation	730	10200	1090
Distribution	910	12800	870
Total	3750	51000	3860

sq–ft – square feet
cu–ft – cubic feet
CFM – cubic feet per minute

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