U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
CENTER FOR DISEASE CONTROL
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
CINCINNATI, OHIO 45226

HEALTH HAZARD EVALUATION DETERMINATION REPORT 75-195-396
UNITED AIRLINES MAINTENANCE BASE
SAN FRANCISCO INTERNATIONAL AIRPORT
BURLINGAME, CALIFORNIA

MAY 1977

I. TOXICITY DETERMINATION

It has been determined that at the United Airlines Maintenance Base, Burlingame, California:

1) Employees working in and around jet aircraft during the paint stripping process without respiratory protection are exposed to potentially toxic concentrations of methylene chloride vapors. This determination was based on the fact that air levels of methylene chloride vapors, at times, exceeded 250 parts per million (ppm) which is the American Conference of Governmental Industrial Hygienists recommended Threshold Limit Value (TLV) Short-Term Exposure Limit (STEL) for methylene chloride and the fact that a high percentage of employees in all job categories have complained of occasional eye irritation, throat irritation, and head congestion when in close proximity to the paint stripping operations.

2) Employees who have contact with such other organic solvents as toluene, methyl ethyl ketone, n-butyl acetate, n-butyl alcohol, isopropyl alcohol, cyclohexanone, ethyl acetate, methyl isobutyl ketone, xylene, cellosolve acetate, and phenol during prime-coat painting, top-coat (enamel) painting, paint stripping, plane washing, sealant and adhesive application, and fuel tank entry operations are not exposed to toxic levels of these chemical agents. This determination was based on the fact that measured air concentrations were low, employee exposure times were short, or measures such as engineering controls and personal protection were mandatory and judged to be adequate by NIOSH investigators, and the fact that the medical examinations and biological tests performed by NIOSH physicians failed to establish the presence of adverse effects due to these chemical agents.

3) Employees who spray paint jet aircraft with enamel paint containing hexamethylene diisocyanate (HDI) may be exposed to potentially toxic levels of HDI although this fact could not be conclusively established. This determination was based on the fact that air concentrations of HDI reached 2.0 mg/m^3 (no standard for HDI exists) while some workers were observed in the workplace with respirators being worn improperly, and the fact that HDI is similar in chemical structure to the more toxic isocyanate compounds even though little background toxicity information on HDI is present in the literature. No medical findings could be related to overexposure to HDI.

The above determinations and conclusions have been made concerning the major paint stripping and paint application procedures found during normal operations at the United Airlines Maintenance Base. Many of the operations observed are short-term and sporadic which made a more extensive determination difficult to complete. Detailed information concerning the above medical and environmental results of this determination are contained in the body of the report. Recommendations are included in Section IV F of this report. These recommendations are designed to keep employee exposure to these chemical agents to a minimum.

II. DISTRIBUTION AND AVAILABILITY OF DETERMINATION REPORT

Copies of this Determination Report are currently available upon request from NIOSH, Division of Technical Services, Information and Dissemination Section, 4676 Columbia Parkway, Cincinnati, Ohio, 45226. After 90 days the report will be available through the National Technical Information Service (NTIS), Springfield, Virginia. Information regarding its availability through NTIS can be obtained from NIOSH, Publications Office at the Cincinnati address.

Copies of this report have been sent to:

(a) United Airlines Maintenance Base
(b) U. S. Department of Labor - Region IX
(c) CAL/OSHA
(d) NIOSH - Region IX
(e) Authorized Representative of Employees - International Association of Machinists and Aerospace Workers, Lodge 1781

For the purpose of informing the approximately 1,400 employees, copies of the report shall be posted in a prominent place accessible to the employees for a period of 30 calendar days.

III. INTRODUCTION

Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6), authorizes the Secretary of Health, Education, and Welfare, following a written request by an employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

An official request (RHE 75-195) was submitted by the authorized representative of employees of the International Association of Machinists and Aerospace Workers, Lodge 1781, Burlingame, California. The work site was identified as all of the working hangars: nos. 1 - 7, North B29, and South B29 (see attachment A). The substances in the request were identified as all of those which were used in the stripping, priming, and painting of jet aircraft and miscellaneous solvents which were used in the preparation and repair of the interior sections of the plane.

Such an extensive environmental and medical study of all employees with their potential exposures to every substance used at the United Airlines Maintenance Base is beyond the scope and manpower of the Hazard Evaluation Program. Up to 1450 employees can work in the dock area during a 24-hour shift. To complicate matters, the painting and stripping operations are sporadic and several days or even weeks can pass before another plane enters the base for painting and stripping. Therefore, for the purposes of this hazard evaluation, it was decided to conduct a medical study on a representative sample of workers and to take environmental measurements during all operations which were believed to be of industrial hygiene significance. These operations were related mainly to the stripping and painting of jet aircraft. Other operations where a potential for chemical exposure existed were either observed by NIOSH researchers to note whether company safe handling procedures were adequate to protect workers or if the job could not be observed, applicable California OSHA (CAL/OSHA) investigation reports were reviewed.

IV. HEALTH HAZARD EVALUATION

A. Description of Process

The United Airlines Overhaul Division is involved in all aspects of aircraft maintenance. The "Hangar Area" or "Dock Area" (see attachment A) combines docks in the main facility and two other separate buildings. The main facility houses five docks (nos. 3 - 7). The capacities of these docks limit the size of the aircraft that can be serviced and are designed for the smaller narrow-body jets. Wide-body jets are serviced in the newest hangars which are designated as docks 1 and 2. Aircraft are also serviced in North and South B29 hangars. Every dock is essentially a complete unit and contains the equipment to conduct most necessary operations including stripping and painting of planes. Each dock is equipped with exhaust ventilation capabilities and sliding doors to secure the area from outside entry. The largest dock is approximately 160 X 160 feet and the smallest is about 60 X 70 feet.

The approximate 1400 employees in the dock area are licensed airline mechanics but are identified by their job classification, e.g., painters, cleaners, cabin, sheet metal, rigging, hydraulics, etc. Except during the actual painting of planes when a dock has restricted entry, all or only a few of the various mechanics can be in and around an aircraft for any length of time. Any number of chemical substances can be used by the mechanics or none at all. Therefore, it was extremely difficult to pinpoint exposures or airline mechanics to all potentially toxic substances on a day-to-day basis. The information in the following paragraphs is a brief description of some of the processes where chemical substances are used by employees during the stripping and painting of planes.

All United Airlines planes are brought into the maintenance base for regular and emergency servicing. Heavy maintenance visits and overhauls are performed at 12,000 to 21,000 hours of flying time. Other visits are made at shorter flying hours and very from special route visits to emergencies and phase checks. All planes which enter the base for repainting must go through four phases. During other types of service visits, planes may or may not be washed (phase 1). The four phases are:

Phase 1 - "Wash Down" of planes is the hand-washing of aircraft with a mixture of organic solvents and water. For dirty planes, the mixture is 3 parts Airshow W, 2 parts stoddard solvent, and 1 part water. The Airshow W is a proprietary mixture of 35% aromatic hydrocarbons and 10% butyl cellosolve. The threshold limit value (TLV) is listed on a material safety data sheet as 100 parts per million (ppm) for this mixture. No benzene is reported to be in this mixture. The wash down is done outdoors by three or more employees and takes 45-60 minutes to complete. Workers wear protective clothing, gloves, and NIOSH certified respirators with organic vapor cartridges. About ten planes per month are washed completely.

Phase 2 - Paint stripping involves three steps. First, the stripper is applied to the plane through hoses. This application takes 20-30 minutes. The stripper is allowed to set for at least 30 minutes. The stripper and loose paint is "scraped down" by workers into troughs with hand-held scrapers and the remaining stripper and old paint is "brushed down" with hot water and hand-held brushes. The latter two steps takes about 30-45 minutes each and requires four to six employees. All employees involved in paint stripping are required to wear NIOSH certified respirators with a combination organic vapor cartridge and high-efficiency pre-filter. However, cockpit and cabin personnel do not wear respirators while paint stripping is being done. The stripper is mainly methylene chloride with small amounts of phenol and ammonia.

