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ROCKWELL INTERNATIONAL
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NIOSH INVESTIGATOR:
John A. Decker, M.S.

I. SUMMARY

In response to a Rockwell management request, the National Institute for Occupational Safety and Health (NIOSH) conducted an industrial hygiene survey of the axle painting area at Rockwell International, Newark, Ohio, to investigate possible employee exposures to paint solvents and aerosols. Full-shift personal monitoring for solvent vapors (eight employees) and general area air monitoring for metals and diisocyanates were conducted throughout the axle painting line. The paint booth systems were observed, employee interviews were conducted, and health symptom questionnaires were distributed to the affected employees.

Results of full-shift personal exposure monitoring indicated methyl ethyl ketone (MEK) concentrations ranging from 0.4 to 13.4 parts per million (ppm), methyl isobutyl ketone (MIBK) ranging from 0.2 to 1.2 ppm, and xylene ranging from 0.1 to 1.6 ppm. The highest personal exposures occurred during touch-up painting of axles. These exposures, however, were below the NIOSH Recommended Exposure Limit (REL) time-weighted average (TWA) criteria of 200 ppm for MEK, 50 ppm for MIBK, and 100 ppm for xylene.

Area sampling for hexamethylene diisocyanate (HDI) was conducted on October 25, 1990, and February 14, 1991. Concentrations above the NIOSH REL TWA criteria of 35 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$) were found in the Paint Kitchen, near the hook touch-up painter (who used a spray bottle), behind a paint robot, and at the exit to a touch-up booth. One measurement behind the paint robot ($162.6 \mu\text{g}/\text{m}^3$) was above the NIOSH Short Term Exposure Limit of $140 \mu\text{g}/\text{m}^3$. Respirators were not being used in these areas. Because of a problem with high field blank values, a photodiode array ultraviolet detector was used to corroborate HDI oligomer data obtained by NIOSH analytical method 5521.

Results of area sampling for chromium and cobalt indicated very low air concentrations, mostly under the limit of detection.

Ten employees were either interviewed or completed questionnaires regarding possible health symptoms in the axle painting area. Several of the employees reported sinus and respiratory symptoms, dizziness, and drowsiness. Of the four employees who reported sinus or respiratory problems, three indicated that they had allergies or often had sinus problems when not at the plant. One employee reported headaches while at work and one reported occasionally feeling "flush to the face."

Based on the results of this investigation, a potential health hazard from exposure to hexamethylene diisocyanate was found in specific areas of the

axle painting area. Recommendations for improving engineering controls, safe work practices, and the use of personal protective equipment are included in Section VII of this report.

KEYWORDS: SIC 3714 (Axle housings and shafts, motor vehicle), hexamethylene diisocyanate, HDI, 1,6-diisocyanatohexane, isocyanates, diisocyanates, methyl isobutyl ketone, methyl ethyl ketone, xylene, chromium, cobalt, polyurethane paint, epoxy paint.

II. INTRODUCTION

On August 23, 1990, the National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation from the Rockwell International facility in Newark, Ohio. The request, received from Rockwell management, was a follow-up to a previous NIOSH investigation conducted in March 1989 (HETA 89-144) in which the axle painting operation was evaluated. Since the first NIOSH investigation, Rockwell had made several changes in the operation and was requesting a re-evaluation of work practices and equipment modifications to the axle painting operation. Site visits were conducted by NIOSH on October 24 and 25, 1990, and February 14, 1991.

III. BACKGROUND

At the Rockwell facility in Newark, Ohio, workers machine and assemble axles for over-the-road and military vehicles. Over a thousand employees work in the 17.5 acre structure.

The axle painting procedure involves the application of two coats of paint: a white epoxy-based primer and a green polyurethane top coat, known as Chemical Agent Resistant Covering (CARC) paint. Generally, eight to ten employees per shift work in the axle painting area during the first and second shifts. Maintenance and cleaning of the paint booths is performed by two or three employees during the third shift.

Before painting, the axles are detergent-washed and conveyed through a semi-automated, metal conditioning zinc phosphate treatment. The axles, suspended from hooks, then proceed on the conveyor system through the paint line and first pass through a robotic spray paint operation, where an epoxy base coat is applied. Two employees apply touch-up epoxy paint to hard to reach areas with spray bottles before the axles enter the robotic painting system. Following the application of epoxy paint, the axles proceed through a curing oven.

