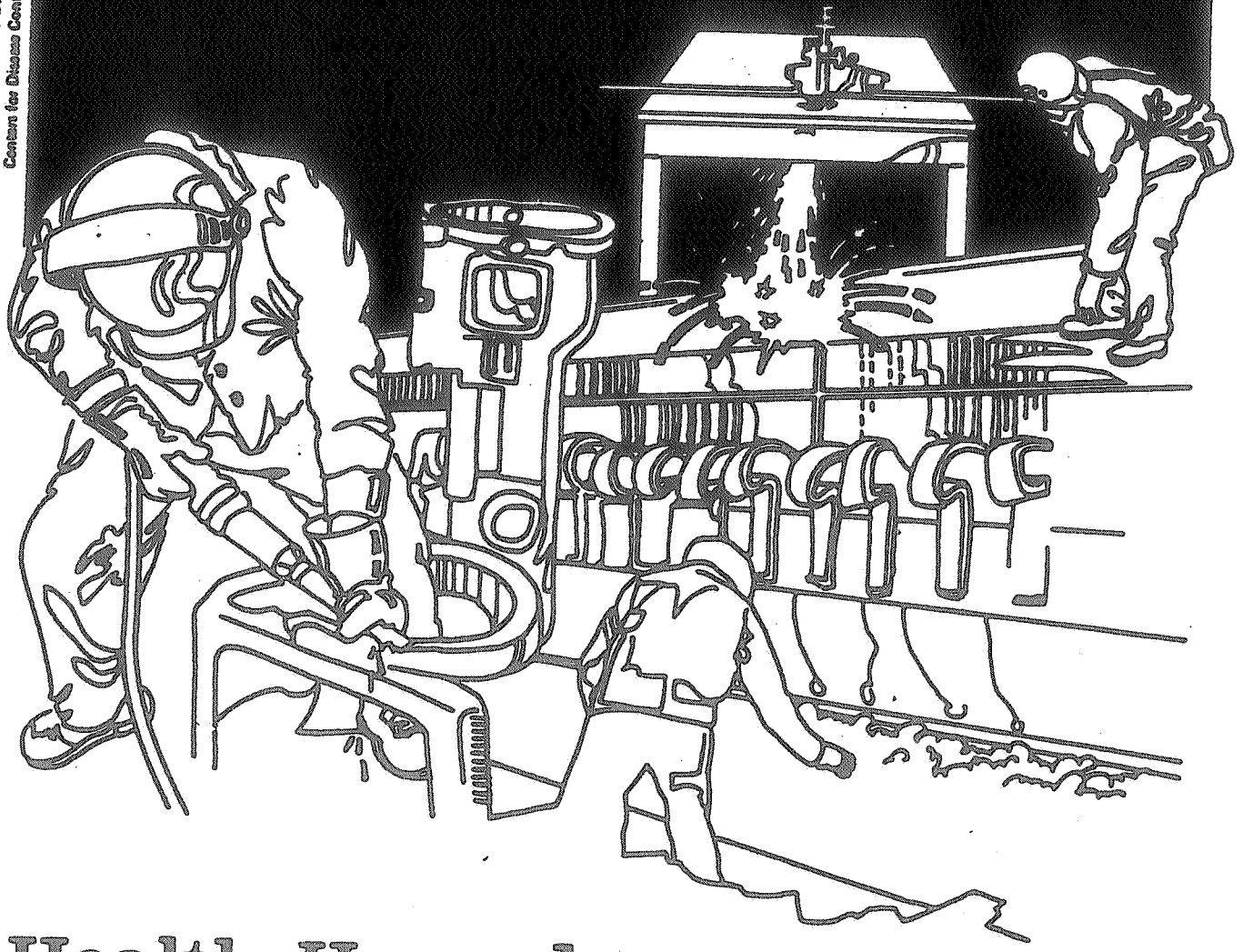
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES ■ Public Health Service
Centers for Disease Control ■ National Institute for Occupational Safety and Health

NIOSH



Health Hazard Evaluation Report

HETA 82-181-1720
FORD MOTOR COMPANY
UTICA, MICHIGAN

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any 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.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

HETA 82-181-1720
August 1986
FORD MOTOR COMPANY
UTICA, MICHIGAN

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I. SUMMARY

In August 1983, NIOSH surveyed 261 current workers at the Utica Trim Plant, where toluene diisocyanate (TDI) is used in the manufacture of cushions for automobiles. TDI and other isocyanates are irritants and sensitizers. Reported health effects include irritation (especially eye, nose, and throat), lower respiratory tract symptoms (chest tightness, wheezing), and reduced pulmonary function. NIOSH recommends that toluene diisocyanate concentrations be no greater than 5 ppb as a TWA concentration.