Phase 3 - Primer paint application is the first step in the painting of aircraft. Airless spray guns are used and the entire aircraft is given a quick coat of primer paint which requires less than 30 minutes. The number of painters can vary from five to eight. The primer paint contains no isocyanate compounds. It contains a large mixture of solvents and some fillers and pigments. The solvents include butyl acetate, n-butanol, cyclohexanone, isopropyl alcohol, methyl ethyl ketone, and toluene. The primer also contains trace amounts of aromatic and aliphatic amines. All personnel in the dock area are required to wear NIOSH certified respirators with a combination organic vapor cartridge and high-efficiency pre-filter. The dock area is closed to all other personnel during the painting process.

Phase 4 - "Top coat" paint spraying is the application of two coats of white enamel paint. The coats are applied one after another with at least a thirty minute break. Five to eight painters are used, and the same respiratory protection used during primer painting is required. Also, the dock area is secured from other personnel. Each coat of paint takes from 25-45 minutes to apply. The top coat paint contains such solvents as cellosolve acetate, butyl acetate, ethyl acetate, methyl isobutyl ketone, methyl ethyl ketone, and xylene. Additionally, it contains an aliphatic isocyanate compound known as hexamethylene diisocyanate (HDI). For HDI-containing paints, the top coat take the most paint and time to complete. Lessor amounts of time and manpower are needed to apply the trim colors. Approximately four to six planes per month are brought into the maintenance base for stripping and painting.

The greatest exposure to potentially toxic chemicals for employees is the stripping and painting operations. Other applications using chemicals

which were noted in the official request but were not observed during the survey were the use of sealants and adhesives and the fuel tank entry process. These operations are sporadic and did not occur during the scheduled times of NIOSH's visits. However, information about each procedure was reviewed and described below.

Fuel Tank Entry - Every plane which is serviced in a dock has its fuel supply drained from its wing tanks. If work in the tank is necessary, entry into the tank is via small wing ports. Only employees small in size can fit into these ports. The tanks are purged with fresh air mechanically for 12 hours prior to tank entry. The oxygen content and the jet fuel (hydrocarbon) concentration is monitored continuously with a portable direct-reading instrument. Under no circumstances is an employee allowed into the tank if the oxygen content is less than 19.5% The direct-reading instrument is calibrated with standards for the jet fuel. Workers must wear NIOSH certified respirators if the concentration of jet fuel in the tank is between 100-1000 ppm. Above 1000 ppm, employees are not allowed in the tank until the concentration is lowered. An observer is at the tank opening at all times during tank entry. Tank entry was not scheduled while NIOSH personnel were conducting their measurements and the actual procedure was not witnessed. Chevron Jet Fuel B is the fuel used in United's aircraft. The Chevron Corporation provided NIOSH with their official material safety data sheet on Jet Fuel B. No OSHA standard has been promulgated for this fuel mixture but it contains up to 95% paraffins and up to 20% aromatics. It does not contain benzene or xylene. The suggested TLV by Chevron for Jet Fuel B is 200 ppm. After the purging of the tanks, no residual organic solvent vapor is normally present. Therefore, chemical exposure to employees in the tanks would be limited to any substances applied by hand. Some environmental safety staff may be necessary.

Sealants and Adhesives - Two adhesives are used by airline mechanics on a sporadic basis. These are identified as PR1422-B2 and PR1005L. PR1422-B2 is mainly a polysulfide polymer with less than 5% toluene, dimethyl formamide and calcium dichromate. PR1005L is a phenolic resin which contains methyl isobutyl ketone, methylene chloride, and isopropyl alcohol. A neoprene contact adhesive (Stabond T-150D) is also used by airline mechanics. This adhesive contains hexane, methyl ethyl ketone, and toluene. All of the sealers and adhesives are applied by hand from cans or tubes and are used only for small applications which may only last for seconds. An instance where these products were used did not occur during our studies of other chemicals. Adequate general and local ventilation and work practices should be utilized to prevent health hazards during short-term use of the substances.

B. Study Design

1. Environmental

The factors considered for the selection of the final study design were the substances being used, the workers' potential exposures to these substances, the durations of exposure, data from previous CAL/OSHA industrial hygiene surveys, and the existing control measures required

by the company during contact with these chemicals. Based upon the gathered data and the staff available, it was decided that the final environmental study would be an attempt to evaluate employee exposure to the following chemicals during paint stripping and paint spraying operations:

(a) Hexamethylene diisocyanate (HDI)

(b) Such organic solvents and chemicals as methylene chloride, phenol toluene, methyl ethyl ketone, butanol, isopropyl alcohol, cyclohexanone, ethyl acetate, methyl isobutyl ketone, butyl acetate, xylene, and cellosolve acetate.

Every effort was made to coordinate the environmental study with the medical team's visit. The final medical evaluation was scheduled for April 20-23, 1976. All of the environmental data could not be gathered during this time period. It was difficult to coordinate the medical study with the concurrent environmental exposures of the pre-selected sample of employees. Only one or two planes per week were scheduled for stripping and painting. Sometimes, no work was scheduled for over a week, and the schedules changed constantly. It was NIOSH's experience that even if a plane was scheduled to be stripped or painted at a certain time of day, the actual operation would invariably be delayed. In one instance, the delay was 16 hours after schedule. Since 24-hour shifts are in operation, it was difficult to be prepared for environmental sampling. Therefore, the environmental data could not be directly related to a specific person's medical results. Environmental samples were collected on April 19, 22, 23, 1976. The HDI samples collected on April 23 were lost during laboratory analysis, but the sampling was repeated on June 26 and July 14, 1976.

Environmental samples for some operations were not obtained during NIOSH's investigation. It was felt that fuel tank entry (which did not take place during NIOSH's visits) would not be a significant industrial hygiene problem because of the company's strict control measures. The use of adhesives and sealers was also not monitored because of the sporadic nature of the operation. The wash down of planes was observed but no samples were collected. The designated OSHA Agency in California (CAL/OSHA) had done extensive sampling during this operation and solvent vapor levels were low. The observation of this procedure was to substantiate the fact that protective equipment was being worn by the employees. All employees wore protective water-repellant gear and organic vapor cartridge respirators. Again, the wash down procedure is sporadic and performed outdoors. It was felt that this procedure did not present a health hazard to the employees.

2. Medical Design

a) Preliminary Study

The medical portion of the preliminary survey was carried out on March 15 - 17, 1976 by the NIOSH representatives Drs. Robert Rostand, Robin Ryder, Edward Baker, William Keith, and Mr. Larry Edmonds. A preliminary questionnaire and walk-through survey were done to assess the problem of indiscriminate exposure to toxic chemcials and paints. Employees were picked at random from a master roster of workers as well as a few employees who requested to be interviewed. A combined total of 67 employees were interviewed.

The preliminary questionnaire indicated that all employees who were interviewed complained of instances of acute symptoms secondary to working with chemical solvents or paints in the work environment. The questionnaire results revealed significant problems among cleaners and miscellaneous workers who find themselves in the vicinity of the stripping process. These workers developed acute symptoms consisting of eye, nose, and throat irritation as well as lightheadedness, headache, and dizziness. Workers also complained of skin rashes, chest pains, and allergic reactions secondary to working with the chemicals.

After complete analysis of the questionnaire, the NIOSH medical team felt that a more detailed investigation was necessary. To answer the questions and concerns brought out by the preliminary study, the investigation would include a detailed interview, physical examinations, and specific laboratory determinations. From this study, it was anticipated that the presence of a health hazard could be determined.

b) Follow Up Study

A follow up medical survey was conducted on April 20 - 23, 1976. Due to varying exposures during a work shift, maintenance workers were divided into four categories which reflected their job title and/or amount of chemical exposures. The four categories are: (1) painter, (2) cleaner, (3) tool crib, and (4) miscellaneous.

The study itself was divided into three components. All workers included in the study would be administered a brief, but detailed questionnaire. Out of this group, 100 employees would be selected to undergo a brief physical examination of the head, chest, skin, and nervous system. Additionally, a complete blood count, serum CO, complete serum multi-phasic analysis (S.M.A.-12), and urinalysis was done. From this group of 100 employees, approximately 60 nonsmoking workers would be asked to participate in pre and post shift pulmonary function tests and expired air alveolar carbon monoxide measurements.