After the epoxy is dry, a coat of polyurethane (CARC) paint is applied in a second robotic spray paint operation. The axles are then conveyed through touch-up booths, which are used to apply the CARC paint in areas not covered by the robots. The employees who work in the touch-up booths wear full body Tyvek® suits, rubber gloves, and 3M Brand W-2860 Hardcap Assembly supplied air respirators (Type C, MSHA/NIOSH approved). A La-Man® compressed breathing air system is used to purify the breathing air from the compressor, so that it meets the Occupational Safety and Health Administration (OSHA) Grade D guidelines. A Neotronics® internal sensor monitors oxygen levels, relative humidity, carbon dioxide, carbon monoxide, oil mist, and total hydrocarbons. The two touch-up booths are staffed by a three man rotation; two employees stagger 1-hour shifts in the booths, receiving 30-minute breaks, covered by the third, a relief worker. Since the

installation of touch-up booths, touch-up painting in open areas has been substantially reduced.

The axles then proceed through a second drying booth and are removed from their hooks. Using a manually operated spray bottle, an employee sprays CARC paint on the hook marks in an open area. Following an on-site government inspection in a large open area (Presentation Area), the remaining defects in the CARC coat are touched-up, using a paint brush and an open bucket of paint.

Both types of paint are prepared in the paint mixing area ("Paint Kitchen"). The paints are poured from drums into large vats and then are piped to the painting operation. The polyurethane catalyst and pigmented component are piped separately and mixed just prior to entering the spray nozzle.

During the October visit, two employees were applying epoxy with spray bottles, one was applying CARC to hook marks with a spray bottle, and two were applying CARC in the Presentation Area with brushes. These employees were wearing rubber gloves. The employees in the Presentation Area also were wearing Tyvek® suits. Except for the employees working in the CARC touch-up booths, respiratory protective equipment was not used. A robot machinist, present during robotic problems, was working in back of one of CARC robots for part of the day.

The zinc phosphate metal conditioning line, as well as the robotic booths, are exhausted through the roof. The robotic spray painting booths are equipped with down-draft water engineering controls for over spray. The touch-up booths, containing a fabric type filter, are exhausted through the floor. General ventilation of the area includes tempered make-up air and the use of open doors. The Paint Kitchen is equipped with an exhaust that vents room air to the outside.

The epoxy base coat, polyurethane catalyst, and pigmented polyurethane component contain various solvents including xylene, naphtha, methyl ethyl ketone (MEK), methyl isobutyl ketone (MIBK), methyl *n*-amyl ketone, *n*-butyl acetate, 2-propanol, 1-butanol, and polyamide. The polyurethane catalyst contains 75% hexamethylene diisocyanate (HDI), most of which is in a polymer form, according to the Material Safety Data Sheet. The pigmented polyurethane component also contains trivalent chromium oxide and cobalt.

Since the previous NIOSH health hazard evaluation (HETA 89-144), the use of "K-1" solvent, which contained methylene chloride, has been discontinued. Additionally, the installation of touch-up booths has dramatically reduced the need for manual touch-up painting (using spray bottles) in open areas.

IV. METHODS

A. Air Sampling

Paint Solvents Fifteen full-shift air samples for organic solvents were collected with charcoal tubes at a air flow rate of 150 milliliters per minute (ml/min). Eight personal breathing zone samples and seven area samples were collected from various locations around the robotic painting and Presentation Area.

Two of the seven area charcoal tube samples were desorbed with carbon disulfide and qualitatively analyzed by gas chromatography - mass spectrometry (GC-MS) to identify the individual solvent components emitted from the curing paints. These two charcoal samples were desorbed with 1 milliliter (ml) of carbon disulfide and screened by gas chromatography, using a 30 meter DB-1 fused silica capillary column and flame ionization detection. The individual components were then analyzed by mass spectrometry.

The remaining charcoal tubes were quantitatively analyzed, based on the qualitative GC-MS data, for MEK, MIBK, and xylene. The samples were desorbed with carbon disulfide and analyzed by gas chromatography, using modifications of NIOSH methods 1300 and 1501. The gas chromatograph utilized a 30 meter Supelcowax-10® fused silica capillary column. For both MIBK and xylene, the limits of detection and quantitation were 0.01 and 0.03 mg/sample. The values for MEK were not determined.