Pre- and post-shift spirometry, acute and chronic respiratory symptom questionnaires, and personal environmental measures of isocyanates were collected on workers in 3 exposure Groups: A, B1, and B2. Group A was made up of 86 men, selected at random from within 5 year age strata of employees who were currently working on the foam lines. Workers in Group B1 were age-matched to those in Group A and consisted of 88 men who had formerly worked on the foam lines. Group B2 consisted of 87 men, age-matched to those in Group A, and who had never worked on the foam lines.

An external comparison group of 145 non-isocyanate exposed men from the Romeo plant were selected and age-matched to workers in Group A. These controls were divided into 2 groups: 70 workers were administered chronic respiratory questionnaires and baseline spirometry (C1). The other 75 workers were in addition administered acute symptom questionnaires and pre- and post-shift spirometry (C2).

The questions to be answered in this study include:

1. Are there greater prevalences of acute (over-the-shift) and chronic health effects commonly associated with isocyanates among workers exposed to isocyanates at Utica Trim Plant compared to a group of non-isocyanate exposed workers at the Romeo plant?

2. Is there an association, specifically a dose-response relationship, between the health effects studied and isocyanate exposure?

The analysis to answer these questions is as follows:

1. External Comparisons: The prevalence and levels of the health effects variables (symptoms and pulmonary function) of isocyanate-exposed workers (Groups A, B1, B2) were compared to non-isocyanate exposed workers (C1, C2). Adjustments for potential confounding variables (age, smoking) were made in the analyses.

2. Internal Comparisons: The same health effects and potential confounders were studied as in the external comparisons. In this analysis the association of these variables with exposure was

evaluated. Exposure indices included exposure to spills, whether or not the worker became symptomatic following a spill exposure, and measured TDI exposure over-the-shift. Chronic exposures were also estimated by duration of exposure, or tenure.

All TDI exposed groups at Utica Trim showed elevated but non-statistically significant odds ratios for eye irritation and chest tightness compared to the non-isocyanate exposed groups at Romeo. No other acute responses (sore throat, headache, wheezing, breathlessness, or reduction in ventilatory function) showed any consistent excess or deficit (Summary Table 1).

Over-shift changes in pulmonary function showed no association with any of the isocyanate exposure variables studied. There were no strong dose-response relationships between acute symptoms and exposure. Eye irritation was weakly associated with exposure to TDI spills, "symptomatic following spills", and chronic TDI exposure. Other symptoms showed a weak association with exposure measured as TDI spills (sore throat, wheezing, breathlessness) and symptoms following spill exposure (sore throat, wheezing, breathlessness) (Summary Table 1).

In general, the study shows no clear excess of acute morbidity among TDI-exposed workers. Additionally, no dose-response relationship between isocyanate exposure and acute health effects was demonstrated.

In the external comparison of chronic symptoms, Utica Trim exposure groups had excess prevalences of cough, phlegm, shortness of breath when walking on level ground; asthma; and chest illness that resulted in 4 or more days off work. None of these are statistically significant. In the internal comparison, chronic respiratory symptom rates tend to increase with increasing exposure (e.g., number of TDI spills, longest time exposed to a spill, and symptoms experienced following a spill exposure). The increases are not statistically significant ($p > .05$) except among those experiencing symptoms following exposure to a TDI spill (Summary Table 2).

There is no reduction in baseline pulmonary function of Utica Trim workers, compared to Romeo, nor is there a reduction with increasing exposure. Thus, there is no evidence of an effect of TDI on baseline pulmonary function in the study population (Summary Table 2).