Since the maintenance base is a 24-hour operation, workers were interviewed from all shifts and job categories in the following distribution:

SHIFT	TOOL CRIB	MISCELLANEOUS	PAINTER	CLEANER	TOTAL
1	12	43	19	11	85
2	8	38	16	18	80
3	4	44	15	29	92
Total	24	125	50	58	257

A total of 230 people were interviewed out of 257 employees. Seven of the 230 people were not part of the randomized sample. All of them were males with a mean age of 39.0 years (range 21 - 67). A control group was not studied because of the difficulty in finding a good matching group which did not have significant chemical exposure.

C. Evaluation Methods

1. Environmental Methods

Personal air samples were taken to evaluate "actual" and "potential" exposures to chemical substances. Actual exposures are those of workers who were not wearing respiratory protection while environmental samples were collected in their breathing zones. Potential exposures refer to breathing zone samples taken on workers who were wearing respiratory protection. Most of the operations which were sampled required the use of respiratory protection. Only during paint stripping of planes were any employees allowed in the work area without respiratory protection. These workers carried out their functions in the cockpit or cabin of the aircraft. Air samples were mostly breathing zone samples, but several general area samples were also collected. For personal samples, the collecting devices (charcoal tubes, impingers) were attached on or near the lapels of the employees.

Special charcoal tubes were used to determine the concentrations of organic solvent vapors in air. MSA Model H battery powered low flow pumps were used to draw air through the charcoal tubes at a rate between 250-310 cubic centimeters (cc) per minute. For methylene chloride samples, two charcoal tubes were used in series for one measurement. For phenol samples, midget impingers containing 15cc of absorbing solution replaced the charcoal tubes. Air was drawn through the impingers at a rate of 1.0 liters per minute (lpm). The charcoal tubes were analyzed by the gas chromatographic method described by L.D. White, et al.[1] HDI samples were collected by bubbling air through midget impingers containing 15cc of absorbing solution The flow rate was 1.0 lpm. The absorbing solution was analyzed by a special chromatographic method developed for NIOSH by the University of Missouri.[2] Individual samples for all substances were run for a period of less than 60 minutes. Stripping and painting operations lasted less than two hours. Therefore, accurate time-weighted average (TWA) concentrations over an eight-hour work shift could not be calculated.

2. Medical Methods

a) Sample Selection

The sample size was calculated from the method described by G. S. Snedecor.[3] In the selection process for employees in the study, four job categories were assigned risk factors to reflect severity of chemical exposures. Three categories were considered a higher risk than the fourth one. This risk factor was taken into consideration when selecting the total number of employees picked for each category. The total number of employees for each category were provided to NIOSH and the workers were listed by seniority. This list was stratified and the employees were then selected in a random manner.

b) Pulmonary Function Testing

Pulmonary function tests were administered to workers using a "Vitalograph" bellows type spirometer. Each worker was tested with the same machine and technician throughout the study. Forced vital capacities (FVC) and forced

expiratory volume at one second (FEV_1) were read from the spirometer graphs. The best results from five tests were utilized, and the individual's best effort from all tries was considered his normal pulmonary function. An individual's pulmonary function test data was compared with his predicted values. The predicted normal values were read from a standard nomogram that has been adjusted for height, age, and sex.

c) Carbon Monoxide Concentrations in Alveolar Air

As a possible indicator of unexpected methylene chloride exposure among employees throughout the maintenance base, alveolar CO levels in pre and post shift expired air samples from the same people who underwent pulmonary function testing were measured. To eliminate the bias of individuals who smoke, only nonsmokers were considered. Alveolar air samples were collected by an expired air technique which is described in the medical criteria section of this report.

d) Blood Testing

A venous blood specimen for such tests as hemoglobin, hematocrit, leukocyte count, differential count, creatinine, glucose, BUN, uric acid, cholesterol, bilirubin total, total protein, albumin, globulin, A/G ratio, LDH, alkaline phosphotase, SGOT, phosphates, chlorides, sodium, potassium. calcium, SGPT, and carbon monoxide were obtained from 104 men in the study. Also a urinalysis was run on each of the men. The blood was drawn at the plant by a technician supplied by ICM Medical Laboratories, Inc., 6060 N.W. 112th Avenue, Portland, Oregon. The specimens were brought to their local laboratory by the technician for analysis.

e) Questionnaire

A detailed questionnaire was designed to record medical histories, acute symptomatology, and chronic health problems. By administering this questionnaire, the symptoms elicited from the employees could be compared to those one would expect from exposure to the chemical hazards listed by the union in the official request. A brief physical examination was performed at the same time in order to evaluate the mucous membranes, eye, nose, throat, skin, abdomen, and the nervous system for obvious signs of any abnormalities.

D. Evaluation Criteria

1. Environmental Standards or Criteria

The three primary sources of environmental evaluation criteria which came under consideration for this report are: (1) NIOSH Criteria Documents for recommended occupational health standards; (2) American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLV's); and (3) Federal occupational health standards promulgated by the U. S. Department of Labor. The TLV's recommended by the ACGIH are listed below as a reference point for the environmental samples taken. The recommendations in the Criteria Documents or the standards in the Federal Register may have different limits but these values will not be listed separately.

If information on these limits is pertinent to this evaluation it will be discussed in the text of the report.

The occupational health exposure limits adopted by the ACGIH (1976) applicable to the principal individual substances of this evaluation are as follows:

Substance	Adopted 8-Hour Time-Weighted Average (TLV-TWA)		Tentative TLV Short-Term Exposure Limit (TLV-STEL)*	
	ppm[a]	mg/m^3 [b]	ppm	mg/m^3
Methylene Chloride	200	720	250	900
Toluene	100	375	150	560
Methyl Ethyl Ketone	200	590	300	885
n-Butyl Acetate	150	710	200	950
"C" n-Butyl Alcohol-Skin	50	150	50	150
Isopropyl Alcohol-Skin	400	980	500	1,225
Cyclohexanone	50	200	50	200
Ethyl Acetate	400	1,400	400	1,400
Methyl Isobutyl Ketone-Skin	100	410	125	510
Xylene-Skin	100	435	150	655
Cellosolve Acetate-Skin	100	540	150	810
Phenol-Skin	5	19	10	38

a - parts of vapor or gas per million parts of contaminated air by volume (ppm)

b - approximate milligrams of substance per cubic meter of air (mg/m^3)

"C" - denotes a ceiling limit of concentration for the substance which should not be exceeded even instantaneously.

* - TLV-STEL is the maximum concentration to which workers can be exposed for a period up to 15 minutes continuously provided that no more than four excursions per day are permitted, with at least 60 minutes between exposure periods, and provided that the TLV-TWA is also not exceeded.

When two or more hazardous substance are present and there is no information to the contrary, their combined effect rather than that of either individually, should be given primary consideration. The effects of the different substances should be considered additive. The sum of the fractions of the actual concentration over the exposure limit for each substance ($C_1/T_1 + C_2/T_2 + \ldots + C_N/T_N$) should not exceed unity or one (1.0). In this regard, the effects of the organic solvents listed above when used together would be considered additive.

There are no current recommended standards and little background information concerning hexamethylene diisocyanate (HDI). In this regard, it is noted that HDI has about the same molecular weight (M.W. approximately 168) and cyanate-NCO-groups as toluene diisocyanate (TDI). NIOSH recommends in a recent Criteria Document that the health standard for TDI be lowered to a TWA of 0.005 ppm (0.036 mg/m^3) and a ceiling concentration for any 20-minute

period of 0.02 ppm (0.14 mg/m^3). The ACGIH recommends a TLV (and a ceiling) of 0.02 ppm (0.14 mg/m^3) for TDI. In a recent NIOSH Hazard Evaluation Report,[4] NIOSH investigators felt that a TWA of 0.1 mg/m^3 or more for HDI may be considered as being significant in terms of potential adverse health effects.

2. Medical Standards or Criteria

a. Organic Solvents (MEK, toluene, xylene, etc.)

The acute effects resulting from excessive exposure to the organic solvents found in this evaluation are generally similar with some minor differences. Toluene has been the most extensively studied, giving rise to mild fatigue, weakness, and paresthesias of the skin with exposures at or above the TLV. At higher concentrations, loss of coordination, headache, dizziness, nausea, extreme nervousness, and finally, unconsciousness may occur.