Diisocyanates Hexamethylene diisocyanate (HDI) was collected in 25 ml Midget impingers, containing 15 ml of absorbing solution (1-(2-methoxyphenyl)-piperazine dissolved in toluene) at a nominal flow rate of 1.0 liters per minute. Area samplers were placed as close as possible to the hook-mark and Presentation Area touch-up painters and were located about 4 to 5 feet above the floor. Other samplers were placed in the vicinity of the robotic and touch-up booths. During the October 1990 visit, seven air samples for HDI were collected in the CARC painting area. During the return visit in February 1991, twenty-two additional samples were collected.

Upon completion of sampling, the impinger solutions were transferred to 20 ml glass vials and stored under refrigeration until analysis. The samples were analyzed according to NIOSH method 5521. Each sample was acetylated with 10 microliters (µl) of acetic anhydride and then evaporated under nitrogen to dryness. The residue was re-dissolved in 5 ml of methanol while agitating the sample in an ultrasonic water bath for 15 minutes. The samples were then analyzed by high pressure liquid chromatography (HPLC) with a Waters® model 600 liquid chromatograph equipped with a C-18 radial-pak column, an Applied Biosystems® ultraviolet detector set at a wavelength of 242 nanometers (nm) and an Applied Biosystems® electrochemical detector. The standard solutions were HDI urea derivative in methanol.

High field blanks were observed in the October HDI samples. For this reason, the HDI sampling was repeated in February. Upon initial investigation of the data, it appeared that the field blanks were again high in this repeat survey. Later in the data analysis, it was determined that the particular peak responsible for the high field blank data was not an diisocyanate-derived peak.

In an effort to corroborate oligomer data obtained by using NIOSH Method 5521, a photodiode array (PDA) ultraviolet (UV) detector was used to obtain the spectra of the oligomeric peaks in the HPLC chromatograms. The PDA spectra of the two oligomeric peaks were identified by retention times and ratios as HDI. Based on the fact that the PDA spectra of the first peak (retention time 11 minutes) consistently showed the diisocyanate pattern in all of the samples, this peak was judged to be an oligomeric peak. The electrochemical detector data was used to quantitate the results for this peak. The PDA spectra for the second peak (retention time of 18 minutes) did not show the characteristic diisocyanate pattern for an diisocyanate functionality. Since this particular peak appeared in the chromatograms of the field blanks, discounting this peak resulted in negating the data for the high field blanks. The limits of detection and quantitation were 0.4 and 1.2 micrograms per sample ($\mu\text{g}/\text{sample}$), respectively.

Metals Five area air samples for airborne chromium and cobalt were collected on cellulose ester filters. These metals, present in the pigmented CARC component, were analyzed by atomic absorption spectroscopy according to NIOSH methods 7024 and 7027. The filters were ashed and then quantitatively transferred to 25 ml volumetric flasks. For chromium, the limits of detection and quantitation were 1.0 and 3.9 $\mu\text{g}/\text{sample}$, respectively. For cobalt, the limits of detection and quantitation were 4 and 14 $\mu\text{g}/\text{sample}$, respectively.

B. Questionnaires and Employee Interviews:

Seven questionnaires were completed by employees who work in the axle painting area. The questionnaires were primarily directed toward respiratory tract and neurological symptoms among the workers over the previous 30 days.

Confidential interviews were conducted with ten employees who work in the axle painting area. Two of the employees worked on the third shift, when the paint booths are cleaned. Most of the employees who were interviewed also completed questionnaires.

C. Paint Booth Evaluations

On the day of the NIOSH survey, smoke tests were performed to determine pressure relationships and direction of air movement between the paint booths and adjacent areas. Similar smoke tests were performed in the Paint Kitchen.

V. EVALUATION CRITERIA

The primary sources of environmental evaluation criteria for the workplace are the following: 1) NIOSH Recommended Exposure Limits (RELs) 2) the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs), and 3) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs).^[1,2,3] The OSHA standards also 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.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance over the course of normal 8- to 10-hour workday. Some substances have a short-term exposure limit (STEL) or ceiling (C) values where there are recognized toxic effects from high short-term exposures. The environmental evaluation criteria are intended to protect workers continually exposed up to 40 hours/week for a working lifetime without experiencing adverse health effects.

Not all workers will be protected from adverse effects even if their exposures are maintained below the evaluation criterion. A small fraction may experience health effects as the result of individual susceptibility, a medical condition, or hypersensitivity (allergy). In addition, some substances may act in combination with other workplace exposures to produce health effects, even if the occupational exposures are controlled to a limit set by the evaluation criteria. 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. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that industry is legally required to meet those limits specified by an OSHA PEL.