Based upon the results of this investigation, NIOSH concluded that this population appears to have little or no acute or chronic effects of TDI exposure on spirometric lung volumes or flow rates. There is a suggestion of some increase in eye irritation at work, and some increases in chronic respiratory symptoms, primarily among workers previously experiencing symptoms following exposure to a spill. NIOSH recommends annual spirometry for all workers exposed to TDI. All workers who experienced symptoms following a spill are at greater risk and should be followed on a regular basis with both clinical examinations and acute function studies to detect any exposure-related symptoms or declines in pulmonary function.

KEY WORDS: SIC: 3714, 3523; Isocyanates, toluene diisocyanate (TDI), ventilatory function, symptoms, shift study

SUMMARY TABLE 1

Summary of Odds Ratios of Acute Symptoms and Pulmonary Function Changes Occurring Over the Work Shift

	External Comparison		Internal Comparisons					
			Symptoms Following Spill			TDI Exposure ppb		
	Utica	Romeo	0	1-4	5-8	<.05	.051-.8	>1
Odds ratios relative to lowest exposure group, adjusted for age and cigarettes per day. (See Text and Tables 6, 8D, and 8E.								
At work today, did you have _____?								
Eye irritation (itch,burn,water)	4.20-5.14***	1.00	1.00	1.05	4.54	1.00	2.15	2.23
Chest tightness	*	*	1.00	0.93	1.00	1.00	1.22	1.22
Wheezing or whistling chest	*	*	*	*	*	*	*	*
Sore throat	*	*	**	**	**	1.00	0.37	0.89
Headache	0.66-2.33	1.00	1.00	2.92	1.36	1.00	0.33	1.95
Feel breathless	1.04-1.48	1.00	1.00	2.37	5.58	1.00	1.76	1.31
Mean change in pulmonary function over shift, adjusted for age, shift, and cigarettes per day. (See Text and Tables 7 and 9)								
Δ FEV_1 - mL	-9 to -34	-53	-23	-19	- 6	-23	13	-127
Δ FVC - mL	-5 to 2	-15	-24	15	-17	-28	45	- 76

Conclusion: Only eye irritation shows possible higher rate in external comparison and dose-response relation in internal comparison.

*Too few positive responses for analysis.

**Odds ratios depended on age.

***Range

SUMMARY TABLE 2

Summary of Odds Ratios of Chronic Symptoms and Baseline Pulmonary Function

	External Comparisons		Internal Comparisons						
			Symptoms Following Spill			Tenure-Yrs			
Symptoms (Odds/Ratios)	Utica	Romeo	0	1-4	5-8	0-9	10-12	13-17	18+
Odds ratios relative to lowest exposure group, adjusted for age, shift, and smoking status. (See Text and Tables 10, 12D, and 12E)									
Cough 3mos/yr	0.99-1.61	1.00	1.00	0.83	3.06	1.00	1.97	2.93	0.83
Phlegm 3mos/yr	1.30-2.20	1.00	1.00	1.50	2.58	1.00	1.65	2.07	2.43
Shortness of Breath walking on level ground	1.30-3.71	1.00	1.00	1.42	2.30	1.00	2.34	1.69	3.06
Chest Wheezing	0.62-1.97	1.00	1.00	0.43	2.54	1.00	3.10	5.84	5.89
Asthma	1.29-2.07	1.00	1.00	0.75	2.55	1.00	1.06	1.36	0.38
Chest Illness off work $\geq$ 4 days	1.43-1.85	1.00	*	*	*	1.00	2.50	2.62	1.66
Mean baseline pulmonary function (adjusted for age, ht, race, smoking, and shift). (See Text and Tables 11 and 13)									
FEV_1 (liters)	3.58-3.73	3.56	3.57	3.65	3.54	3.64	3.53	3.54	3.64
FVC (liters)	4.53-4.73	4.69	4.56	4.60	4.52	4.65	4.56	4.43	4.65

Conclusion: Increased symptoms at Utica compared to Romeo (not statistically significant)
Symptoms increase with increase in number of symptoms experienced following spill exposure.
No reduction in pulmonary function in external and internal comparisons.

*Odds ratios depended on age.

II. INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) at the request of the UAW conducted a Health Hazard Evaluation of the Ford Motor Company Utica Trim Plant on May 11-12, 1982. (Abrons, Jankovic, Hodgson, 1983) Personal environmental measures of TDI and MDI were below 5 ppb. The prevalence of symptoms among the workers assigned to jobs involving TDI was determined by questionnaires. The prevalence of chronic phlegm production was 44% and of wheezing during the workweek but not during the weekend was 32%; the prevalence of acute symptoms (eye and throat irritation and nasal stuffiness) was 59% and 61% respectively. Persons with wheezing were more likely to have been exposed to TDI spills. Subsequently, the following survey was conducted to further evaluate these symptoms.

A. Background

The foam molding operations at Utica Trim produce polyurethane automotive seat cushions, backs, and head rests. There are five toluene diisocyanate (TDI) foam lines working two shifts. TDI is used in the production of seat cushions and backs. Methylene di-phenyl diisocyanate (MDI) is used in the production of head rests and for repairing seat cushions damaged during removal from molds. The three major job categories are: production, clean-up, and maintenance. Foam line production workers are further categorized as: build-up and assembly, stocker, trim order filler, repair, and equipment and set-up. Cleaners, employees who also work routinely on the foam lines and inside the pouring stations, fall under the maintenance classification.

Polyurethane foam is made by reacting isocyanates and polyols (polyhydroxy compound) in the presence of curing agents and catalysts. The molding process employs a one-shot liquid casting system. In the first step, mixing, the polyol and the diisocyanate react to form urethane which subsequently reacts with additional polyol to produce polyurethane. In the second step, casting, the mix is poured into a clean, waxed, preheated mold as it passes through a pouring station on a conveyor. (Pouring stations are partially enclosed.) The mold then passes through a curing oven for approximately seven minutes at an oven temperature of 170°F. After leaving the oven the foam product is removed from the mold, trimmed, repaired if necessary, and shipped to storage (see Figure 1).

TDI has a room temperature vapor pressure of about 0.04 mm Hg. In the absence of adequate ventilation in confined or restricted spaces, sufficient quantities of TDI can volatilize to create exposures in excess of occupational health limits. Since much of the foaming process does not lend itself to local exhaust ventilation, workers may be at some risk of exposure until the foam is completely cured. There is also evidence that sewing machine operators may be exposed to uncured TDI released when foam cells containing unreacted isocyanate are punctured by sewing needles, with the possibility of sensitization (White et al., 1980). It is conceivable that TDI disseminates throughout the whole

plant in low concentrations, although the chemical rapidly reacts with air moisture to form toluene diamine (TDA) (NIOSH, 1978).

Environmental sampling for TDI after 1975 by Ford Motor Company and the Michigan State Occupational Health Division have demonstrated no airborne levels above the Federal standard of 20 parts per billion parts of air (ppb). With the exception of the pouring stations, foam line exposures measured since 1980 have generally been below the NIOSH recommended time weighted average (TWA) of 5 ppb. Ford data on spills demonstrate airborne levels which are no greater than what is generally encountered in the pouring stations.

B. History of Isocyanate Use at Utica Trim Plant

Isocyanates (TDI prepolymer) were first utilized in 1963. However, urethane foam products were sewn prior to 1963 (seat covers). In 1970-71, the company switched from the pre-polymer mix to an 80/20 isomer mix of 2,4- and 2,6-TDI. This same formulation is currently in use at the plant. In 1975, employee health complaints from both foam workers as well as non-foam workers in adjacent areas were reported to the company.

III. ENVIRONMENTAL STUDY

A. Materials and Methods

The Michigan State Department of Health and Ford Motor Company collected environmental samples prior to 1982. NIOSH conducted a preliminary survey in 1982. A more comprehensive industrial hygiene survey was conducted in 1983 in conjunction with a medical survey. The results of the environmental surveys are discussed in this section. The results of the medical survey and pertinent environmental results are discussed in section IV.