Xylene is similar in its acute toxic effects to those of toluene, but notable has more irritant effect on the skin, conjunctiva, and respiratory tract. It also has some variable effects on the liver and kidneys and irritant, nonspecific effects on the gastrointestinal tract. The reported effects on the kidney are albuminuria, microhematuria, and hypuria. It was reported that there was found in one patient serological evidence of hepatitis.[12] Chronic effects of exposure to these agents range from weakness, dizziness and fatigue to dermatitis. Other chronic effects are less well defined. None of the agents listed in the table above have been noted to cause bone marrow changes.

Phenol can be readily absorbed through skin contact and inhalation. Excess exposures to phenol can cause a wide variety of adverse effects. These effects have been reported in the literature but are attributable only to exposures by ingestion or skin contact. No report was found concerning acute or chronic human exposure by inhalation to phenol vapors or aerosols. Also, no epidemiologic study of an employee population exposed to phenol by inhalation was found. Severe chronic poisoning in man is characterized by digestive disturbances, nervous disorders, and damage to the liver and kidneys.

Methyl ethyl ketone and cellosolve acetate are like phenol in terms of their adverse effects. They cause eye and mucous membrane irritation at or slightly above the TLV. Prolonged skin contact with these substances may result in a dermatitis. Inhalation of excessive amount of MEK or cellosolve acetate vapors will give rise to such symptoms as narcosis, headache, nausea, vomiting, dizziness, incoordination, and even unconsciousness.

Methylene chloride is also an organic solvent. It is primarily used as a paint stripping agent. Therefore, the effects of excess exposure to methylene chloride will result in many of the sign and symptoms common to other organic solvents. However, recent data has indicated that exposure to methylene chloride can elevate the carboxyhemoglobin (COHb) concentrations in blood. NIOSH recommends that exposures to methylene chloride be limited to 75 pp. (261 mg/m^3) or less on a time-weighted average and 500 ppm (1,740 mg/m^3) peak concentration if the ambient CO level are less that 9 ppm. If CO levels in the workplace exceed

9 ppm, the methylene chloride exposure should correspondingly drop to a level of zero exposure as the CO level reaches 35 ppm. This recommended standard is designed to keep COHb concentrations in blood below 5%.[5]

An estimation of COHb can be calculated from the alveolar CO levels in expired air using the method described by Ringold, et al.[6] Per cent COHb can be estimated by alveolar CO concentrations by the equation: $\%COHb = 0.5 + \frac{CO \text{ in ppm}}{5}$. This equation can be further simplified to an equation without much (if any) reduction in accuracy to $\%COHb = \frac{CO \text{ in ppm}}{5}$.

At United Airlines, alveolar air samples were collected by the expired air technique. Each employee was requested to inhale deeply and hold his breath for 20 seconds. Then the employee was asked to expire most of his air into the atmosphere and the last few hundred milliliters into a polyethylene collection bag. CO concentrations were measured immediately after collection using an Ecolyzer Model 2400 CO Analyzer (0-100 ppm scale). Expired air samples were take pre and post shift. A paint stripping operation was scheduled so that methylene chloride levels could be compared with pre and post shift alveolar CO concentrations.

For persons unexposed to CO, the normal %COHb levels range between 0.5% - 0.75%, which corresponds to expired air CO levels of 2.5 - 3.75 ppm. Cigarette smokers can exhibit %COHb levels of 5 - 10%. The NIOSH recommended standard for methylene chloride is designed to keep %COHb in workers below 5%. According to Peterson and Stewart, an average exposure to 35 ppm of CO (the NIOSH recommended standard) will result in a %COHb of 5% after eight hours.[7] In a study by Ratney and his associates, nonsmoking workers exposed to 180 ppm of methylene chloride on an every day basis reported to work with a %COHb of 4.5% which rose to 9% post shift before dropping back to 4.5% in the morning.[8] The authors concluded that methylene chloride exposures should be kept well below 100 ppm for a work shift in order to maintain a %COHb below a level of 5% in nonsmokers. The NIOSH recommended standard does not take into account smoking histories when applying the 5% rule-of-thumb. Additionally, the NIOSH recommended standard does not take into account pre-existing coronary heart disease with this 5% threshold limit when recent data indicates that elevated %COHb of less than 5% may be detrimental to heart patients.[9]

b. Aromatic and Aliphatic Isocyanates

Four main isocyanates are used in industry. Of these, toluene diisocyanate (TDI) is the most volatile and apparently the most toxic. Little information is available on the toxicities of the other isocyanates. TDI is an aromatic isocyanate but is <u>not</u> present in the paints used at United Airlines. The isocyanate used in the paint at United is an aliphatic isocyanate known as hexamethylene diisocyanate (HDI). The only isocyanates with current TLV's are TDI and methylene bisphenyl isocyanate (MDI). In general, the isocyanates in high concentrations are corrosive and may cause irritation of the eyes, throat, and bronchi plus asthmatic symptoms. Additionally, hyper-sensitivity to isocyanates (TDI) may develop with severe asthmatic symptoms occurring even with exposure to minute concentrations of isocyanates. HDI is less volatile and therefore probably less toxic than TDI, but little information is definitely known about HDI. Thus, exposures to HDI should be kept as low as possible in the workplace.

E. Evaluation Results and Discussion

1. Environmental Results

a) Hexamethylene Diisocyanate (HDI)

HDI samples were collected on two different occasions (June 26 and July 14, 1976) when jet aircraft were scheduled for top-coat painting. On June 26, a wide-body jet was painted in Dock #2, and the results of the sampling are contained in Table IX. After observing the painting operation, it was evident that the exposure to both solvents and HDI were highly variable and dependent upon the amount of overspray a painter was subjected to. Again, all painters wore respiratory protection, and no exposures to toxic substances were expected. Four painters (window level, belly tail, belly forward, and tail top) were selected to be sampled. An impinger sample was collected on these painters during the application of each coat of paint. A coat of paint was applied in approximately 45 minutes for a wide-body jet and 30 minutes or less for a narrow-body jet. Two general area samples were also collected on the mezzanine desk of the dock. Out of the 10 samples for HDI, eight were positive and the levels ranged from 0.19 mg/m^3 to 2.0 mg/m^3. The highest values were found near the belly of the plane.

Table VIII contains HDI levels measured during the top-coat painting of a narrow-body plane on July 14, 1976. Ten samples were taken, but two of them were lost during analysis. The analysis of this batch of samples was complicated by the fact that a contaminant was present which interfered with the gas chromatograph column. Pre-treatment of each sample was necessary and the NIOSH chemist placed the accuracy of these results at $\pm$ 15%. In spite of the error factor, all eight samples were positive for HDI. The levels ranged from 0.5 mg/m^3 to 3.2 mg/m^3 ($\pm$ 15%). Painters were used only on two levels for the smaller narrow-body planes. All the HDI samples represented short-term levels and not time-weighted averages.

b) Organic Solvents (except methylene chloride and phenol)

Eleven short-term personal and two short-term general area samples were collected during the prime-coat painting of a wide-body jet. The results are contained in Table I. Each sample was analyzed for toluene, methyl ethyl ketone, butyl acetate, n-butyl alcohol, isopropyl alcohol, and cyclohexanone. None of the individual solvents in these samples were in excess of their respective TLV's. It was assumed that the effects of individual solvents were additive. Therefore, the TLV of the mixture was considered to be exceeded if the sum of the ratios of concentrations of each substance over its individual TLV was greater than unity (1.0). This calculation was done on these samples with the result that only three out of 11 samples showing a value in excess of 1.0. Two of these samples were collected on workers painting the bottom or belly of the plane. It must be stressed that these calculations were made on sample collection times of 20 - 30 minutes (the time required to paint the prime-coat). Therefore,

if TWA's were calculated for individual solvents based on an eight-hour time period prior to the calculation of the TLV for the mixture, the resultant combined values would be much lower.