Table I lists the evaluation criteria for the various airborne substances measured during the NIOSH investigation.

A. Methyl Isobutyl Ketone (MIBK)

MIBK is an irritant of the eyes, mucous membranes and skin. Skin contact can cause drying and defatting of the skin which may lead to dermatitis. High inhalation exposures result in central nervous system depression, which can progress to narcosis.^[4,5]

B. Methyl Ethyl Ketone (MEK)

MEK is also an irritant of the eyes, mucous membranes and skin. High exposures to the vapor result in central nervous system depression, which can progress to narcosis. Skin contact may cause drying and

defatting of the skin, which may lead to dermatitis. Worker exposures of 100 and 200 ppm have reportedly caused nose and throat irritation.^[5] Long term exposure may produce a toxic sensory-motor peripheral neuropathy, resulting in symptoms such as loss of tactile sense and sensitivity to pain and temperature.^[4,5]

C. Xylene

Xylene vapor may cause irritation of the eyes, nose and throat. Repeated or prolonged skin contact can cause drying and defatting of the skin, which may lead to dermatitis.^[5] Workers exposed to approximately 200 ppm reported loss of appetite, nausea, vomiting, and irritation of the eyes, nose, and throat. High concentrations of xylene vapor may cause dizziness, drowsiness, and unconsciousness.^[4,5]

D. Hexamethylene Diisocyanate (HDI)

All diisocyanate-based compounds contain two $-N=C=O$ functional groups, which readily react with compounds containing active hydrogen atoms to form urethane polymers. The high reactivity of diisocyanates, and their ability to cross-link, make them ideal for the production of polymer-based products, including surface coatings, adhesives, resins, and polyurethane foams.^[6]

Respiratory hazards to diisocyanates are generally related to the vapor pressures of the individual compounds. The lower molecular weight diisocyanates tend to volatilize to a greater extent than the higher molecular weight compounds, creating a vapor inhalation hazard. However, in poorly ventilated areas the higher molecular weight diisocyanates may still generate vapor concentrations sufficient to cause adverse reactions. In addition, all forms of diisocyanates can be an inhalation hazard if aerosolized in the work environment. To reduce the vapor hazards associated with lower molecular weight diisocyanates, oligomer forms (chains of monomers) of diisocyanates have replaced the monomer forms in many products. For example, the HDI in the CARC paint at Rockwell primarily consists of oligomer forms of HDI, having a higher molecular weight and a lower vapor pressure than the pure monomer form.^[7]

All diisocyanates, including HDI, can cause irritation to the eyes, skin, mucous membranes, and respiratory tract. Exposure to airborne diisocyanates can result in chemical bronchitis, chest tightness, difficulty breathing, tearing of the eyes, coughing, burning of the nose and throat, pulmonary edema, and death.^[7,8]

Sensitization to HDI can also occur, resulting in allergic dermatitis and/or asthmatic-like responses. Dermal sensitization can include symptoms such as rash, itching, hives, and swelling of the extremities. The asthmatic reaction is characterized by difficulties in breathing; e.g. coughing, wheezing, shortness of breath, and tightness in the chest.

After sensitization, any exposure, even levels well below any occupational limit, will cause an allergic response which may be life threatening. The symptoms of both dermal and respiratory sensitization may develop immediately or several hours after an exposure, after the first few months of exposure, or after several years of exposure. The only treatment for a sensitized individual is removal from exposure to isocyanates.^[9,10,11] Persons sensitized to diisocyanates often will experience increased allergic reactions when exposed repeatedly. The incidence of diisocyanate-induced occupational asthma are estimated to range from 5% in diisocyanate production facilities to 30% in a polyurethane seat cover operation.^[7,12]

Experimental studies in animals have demonstrated that toluene diisocyanate is a carcinogen in rats and mice. In both species, tumors were induced at multiple sites (pancreas, liver, skin, mammary glands, and circulatory system).^[11] Though evidence does not exist to demonstrate the carcinogenicity of HDI, the information increases the awareness of the toxicological importance of diisocyanates.

E. Chromium

Chromium exists in a variety of chemical forms depending upon its valence state, a term simply describing the compound's atomic arrangement. It is necessary to specify the form of chromium because of the range of health effects that chromium compounds may cause. For example, elemental (metallic) chromium is relatively nontoxic and does not produce allergic dermatitis.^[5] Other chromium compounds can cause primary skin irritation, which can vary from a dry erythematous eruption to a weeping eczema. These conditions are associated with prolonged exposure and would be less likely to occur following an isolated, low concentration exposure.^[5] Chromium exposure can also result in skin sensitization and allergic dermatitis. Sensitization appears to be independent of the degree of exposure.^[13] Exposure to chromate salts has also been associated with the development of allergic asthma; this association has been seen in metal platers, who have a prolonged occupational exposure.^[5]

In the hexavalent state (CrVI), chromium compounds are irritating, corrosive, and carcinogenic. Until recently, the less water-soluble CrVI forms (i.e. lead and zinc chromate) were considered carcinogenic, while the water-soluble forms were not. Recent epidemiological evidence indicates carcinogenicity among workers exposed to soluble CrVI compounds. Based on this new evidence, NIOSH recommends that all CrVI compounds be considered as occupational carcinogens.^[14]

Trivalent chromium compounds (CrIII), such as chromium oxide, are considerably less toxic than the hexavalent compounds. There is limited evidence of the toxicity of these compounds, probably because of poor penetration into skin and mucous membranes.^[5] NIOSH does not have occupational exposure limits for CrIII; however, the ACGIH

and OSHA have set limits of 0.5 mg/m³ as 8-hour TWAs (see Table I). The CARC paint at Rockwell contains trivalent chromium, according to the MSDS.

F. Cobalt

Airborne cobalt can cause upper respiratory tract irritation and skin sensitization.^[15] Exposure to cobalt can result in pulmonary fibrosis and pneumonitis, and sensitization of the respiratory tract and skin. The pulmonary allergic response is characterized by wheezing, cough and shortness of breath while at work.^[6]

VI. **RESULTS and DISCUSSION**

A. Environmental

1. *Qualitative Analysis for Airborne Solvents*

Two area air samples for organic solvents, collected with charcoal tubes, were analyzed by Gas Chromatography/Mass Spectrometry (GC/MS). One sample was collected near an opening to CARC booth #6 and the other was collected at the electricians' desk, located near the exit of the epoxy paint booth. Both chromatograms were nearly identical, indicating the following major airborne chemicals: MEK, MIBK, xylene isomers, and toluene (from the diisocyanate sampling media).

2. *Quantitative Analysis for Airborne Chemicals*

The concentrations of airborne xylene, MEK, and MIBK collected with the remaining charcoal tubes are listed in Table II. The highest concentrations of solvent were found in an area sample collected in the Paint Kitchen (11.9 ppm MEK) and a personal sample from the Presentation area (13.4 ppm MEK, 1.3 ppm MIBK, 1.6 ppm xylene). The air concentrations for MEK are estimates, due to reported instability of the analyte on charcoal.

Sample numbers H01, H02, and H04 were personal samples collected from the interiors of the supplied air respirator hoods while painters worked in the touch-up paint booths. These levels ranged from 0.4 to 1.3 ppm MEK, 0.2 to 0.6 ppm MIBK, and 0.1 to 0.3 ppm xylene. All vapor concentrations were well below the evaluation criteria listed in Table I.

Although a noticeable solvent odor was present in the painting area, concentrations of solvent vapors were all under the PELs, RELs, and TLVs. MIBK and xylene have relatively low odor thresholds, which is reported to be approximately 0.5 ppm.^[16] The odor threshold, of course, varies among individuals.

3. *Hexamethylene Diisocyanate (HDI)*

Sampling for HDI was performed during the October and February NIOSH visits. Only oligomeric HDI was found in the air samples; no HDI monomer was found, which is reasonable to expect, since the material safety data sheet (MSDS) indicates that the catalyst component of CARC contains approximately 75% oligomer and <1.2% monomer by weight.^[17]

The samples collected during the October visit appeared to contain oligomeric HDI; however, the field blanks, which were not exposed to HDI, also indicated significant levels of oligomer. Analyte was not expected in the field blanks, and therefore, the accuracy of the results was questioned.

Sampling for HDI in February also resulted in high field blanks. However, the high field blank data was negated by subtracting the 18-minute peak, which did not show the characteristic diisocyanate pattern in the PDA UV spectra.

Since the vapor pressure of the oligomeric HDI is approximately 7.5×10^{-5} mm Hg @ 20° C, air concentrations due to spray painting are likely to be in the form of an aerosol, rather than vapor.^[17] At higher temperatures, such as in a drying booth, the potential for release of vapor into the air is increased. The sampling results for the February visit can be found in Table III. The results from the initial October diisocyanate sampling will not be reported, since the samples were not analyzed by PDA.