Table II contains the results of samples taken for solvents during the top-coat painting of a wide-body plane. Nine personal and two general area samples were collected. All employees in the area were required to wear respiratory protection. Analyses were made for air levels of ethyl acetate, methyl ethyl ketone, methyl isobutyl ketone, butyl acetate, xylene, and cellosolve acetate. Concentrations of individual solvents were not found to be in excess of their respective TLV's. Four out of nine samples showed combined exposure levels in excess of 1.0 (range 1.0 - 1.76). These calculations were made from short-term samples and not TWA's. TWA's were not calculated because total solvent exposure time for painters was short.

c) Methylene Chloride and Phenol

Methylene chloride (MC) and phenol concentrations were measured during a paint stripping operation on a wide-body jet. The results are contained in Table III. All employees except cabin personnel wore certified respirators. Ten samples were collected for phenol. Four of them during the application of the stripping compound. The phenol concentrations were below detectable limits. Six samples were collected during the scraping and water washing phases. Five out of the six samples were below detectable limits. The other sample showed a phenol level of 0.2 mg/m^3. During the same stripping operation, MC samples were also collected. Samples were taken at the upper and lower plane sections and inside the cabin. Twenty-five individual samples were taken. The MC concentrations were found to vary over a wide range from a low of 79 mg/m^3 (23 ppm) to a high of 950 mg/m^3 (273 ppm). Each sample was run for less than 60 minutes.

Table IV contains a summary of the individual MC samples by area over time during the same paint stripping operation. The TWA's were calculated over an approximate 2 1/2 hour time period (which is the length of time usually required to strip a wide-body jet). Therefore, these values cannot be used to represent an eight-hour TWA. Two employees worked on the upper section of the plane. Their average MC exposure was 150 mg/m^3 (43 ppm) and 309 mg/m^3 (89 ppm). Two employees were monitored while they worked on the lower section of the plane. Their average MC exposures were 384 mg/m^3 (110 ppm) and 914 mg/m^3 (263 ppm). One cabin mechanic was monitored and his average MC exposure was 416 mg/m^3 (120 ppm). Also, a general area sample was collected in the cabin. The MC level was 391 mg/m^3 (112 ppm).

Table VI contains MC levels found during the paint stripping of a narrow-body jet. Phenol samples were not taken since the levels found during a previous paint stripping operation were mostly below detectable limits. This finding substantiates the results of CAL/OSHA and the United Airlines industrial hygiene staff. Thirty-two individual samples for MC were collected.

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All personnel except the cabin mechanics were required to wear respiratory protection. General area samples were taken in the cabin and at the mezzanine. Breathing zone samples were collected only on the painters. The MC levels varied from a low of 38 mg/m^3 to a high of 2820 mg/m^3 (811 ppm). These individual samples were usually taken over a period of 30 minutes or less. The employees left the work area after the completion of each phase of the paint stripping operation.

Table V contains a summary of the MC levels which are found in Table VI. Four painters who were working on the main body of the jet were sampled over a period of 86 - 93 minutes each. The average MC levels ranged from 570 mg/m^3 (164 ppm) to 1,288 mg/m^3 (370 ppm). The overall average for these painters was 892 mg/m^3 (256 ppm). The painter at the tail section of the plane was exposed to an average MC level of 273 mg/m^3 (79 ppm) over a 113-minute time period. General area samples were collected in the forward cabin, mid-cabin, and at the mezzanine. The average MC level in the forward cabin and mid-cabin were respectively 1,065 mg/m^3 (306 ppm) and 759 mg/m^3 (218 ppm). The average MC concentration at the mezzanine was 233 mg/m^3 (76 ppm). Cabin crews can vary from one to ten or more employees.

d) Discussion of Environmental Results.

It is apparent from the summary of environmental results that employees' exposures to organic solvents and other chemicals are sporadic, highly variable, and are influenced by the use of personal protective devices. No study was made to assess the effectiveness of half-mask respirators for use against exposures to organic solvents and isocyanates, but it is felt that they provide some degree of protection. In one area (aircraft interior cabin) during paint stripping operations where employees don't wear respiratory protection, it was found that methylene chloride levels can exceed the ADGIH recommended short-term excursion limit of 900 mg/m^3 (250 ppm). During other phases of paint stripping, MC levels also reach high level (up to 811 ppm) for short periods of time, but exposed workers are required to wear respiratory protection. Exposures to other organic solvents were also short-term but levels did not approach maximum allowable limits. No standard for haxamethylene diisocyanate exists, but concentrations are high if comparisons are made to the toluene diisocyanate standard. However, there is no conclusive basis to make such a comparison and workers exposed to HDI are required to wear respiratory protection. In conclusion, potentially toxic concentrations of organic solvents and isocyanates occurred for short periods of time, but in most cases, employees were protected by respirators and/or the fact that total exposure times were relatively brief in terms of a 40-hour work week.

2. Medical Results and Discussions

a. Medical Histories

The past medical histories of interviewed employees and the occurrence of acute symptomatology are tabulated in Tables XII and XIII respectively. It is noted that symptoms are sujective on the part of interviewed employees. It was found that there were no statistically significant differences in past medical histories between worker categories. However, in all categories, the presence of conditions related to allergic problems (hay fever

and sinus) and bronchitis was much more prevalent than such other medical problems as hypertension and emphysema. Similarly, there were no significant differences between job categories and the incidence of acute symptoms (Table XIII). But in relation to all workers, there seemed to be a high percentage of employees who complained of eye and throat irritation, head congestion, and skin rashes. Over one-half of the workers interviewed complained of occasional eye irritation. One-third of the workers suffered occasional throat irritation and head congestion. Other symptoms mentioned in decreasing frequency were: skin rashes, headaches, dizziness, and numbness and tingling of the fingers. The use of respiratory protection did not seem to influence the frequency of acute symptoms among the workers. The fact that workers in general may be exposed to chemical agents on a sporadic basis throughout the plant without respiratory protection may account for the high percentage of complaints concerning irritation.

During the initial investigations, two cases of leukemia were discovered. One case was a cleaner who was exposed to a variety of substances and the other worker was classsified in the miscellaneous category. Both employees had been at the maintenance base for over 10 years. It was not possible to determine whether there was any relationship between the disease and the use of any chemicals suspected of causing leukemia.

b. Physical Findings

After their initial interviews, a selected number of employees were given physical examinations. In general, no significant physical conditions were found that could be related to chemical exposures. However, one cleaner who was felt to be suffering from congestive heart failure with bilateral rales and a 3+ pitting edema of his legs was discovered.

c. Pulmonary Function

The results of the pulmonary function tests are contained in Tables XV and XVI. Table XV contains pre-shift, post-shift, and predicted FEV_1's by job category. T-tests were performed on the data and the conclusion was that by job category there were no significant differences. In the painter and cleaner categories, the average post-shift FEV_1 was lower than the pre-shift value, but the drop was not statistically significant when comparing the results to predicted values. T-tests were also performed on pre-shift, post-shift, and predicted FEV_1's by age (Table XVI). Again, no significant changes by age were found. Three employees were unable to complete the pulmonary function tests and were excluded from the statistics.

d. Alveolar CO

Tables X and CI contain data on pre and post-shift alveolar CO levels in expired air samples. Table XI is a summary of CO data by job category and the level of post-shift alveolar CO change. Between job categories, no significant differences were found; however, a large percentage of the painters did show some post-shift increase. The exact cause of this change could not be determined. One unforeseen problem with this test was the presence of an interfering substance in the expired air samples of some of the employees. The CO analyzer readings were much too high.

It was felt that agents such as alcohol or mouthwash could interfere with the CO reading. Cigarette smoking will elevate the alveolar CO, but the problem was not cigarette smoking since only nonsmokers were selected for this study.

Table VII contains more definitive data on expired air CO levels. Pre-shift and post-shift CO levels in expired air were measured and the %COHb's were calculated. Again, some of the subjects' data could not be used, but nine nonsmokers were studied. Four painters (who wore respirators) and five cabin and mezzanine area workers were studied. On an average, the painters who wore respirators and the other personnel showed elevated post-shift CO levels in their expired air samples. The workers who did not wear respirators had a slightly high elevation in expired air CO. None of the workers showed a %COHb in excess of 5% among the nonsmokers. The ambient CO levels in air were less than 3 ppm, and it can, therefore, be concluded that the increase in %COHb was attributed to methylene chloride exposure during the paint stripping process. Two out of the four painters showed a post-shift increase in CO levels. This result may indicate that either the respirator fit or efficiency is inadequate or that these painters are removing their respirators.

e. Blood Tests

Table XIV contains the normal values and the blood test results of our sample of workers by job classification. For all categories, no abnormal results were found. For all individual employees, none showed any indication of gross abnormalities that could be related to exposures to toxic chemicals in the workplace.