There were four areas that contained high HDI levels (in excess of the NIOSH REL TWA criteria). These areas were the Paint Kitchen, the hook touch-up painter area, behind CARC robot #6, and the exit of the second CARC touch-up booth.

Paint Kitchen sample #7, collected between 0728 and 0926, indicated a TWA air concentration of $72.0 \mu\text{g}/\text{m}^3$. The high air concentration probably resulted from transfer of CARC catalyst, which occurred around 0800. Paint Kitchen sample #1, collected between 0728 and 1222, indicated a lower average concentration. This was reasonable to expect, since the sample was collected for a longer period after the catalyst transfer was completed.

The samples collected near the hook touch-up painter were 96.1 and $32.5 \mu\text{g}/\text{m}^3$, one of which was in excess of NIOSH REL TWA criteria of $35 \mu\text{g}/\text{m}^3$. If a personal sample from this painter had been possible, even higher levels of HDI might have been observed, since the sampler would have been even closer to the spray bottle paint source.

High levels of HDI were found behind CARC robot #6, where a robot machinist (mechanic who repairs robotic equipment) often works. All three samples were over the NIOSH REL TWA criteria of $35 \mu\text{g}/\text{m}^3$. One sample was over the NIOSH short-term exposure limit (STEL) of $140 \mu\text{g}/\text{m}^3$.

Near the exit of the second CARC touch-up booth, one sample (#5) was relatively low ($<4.3 \mu\text{g}/\text{m}^3$), while the other sample (#23) was somewhat higher ($45.5 \mu\text{g}/\text{m}^3$). These results might indicate variable amounts of HDI released, perhaps dependent on the number of axles painted in a given time period.

Two samples (#15 and #16) were collected in the axle shaft assembly line. The sample locations, somewhat removed from the axle painting line, had detectable HDI air concentrations (<3.6 and $4.2 \mu\text{g}/\text{m}^3$), which were well below the NIOSH REL. The concentrations in the Presentation Area, ranging from <2.9 to $11.4 \mu\text{g}/\text{m}^3$, were also below the NIOSH REL.

4. *Chromium and Cobalt*

Air sampling for both elements indicated air concentrations below the RELs, PELs and, TLVs, as indicated in Table IV. All samples were extremely low or non-detectable. Generally, detection of these elements would only occur if high concentrations of aerosolized paint spray were escaping into the work area.

B. Questionnaire and Employee Interviews

Several of the employees reported sinus or respiratory symptoms, dizziness, and drowsiness. Of the four employees who reported sinus or respiratory problems, three indicated that they had allergies or often had sinus problems when not at the plant. One employee reported chest tightness, one employee reported occasional dizziness, and one employee reported occasional drowsiness.

Two employees who worked on the third shift (cleaning and maintenance) were interviewed. The booths are cleaned by shoveling the partially dried paint into barrels. One of these employees reported headaches and the other reported occasionally feeling "flush to the face."

C. Paint Booths and Paint Kitchen

During the October visit, smoke tests indicated a definite negative pressure inside all of the paint booths and Paint Kitchen, with respect to adjacent areas. That is, the smoke tests indicated that the direction of air movement was into the paint booths, reducing the potential for paint mist and vapor to escape into the work environment.

VII. RECOMMENDATIONS

The following recommendations are offered as prudent measures to reduce or prevent possible work-related symptoms. These recommendations are supplementary to changes in procedures (installation of touch-up booths, reduction in manual touch-up painting, etc.) already instituted by Rockwell.

- A. A medical surveillance program should be instituted for workers potentially exposed to HDI, which includes all the workers in the CARC paint line, Presentation area, and Paint Kitchen. The surveillance program should include the following elements:^[7]
1. A preplacement examination that includes a comprehensive work and medical history, a smoking history, a physical examination with emphasis on the respiratory tract, a chest X-ray, and pulmonary function test of forced vital capacity, and forced expiratory volume in 1 second.

Special emphasis should be given to pre-existing medical conditions such as asthma, emphysema, bronchitis, or cardiopulmonary disease, which could be aggravated by exposure to diisocyanates.
 2. Interim medical and work histories on an annual basis.
 3. If a worker develops respiratory problems which may be related to the work environment, he/she should be removed from all diisocyanate exposure until evaluated and diagnosed by an occupational medicine physician with experience in diagnosing diisocyanate-induced sensitization.
- B. The possibility of skin and eye contact with HDI-containing liquids or aerosols should be minimized by the use of proper protective equipment. NIOSH recommends that workers wear coveralls, rubber or polyvinyl chloride gloves, and goggles (or faceshields) when handling or applying the HDI based paint. Protective shoe coverings should be worn if HDI-containing paint is on the floor.^[6] These recommendations would apply to workers in the Paint Kitchen, Presentation Area, behind the CARC robot, and the hook-mark touch-up painter. Protective clothing that is contaminated with CARC should be discarded or decontaminated in a solution of 8% ammonia and 2% liquid detergent.^[7]
- C. High concentrations of solvents and HDI are possible when paint containers are open in the Paint Kitchen. Supplied air respirators, in addition to appropriate protective clothing, should be used whenever containers of either type of paint (epoxy or polyurethane components) are transferred into vats. Chemical cartridge respirators are not recommended because diisocyanates have poor warning properties.^[7]

Consideration should be given to using transfer pumps to move paints from drums to mixing vats.

- D. To reduce potential employee exposures to HDI, the application of CARC polyurethane paint in open areas (by spray bottle) should be eliminated. The sampling data indicate that the airborne concentration of HDI near the hook touch-up painter may be above the NIOSH REL at times. Installation of a separate, exhausted booth for hook touch-up painting might isolate potential exposures to the hook touch-up painter and surrounding workers.
- E. Concentrations of HDI behind the CARC robot were above the NIOSH REL. If possible, employees should avoid working in this area. Employees who must work in this location should use supplied air respirators, in addition to the personal protective equipment discussed above.
- F. Both epoxy and CARC paint on some axles may not be completely dry after leaving the drying booths; increased residence time within the existing drying booths (CARC paint) or installation of larger or more effective drying booths (epoxy paint) would reduce the amount of solvent vapors entering the plant.
- G. Some employees reported that the exhaust in the robotic paint booths is reduced when the water chambers become overloaded with paint. Monitoring of paint build-up and air velocity measurements should be continued on a regular basis. This will prevent paint aerosol, HDI, and solvent vapors from entering the plant.
- H. Because of close contact with partially dried paint when cleaning the booths, the third shift crew may be exposed to high levels of solvents and/or HDI. These workers' exposures to solvent vapors should be evaluated. These workers should be equipped with the personal protective equipment outlined above. To reduce possible diisocyanate exposures, consideration should be given to equipping the employees with supplied air respirators.

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IX. AUTHORSHIP AND ACKNOWLEDGEMENTS

Report Prepared by:

John A. Decker, M.S.

Industrial Hygienist

Industrial Hygiene Section

Field Assistance:

Mike Crandall, M.S., CIH

Supervisory Industrial Hygienist

Industrial Hygiene Section

Calvin Cook

Industrial Hygienist

Industrial Hygiene Section

Diisocyanate Analysis:

Rosa Key-Schwartz, Ph.D.
Research Chemist

Measurements Support Section

Measurements Research Support

Branch

Division of Physical Sciences

Originating Office:
Technical

and Engineering
Hazard Evaluations and
Assistance Branch
Division of Surveillance, Hazard
Evaluations and Field Studies

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3. OSHA, Region V

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

TABLE I

Evaluation Criteria
 Rockwell International
 Newark, Ohio
 HETA 90-368

Paint Component		REL ^[1]	PEL ^[2]	TLV [®] ^[3]
Methyl Isobutyl Ketone (ppm)	TWA	50	50†	50
	STEL	NC	75	75
Methyl Ethyl Ketone (ppm)	TWA	200	200	200
	STEL	NC	300	300
Xylene isomers (ppm)	TWA	100	100	100
	STEL	200 C	150	150
Hexamethylene Diisocyanate (µg/m ³)	TWA	35	NC‡	34
	STEL	140 C	NC‡	NC
Chromium III Compounds (mg/m ³)	TWA	NC	0.5	0.5
	STEL	NC	NC	NC
Cobalt (mg/m ³)	TWA	0.05	0.05†	0.05
	STEL	NC	NC	NC

ppm = parts per million

mg/m³ = milligrams per cubic meter

µg/m³ = micrograms per cubic meter

TWA = Time-Weighted Average

STEL = Short-Term Exposure Limit

C = Ceiling, 10 minute (NIOSH)

REL = NIOSH Recommended Exposure Limit, 10-hour TWA

PEL = OSHA Permissible Exposure Limit, 8-hour TWA

TLV = ACGIH Threshold Limit Value, 8-hour TWA

† = Final rule limit, amended 29 CFR 1910.1000

‡ = In the United States, there is no
legally enforceable exposure limit for HDI.