F. Recommendations

In view of the findings of NIOSH's medical and environmental study at the United Airlines Maintenance Base, the following recommendations are made to ameliorate potential health hazards and to provide a better work environment for the employees covered by this determination:

1. All personnel in and around jet aircraft during the paint stripping process should wear NIOSH certified respirators and mechanical ventilation should be researched as a possible control measure to lower methylene chloride vapor concentrations in the interiors of aircraft during the paint stripping process.

2. The respirator program at United Airlines should be analyzed and possible upgraded because there were instances where employees wore respirators improperly or the fit was not correct. An indication of this situation is the elevated alveolar CO levels in the expired air of painters who wore respiratory protection during methylene chloride exposures.

3. Although there may not be a significant relationship between chemical exposures at United Airlines and the two cases of leukemia, the United Airlines Medical Section should establish cancer registry on its personnel as being good industrial medical practice.

4. All employees should receive baseline pulmonary function and blood testing prior to employment at the maintenance base.

5. A periodic medical monitoring program which includes blood and pulmonary function testing should be instituted for employees having significant chemical exposure.

6. The recommendations contained in Chapters I and VI of Criteria for a Recommended Standard...Occupational Exposure to Toluene Diisocyanate[10] are applicable with some modification to airplane paint spraying operations using paint containing hexamethylene diisocyanate (HDI). Because of the considerably lower volatility of HDI, the detailed directions for handling spills and clothing contamination do not seem appropriate. Additionally, the United Airlines Industrial Hygiene staff should conduct periodic HDI environmental monitoring to see if the HDI levels change and whether existing control measures are adequate.

7. It is recommended that environmental sampling for hexavalent chromium be conducted during primer paint spraying. The recommendations contained in Criteria for a Recommended Standard...Occupational Exposure to Chromium(VI)[11] should be followed if applicable.

8. It is suggested that United Airlines conduct periodic environmental evaluations of employee exposures to all organic solvents and other chemicals to assure that the above recommendations are adequate to protect the "affected employees".

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TABLE I. CONCENTRATIONS OF SOLVENTS IN mg/m^3 IN BREATHING ZONE SAMPLES COLLECTED DURING PRIME COAT PAINTING OF A WIDE-BODY AIRCRAFT AT UNITED AIRLINES DOCK #2 ON APRIL 22, 1976

Sample#	Time(am)	Operation	TOL[1]	MEK[2]	BA[3]	BUT[4]	IPA[5]	CYCL[6]	Combined[7]
3C	1:23-1:42	Midlevel	136	48	94	32	76	12	0.93
23C	1:42-2:07	Midlevel	148	65	106	39	126	18	1.13
2C	1:26-2:04	Toplevel	113	48	82	31	93	16	0.88
5C	1:22-1:45	Toplevel	85	30	44	13	11	4	0.46
7C	1:45-2:08	Toplevel	81	28	50	17	ND*	6	0.48
4C	1:29-1:50	Vertical	108	8	38	10	ND	ND	0.42
9C	1:50-2:07	Vertical	115	30	68	20	ND	8	0.63
1C	1:24-1:44	Bottom	179	77	130	47	132	23	1.35
8C	1:44-2:10	Bottom	149	57	107	39	116	18	1.11
6C	1:21-1:46	Bottom	119	44	74	26	32	10	0.75
10C	1:46-2:10	Bottom	125	41	86	30	81	12	0.87
11C	1:32-2:05	Mezzanine	51	16	32	9	ND	3	0.28
12C	1:32-2:05	Assignment Booth	52	19	29	9	ND	3	0.29

1 - TOL/Toluene - TLV = 375 mg/m^3

2 - MEK/Methyl Ethyl Ketone - TLV = 590 mg/m^3

3 - BA/Butyl Acetate - TLV = 710 mg/m^3

4 - BUT/n-Butyl Alcohol - TLV = 150 mg/m^3

5 - IPA/Isopropyl Alcohol - TLV = 980 mg/m^3

6 - CYCL/Cyclohexanone - TLV = 200 mg/m^3

7 - Combined - Assuming additive effects, combined TLV is 1.0 (unity) where calculations are based upon the TLV-TWA and not TLV-STEL for each substance. In this table, the values are levels found in short term samples and do not represent a TWA.

*ND - none detected within the limits of detection for the analytical method used.

TABLE II. CONCENTRATIONS OF SOLVENTS IN mg/m^3 IN BREATHING ZONE SAMPLES COLLECTED DURING TOP COAT (POLY PAINT) PAINTING OF A WIDE-BODY AIRCRAFT AT UNITED AIRLINES DOCK #2 ON APRIL 22, 1976

Sample#	Time(pm)	Operation	EA[1]	MEK[2]	MIBK[3]	BA[4]	XYL[5]	CA[6]	Combined[7]
17C	3:53-4:23	Bottom	707	139	99	184	43	41	1.34
14C	4:23-4:55	Bottom	275	43	32	51	43	41	0.46
21C	3:52-4:20	Bottom	544	117	76	139	33	30	1.10
24C	4:20-4:57	Bottom	363	64	40	64	11	ND*	0.58
25C	4:10-4:35	Midlevel	219	31	35	81	15	19	0.48
19C	4:35-5:07	Midlevel	105	14	13	29	7	ND	0.19
16C	4:32-5:03	Midlevel	533	121	63	112	27	25	1.00
18C	3:55-4:30	Top	857	219	117	210	49	46	1.76
15C	4:30-4:58	Top	486	107	62	108	27	24	0.94
20C	4:12-4:41	Mezzanine	234	40	32	66	16	15	0.47
33C	4:41-5:07	Mezzanine	ND	ND	ND	ND	ND	ND	--

1 - EA/Ethyl Acetate - TLV = 1,400 mg/m^3

2 - MEK/Methyl Ethyl Ketone - TLV = 590 mg/m^3

3 - MIBK/Methyl Isobutyl Ketone - TLV = 410 mg/m^3

4 - BA/Butyl Acetate - TLV = 710 mg/m^3

5 - XYL/Xylene - TLV = 435 mg/m^3

6 - CA/Cellosolve Acetate - TLV = 540 mg/m^3

7 - Combined - Assuming additive effects, combined TLV is 1.0 (unity) where calculations are based on TLV-TWA and not TLV-STEL for each substance.

*ND - none detected within the limits of detection for the analytical method used.

TABLE III. CONCENTRATIONS OF METHYLENE CHLORIDE (MC) AND PHENOL IN mg/m^3(ppm) IN BREATHING ZONE SAMPLES COLLECTED DURING PAINT STRIPPING OF A WIDE-BODY AIRCRAFT AT UNITED AIRLINES MAINTENANCE DOCK #2 ON APRIL 19, 1976

Sample#	Time(pm)	Operation And Job	MC[1] CONC(ppm)	Time(pm)	Phenol[2]
1	6:35-7:20	Applying Stripper/Lower Level	950(273)	6:35-7:31	ND*
1C	7:20-7:31	Applying Stripper/Lower Level	746(215)	6:35-7:31	ND
3	6:38-7:22	Applying Stripper/Lower Level	440(127)	6:38-7:31	ND
2	6:36-7:28	Applying Stripper/Upper Level	91(26)	6:36-7:28	ND
4	6:40-7:30	Applying Stripper/Upper Level	169(49)	6:40-7:32	ND
10	9:02-9:45	Scrapedown/Cabin Mechanic	309(89)	9:02-11:08	ND
11	9:24-10:08	Scrapedown/Cabin Area**	426(123)	9:25-10:57	ND
6	9:05-9:34	Scrapedown/Lower	592(170)	9:05-11:04	0.2
15	9:34-9:46	Scrapedown/Lower	369(106)	9:05-11:04	0.2
8	9:11-9:29	Scrapedown/Lower	79(23)	9:11-11:08	ND
5	9:07-9:27	Scrapedown/Upper	148(43)	9:07-11:08	ND
18	9:28-9:44	Scrapedown/Upper	110(32)	9:07-11:08	ND
7	9:10-9:32	Scrapedown/Upper	310(89)	---	
14	9:33-9:45	Scrapedown/Upper	114(33)	---	
17	10:08-10:57	Water Wash/Cabin Area**	366(105)	9:25-10:57	ND
20	10:03-10:37	Water Wash/Cabin Mechanic	219(63)	9:02-11:08	ND
25	10:37-11:08	Water Wash/Cabin Mechanic	408(117)	9:02-11:08	ND
21	10:01-10:32	Water Wash/Lower	805(232)	9:05-11:04	0.2
9	10:32-11:04	Water Wash/Lower	722(208)	9:05-11:04	0.2
13	10:04-10:33	Water Wash/Lower	187(54)	9:11-11:08	ND
23	10:35-11:08	Water Wash/Lower	647(186)	9:11-11:08	ND
19	10:02-10:36	Water Wash/Upper	615(177)	---	
24	10:36-11:06	Water Wash/Upper	275(79)	---	
12	10:02-10:35	Water Wash/Upper	150(43)	9:07-11:08	ND
22	10:35-11:08	Water Wash/Upper	263(76)	9:07-11:08	ND

1 - MC (Methylene Chloride) TLV-TWA = 720 mg/m^3 (200 ppm)

2 - Phenol TLV-TWA = 19 mg/m^3 (5 ppm)

*ND - Not detected

** General area sample

TABLE IV. TWA's FOR METHYLENE CHLORIDE EXPOSURE IN mg/m^3(ppm) BY WORK AREA DURING ALL PHASES OF A WIDE-BODY AIRCRAFT STRIPPING OPERATION AT UNITED AIRLINES DOCK #2 CONDUCTED ON APRIL 19, 1976

Work Area	Total Sample Time (minutes)	TWA in mg/m^3 (ppm)*
Upper Plane Section	148	309 (89)
Upper Plane Section	154	150 (43)
Lower Plane Section	160	914 (263)
Lower Plane Section	124	384 (110)
Cabin Mechanic	108	416 (120)
Cabin General Area	93	391 (112)

* TLV-TWA for Methylene Chloride = 720 mg/m^3 (200 ppm)

TABLE V. TWA's FOR METHYLENE CHLORIDE EXPOSURE IN mg/m^3 (ppm) BY WORK AREA DURING ALL PHASES OF A NARROW-BODY AIRCRAFT STRIPPING OPERATION AT UNITED AIRLINES DOCK #7

Work Area	Total Sample Time (minutes)	TWA in mg/m^3 (ppm)*
Stripping Paint, Main Body	93	619 (178)
Stripping Paint, Main Body	86	1090 (313)
Stripping Paint, Main Body	93	570 (164)
Stripping Paint, Main Body	91	1288 (370)
Stripping Paint, Tail Section	113	273 (79)
Stripping Paint, Forward Cabin General Area	129	1065 (306)
Stripping Paint, Mid-Cabin General Area	71	759 (218)
Stripping Paint, Mezzanine Desk Area	110	233 (67)

* TLV-TWA for Methylene Chloride = 720 mg/m^3 (200 ppm)

TABLE VI. CONCENTRATIONS OF METHYLENE CHLORIDE (MC) IN mg/m^3 (ppm) IN BREATHING ZONE (BZ) AND GENERAL AREA (GA) SAMPLES COLLECTED DURING PAINT STRIPPING OF A NARROW-BODY AIRCRAFT AT UNITED AIRLINES DOCK #7 ON APRIL 23, 1976

Sample#	Time(pm)	Type	Operation And Job	MC[1] in mg/m^3 (ppm)
1D	7:01-7:26	BZ	Applying stripper/pumping from hose	38 (11)
3D	7:02-7:25	BZ	Applying stripper/pumping from hose	70 (20)
2D	7:08-7:24	BZ	Applying stripper/pushing by hand	1983 (570)
6D	7:05-7:24	BZ	Applying stripper/pushing by hand	805 (232)
4D	7:06-7:26	BZ	Applying stripper/handling barrels	390 (112)
5D	7:02-7:27	GA	Applying stripper/mezzanine desk	458 (132)
9D	7:33-7:50	GA	Applying stripper/mezzanine desk	326 (94)
7D	7:03-7:28	GA	Applying stripper/forward cabin	1379 (397)
11D	7:33-7:53	GA	Applying stripper/forward cabin	1334 (384)
8D	7:03-7:28	GA	Applying stripper/mid-cabin	668 (192)
12D	7:34-7:53	GA	Applying stripper/mid-cabin	791 (227)
18D	9:12-9:39	BZ	Scrapedown	706 (203)
13D	9:13-9:42	BZ	Scrapedown	429 (123)
14D	9:13-1:40	BZ	Scrapedown	645 (186)
20D	9:14-9:47	BZ	Scrapedown	167 (48)
19D	9:15-9:40	BZ	Scrapedown	450 (129)
15D	9:17-9:43	GA	Scrapedown/mezzanine desk	81 (23)
17D	9:18-9:44	GA	Scrapedown/forward cabin	338 (97)
25D	9:59-10:22	BZ	Hot water wash	1149 (331)
29D	10:22-10:40	BZ	Hot water wash	619 (177)
21D	9:59-10:24	BZ	Hot water wash	2820 (811)
30D	10:24-10:46	BZ	Hot water wash	916 (264)
24D	10:00-10:28	BZ	Hot water wash	153 (44)
33D	10:28-11:00	BZ	Hot water wash	414 (119)
22D	10:01-10:20	BZ	Hot water wash	1644 (473)
32D	10:26-10:50	BZ	Hot water wash	558 (161)
26D	10:06-10:25	BZ	Hot water wash	1242 (357)
31D	10:25-10:47	BZ	Hot water wash	700 (201)
28D	9:45-10:08	GA	Hot water wash/forward cabin	1200 (345)
23D	10:08-10:43	GA	Hot water wash/forward cabin	662 (190)
27D	9:48-10:30	GA	Hot water wash/mezzanine desk	156 (45)
16D	10:05-10:32	GA	Hot water wash/mid-cabin	634 (182)

1 - MC/Methylene Chloride TLV-TWA = 720 mg/m^3 (200 ppm)

TABLE VII. PRE-SHIFT AND POST-SHIFT ALVEOLAR CARBON MONOXIDE (CO) CONCENTRATIONS IN PARTS PER MILLION (ppm) WITH CORRESPONDING ESTIMATED PER CENT CARBOXYHEMOGLOBIN LEVELS (% COHb) BY WORK AREA AND SMOKING HISTORY

Subject	Work Area	Pre-shift CO	% COHb	Post-shift CO	% COHb
		NONSMOKERS			
1	Stripping Paint	8 ppm	1.6	15 ppm	3.0
2	Stripping Paint	9 ppm	1.8	10 ppm	2.0
3	Stripping Paint	8 ppm	1.6	8 ppm	1.6
4	Stripping Paint	6 ppm	1.2	13 ppm	2.6
5	Cabin Area	6 ppm	1.2	15 ppm	3.0
6	Cabin Area	7 ppm	1.4	17 ppm	3.4
7	Cabin Area	7 ppm	1.4	17 ppm	3.4
8	Cabin Area	52*ppm	10.4	40 ppm	8.0
9	Mezzanine	7 ppm	1.4	13 ppm	2.6
10	Mezzanine	6 ppm	1.2	13 ppm	2.6
		SMOKERS			
11	Stripping Paint	76*ppm	15.2	67 ppm	13.4
12	Cabin Area	31 ppm	6.2	30 ppm	6.0
13	Cabin Area	23 ppm	4.6	38 ppm	7.6
14	Cabin Area	73*	14.6	65 ppm	13.0
15	Cabin Area	170*ppm	34.0	53 ppm	10.6

* Alveolar CO concentrations were too extreme and suggests that there was an interfering substance in expired air sample which was run through the CO analyzer.