NC = No Criteria

TABLE II
 Air Sampling Results for MEK, MIBK, and Xylene
 (Personal Samples)
 Rockwell International
 Newark, Ohio
 October 25, 1990
 HETA 90-368

Job Title/Location	Sample No.	Sampling Time (min.)	Air Conc. (ppm)		
			MEK	MIBK	Xylene
Assembly Painter #1/CARC Touch-up Booth	H01	476	0.4	0.6	0.3
Assembly #2 Painter/CARC Touch-up Booth	H02	473	0.4	0.2	0.1
	H04	455	1.3	0.4	0.3
Assembly Painter #3/CARC Touch-up Booth					
Assembly Presenter #1/Epoxy Touch-up	H05	457	0.4	0.4	0.1
Assembly Painter #2/Epoxy Touch-up	H06	457	2.2	1.2	0.1
Machinist/Epoxy Robots	H07	442	1.7	1.2	0.4
Machinist/CARC Robot	H08	434	1.8	1.0	0.4
Assembly Presenter #1/ Presentation	H10	423	13.4	1.3	1.6
Assembly Presenter #2/ Presentation	H12	39 (pump default)	0.9	≤0.3	≤0.3
Area Sample/Window CARC booth #4	H13	399	0.8	1.5	0.8
Area Sample/Near Entrance to CARC Booth #7	H14	416	0.5	0.1	0.7
Area Sample/CARC Spray Bottle Touch-up	H03	458	1.7	1.2	0.7
Area/Paint Kitchen	H09	422	11.9	0.5	0.4

TABLE III

Airborne Hexamethylene Diisocyanate Oligomer
(all area samples)
Rockwell International
Newark, Ohio
February 14, 1991
HETA 90-368

Location	Sample No.	Sample Period	(min.)	Conc. ($\mu\text{g}/\text{m}^3$)
Paint Kitchen	7	0728-0926	118	72.0
	1	0728-1222	294	19.7
	25	1302-1427	85	<14.1
Presentation Area	11	0729-1425	416	5.5
	8	0808-1425	377	11.4
Torque Rod Area	12	0740-1441	419	<2.9
Axle Storage Area	14	0805-1441	496	7.3
Between hook touch-up and touch-up booth	9	0731-1103	212	ND
Near hook touch-up	19	1103-1220	77	96.1
	26	1305-1425	80	32.5
Behind CARC robot #6	4	0751-1105	194	49.0
	18	1105-1220	75	162.6
	2	1247-1441	114	81.6
Window into robotic CARC booth	22	1251-1432	101	ND
	21	0750-1220	270	7.0
Near window to first CARC touch-up booth	13	0745-1425	460	<2.6
	20	1246-1432	160	11.3
On table near first CARC touch-up booth	5	0746-1227	281	<4.3
Exit of second CARC touch-up booth	23	1255-1425	90	45.5
	6	0752-1500	428	8.9
Desk between epoxy and CARC robotic booths	15	0911-1445	334	<3.6
Axle Shaft Assembly line (about 1/4 length down line)	16	0915-1445	330	4.2
Axle Shaft Assemble Line (end of line away from painting area)				

$\mu\text{g}/\text{m}^3$ = micrograms per cubic meter air
ND = Not Detected

TABLE IV

Air Sampling Results for Chromium and Cobalt
(all area samples)
Rockwell International
Newark, Ohio
October 25, 1990
HETA 90-368

Location	Sample No.	Sampling time (min.)	Air Conc. ($\mu\text{g}/\text{m}^3$)	
			Cr	Co
CARC touch-up booth #6 above opening	C01	558	ND	ND
CARC Robot Booth #5	C02	482	†	ND
Near manual CARC touch-up with spray bottle	C03	566	ND	ND
CARC touch-up booth #7, entrance	C04	518	0.01	ND
CARC touch-up booth #6, lower edge	C05	524	ND	ND

$\mu\text{g}/\text{m}^3$ = micrograms per cubic meter

ND = Not Detected

† = Detected, but below level of quantitation

Cr = Chromium

Co = Cobalt