TABLE VIII. HEXAMETHYLENE DIISOCYANATE (HDI) CONCENTRATIONS IN mg/m^3 IN SAMPLES COLLECTED DURING TOPCOAT PAINTING OF A NARROW-BODY AIRCRAFT AT UNITED AIRLINES DOCK #5 ON JULY 14, 1976

Sample#	Type	Area or Operation	Time	HDI[1] CONC., IN mg/m^3
21	Breathing Zone	Belly	00:29-01:42	2.60
4	Breathing Zone	Side	00:29-01:37	0.71
25	Breathing Zone	Side	00:29-01:40	3.20
24	Breathing Zone	Tail	00:27-01:40	0.55
8	General Area	Mezzanine	00:26-01:35	1.40
10	Breathing Zone	Belly	10:57-12:04	0.52
2	Breathing Zone	Side	11:02-12:08	1.70
12	Breathing Zone	Tail	10:59-11:59	0.50

1 - HDI has no TLV

TABLE IX. HEXAMETHYLENE DIISOCYANATE (HDI) CONCENTRATIONS IN mg/m^3 IN SAMPLES COLLECTED DURING TOPCOAT PAINTING OF A WIDE-BODY AIRCRAFT AT UNITED AIRLINES DOCK #2

Sample#	Type	Area or Operation	Time	HDI[1] CONC. IN mg/m^3
4	Breathing Zone	Window Level	12:52-13:27	1.65
11	Breathing Zone	Window Level	14:13-15:30	0.33
5	Breathing Zone	Belly Tail	12:54-13:30	1.30
10	Breathing Zone	Belly Tail	14:16-15:15	1.60
3	Breathing Zone	Belly Forward	12:53-13:22	2.00
12	Breathing Zone	Belly Forward	14:14-15:31	1.20
6	Breathing Zone	Tail Top	12:56-13:35	ND*
9	Breathing Zone	Tail Top	14:19-15:08	0.52
8	General Area	Mezzanine	13:00-13:50	ND
13	General Area	Mezzanine	14:15-15:10	0.19

1 - HDI has no TLV

*ND - none detected by the analytic method used; limit of detection is approximately 0.04 mg/m^3

TABLE X. PRE-SHIFT AND POST-SHIFT ALVEOLAR CARBON MONOXIDE (CO) CONCENTRATIONS IN PARTS PER MILLION (ppm) IN EXPIRED AIR SAMPLES OF SELECTED EMPLOYEES BY JOB CLASSIFICATION.

JOB*	NUMBER	PRE	POST
P	101	7	8
P	102	14	9
TC	104	78	3
TC	105	150	5
MIS	106	6	3
C	107	8	5
MIS	108	8	8
MIS	109	8	4
P	112	0	8
P	111	7	6
C	114	7	2
C	116	7	7
MIS	117	6	4
C	118	7	3
C	202	8	5
TC	203	5	7
C	204	12	6
TC	205	6	15
MIS	206	5	7
C	207	5	16
P	208	6	9
MIS	209	6	6
P	210	6	8
P	211	12	14
P	212	8	9
P	213	7	12

JOB*	NUMBER	PRE	POST
C	213	6	7
MIS	215	20	6
C	216	16	16
P	217	6	9
P	218	5	25
P	219	7	18
MIS	220	6	6
MIS	221	6	8
TC	305	64	5
TC	306	6	4
MIS	309	20	5
MIS	311	7	6
P	312	7	19
P	314	7	15
C	315	5	5
C	316	5	7
C	318	5	5
C	320	5	43
C	321	6	9
P	322	19	7

* Job classifications - P (painter),
TC (tool crib),
C (cleaner),
MIS (miscellaneous).

TABLE XI. NUMBERS OF EMPLOYEES BY JOB CLASSIFICATION WITH INTERPRETABLE OR UNINTERPRETABLE CHANGES IN PRE-SHIFT AND POST-SHIFT ALVEOLAR CO IN EXPIRED AIR SAMPLES.

	UNINTERPRETABLE	NO CHANGE OR 1-2 PPM INCREASE	INCREASE 3 PPM OR MORE	DECREASE
PAINTERS	0	4	8	3
CLEANERS	0	6	3	5
TOOL CRIB	3	1	1	1
MISCELLANEOUS	0	5	0	6
TOTAL	3	16	12	15

TABLE XII. PRE-EXISTING MEDICAL CONDITIONS AMONG EMPLOYEES INTERVIEWED BY JOB CLASSIFICATION AT THE UNITED MAINTENANCE BASE

DISEASE	Tool Crib	Miscellaneous	Painter	Cleaner
Diabetes	0%	0%	0%	0%
Emphysema	0%	0.9%	0%	0%
Bronchitis	25%	17.9%	9.8%	10%
Pleurisy	6.3%	6.6%	7.3%	2.0%
Hypertension	12.5%	11.3%	2.4%	8.0%
Hay Fever	18.8%	25.5%	26.8%	18.0%
Sinus	43.8%	27.4%	43.9%	12.0%

TABLE XIII. INCIDENCE OF REPORTED SYMPTOMS AMONG EMPLOYEES INTERVIEWED BY JOB CLASSIFICATION AT THE UNITED AIRLINES MAINTENANCE BASE

Symptom	Tool Crib	Miscellaneous	Painter	Cleaner
Burning of eyes	68.8%	55.7%	78.0%	66.0%
Skin rash	25.0%	18.1%	12.2%	20.0%
Headache	12.5%	18.1%	26.8%	14.0%
Dizziness	12.5%	19.0%	19.5%	10.0%
Numbness and tingling of fingers	18.8%	14.3%	24.4%	10.0%
Tremors	0%	2.9%	9.8%	1.0%
Nausea	12.5%	3.8%	2.4%	10.0%
Head Congestion	31.3%	27.6%	34.1%	20.0%
Throat Irritation	37.9%	28.3%	46.3%	40.0%

TABLE XIV. MEAN VALUES OF SELECTED BLOOD SPECIMEN TESTS BY JOB CLASSIFICATION FROM SAMPLED EMPLOYEES AT THE UNITED AIRLINES MAINTENANCE BASE

Test	Normal Values		Tool Crib	Misc.	Painter	Cleaner
BUN	7-25 mg%	Mean	17.0	18.1	17.6	16.8
		s.d.*	3.7	4.4	4.9	4.9
SGPT	3-23 mg%	Mean	15.3	16.7	17.1	24.1
		s.d.	5.7	8.4	10.0	20.5
SGOT	10-100 mg%	Mean	69.2	57.3	62.5	69.1
		s.d.	23.7	27.1	21.7	31.4
Alk. Phos.	24-100 mg%	Mean	90.2	58.3	56.8	69.6
		s.d.	23.7	18.4	17.6	27.0
Choles-terol	150-280 mg%	Mean	212.3	218.7	213.3	228.8
		s.d.	51.3	39.5	38.8	47.3
Blood CO	0-5% Sat.	Mean	2.3	2.2	2.3	1.6
		s.d.	2.0	1.7	1.9	1.3
WBC	4.7-9.7	Mean	7.9	7.34	7.38	7.44
		s.d.	1.44	2.02	2.02	2.01
Hemoglo-bin	12.5-17.2 gm	Mean	15.0	14.88	15.1	15.16
		s.d.	.94	.71	.92	.96

* s.d. - standard deviation

TABLE XV. PULMONARY FUNCTION TEST RESULTS IN MEAN PRE-SHIFT, POST-SHIFT, AND PREDICTED ONE-SECOND FORCED EXPIRATORY VOLUMES (FEV_1) IN LITERS BY JOB CATEGORY AT THE UNITED AIRLINES MAINTENANCE BASE.

JOB CATEGORY	PRE-SHIFT FEV_1	POST-SHIFT FEV_1	PREDICTED FEV_1
Tool Crib	4.19	4.19	3.85
Miscellaneous	4.17	4.36	4.32
Cleaner	4.67	4.43	4.38
Painter	4.82	4.44	4.68
Total*	4.53	4.39	4.42

* mean values were calculated with three subjects omitted from final total reflected in Table XVI

TABLE XVI. PULMONARY FUNCTION TEST RESULTS IN MEAN PRE-SHIFT, POST-SHIFT, AND PREDICTED ONE-SECOND FORCED EXPIRATORY VOLUMES (FEV_1) IN LITERS BY AGE GROUP AT THE UNITED AIRLINES MAINTENANCE BASE.

AGE GROUP	PRE-SHIFT FEV_1	POST-SHIFT FEV_1	PREDICTED FEV_1
15 - 20	4.96	4.95	4.95
21 - 25	4.85	4.62	4.10
26 - 30	4.76	4.73	4.78
31 - 40	4.47	4.36	4.34
41 - 50	3.85	3.81	4.00
51 - 60	3.51	3.56	3.12
Total	4.29	4.24	4.19

ATTACHMENT A

SFOMB

INFORMATION GUIDE

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