NIOSH conducted two industrial hygiene evaluations at the Utica Trim Plant. The first, on May 11 and 12, 1982, consisted of a limited survey of foam lines A and G as well as two nearby sewing areas (Figure 2). This preliminary sampling was performed in order to gather qualitative and quantitative information on suspected contaminants and to estimate the degree of urgency in handling the request. Area samples were obtained for TDI, MDI, methylene chloride, naphtha, toluene diamine, and aliphatic amines. Short term personal samples on various foam production workers were also collected throughout the shift. The NIOSH hygienist was accompanied by a Ford hygienist who also collected several area samples for isocyanates.

The second survey, and subject of this report, was conducted in August 1983. This was a shift study conducted on three successive Mondays. Full shift personal exposures to TDI and TDA were measured on workers selected to complete pulmonary function tests and health status questionnaires. Other contaminants known to be pulmonary irritants and suspected of being present in the plant were also investigated.

Included in the area environmental sampling were several amines, total reactive isocyanates, and gravimetric and microscopic descriptions of aerosolized particulate in the plant. (See Table 1).

Methodologies for the analysis of all of the chemical components investigated can be found in NIOSH's Manual of Analytical Methods, Vol 1-7. (See Table 1.) Aerosol characterization involved standard respirable and total dust sampling. Sizing was conducted with multi-staged inertial impactors and specific particle characterization by phase contrast and polarized light microscopy. No method was available with which to assess peak personal exposures to TDI and TDA. Area sampling for TDI, TDA, and the other compounds mentioned above were collected in the major process areas of the plant.

B. Evaluation Criteria

The permissible exposure limit for TDI is 20 ppb as a ceiling value (OSHA, 1970). The NIOSH recommended time weighted average is 5 ppb with a ceiling of 20 ppb (NIOSH, 1978). Permissible exposure limits for the other chemical compounds sampled can be found in 29CFR1910.1000 Table Z.

C. Results and Discussion

1. Ford and Michigan Department of Health (Tables 2 and 3)

An analysis of available Ford direct reading data for TDI exposures indicated that concentrations produced by spills were usually lower than that encountered in the pouring stations. Of the six spill records provided, no peaks exceeded the NIOSH ceiling (20 ppb) or TWA standards (max 7 ppb). Forty-two pouring station paper tape records provided by Ford for the time period 1976-81 were reviewed. Of these, two exceeded the ceiling and eight were at or above the 8-hour NIOSH recommended TWA of 5 ppb. Measurement periods ranged from 2 to 6 hours. A summary of Ford samples by year is summarized in Table 2.

Plant engineering audit data of ventilation controls indicated that pouring stations were receiving 60-320 air changes per hour. Metering stations were receiving 70-170 air changes per hour. Foam areas were reportedly at negative pressure with respect to surrounding areas.

Nine inspections at the Utica Trim Plant were conducted by the Michigan Department of Public Health between 10/75 and 11/81 at the request of employees/union. Although a variety of chemicals were sampled, "no violations of state occupational health standards" were reported. (See Table 3.)

2. 1982 Survey (Table 4)

No TDI spills occurred during our visit. Personal TDI and MDI

exposures (Sample No's. 1 through 3D, Table 4) were below NIOSH recommended limits. TDI levels measured inside pouring booths (area samples) were above the NIOSH recommended limit, and two were above the OSHA PEL of 20 ppb.

Not summarized in tables were the results of samples from Line A and G pouring stations which showed no detectable toluene diamine and aliphatic amines. These compounds were not identified, but difficulties were encountered in the analytical procedures. An unidentified peak on the gas chromatograph/mass spectrometer chromatogram for a sample collected in the pouring station on Line A was found. We could not identify the chemical other than that it contained nitrogen and may have been an amine. However, the concentration was too low for identification. Various amines have been associated with asthma (Hagmar et al., 1982).

Personal samples for naphtha on the wire hangers averaged 33 ppm on Line G and 4 ppm on Line A. Methylene chloride concentrations were 315 ppm (area sample in the Line G pouring booth) and 8 ppm (personal sample for the cleaner).

3. 1983 Survey

The results of the personal sampling for TDI are summarized in Table 5A and in Figure 3. Two of the 242 samples (0.8%) exceeded the NIOSH recommended standard of 5 ppb for TDI. One of the two exceeded the NIOSH suggested ceiling limit of 20 ppb. However, both of these levels were measured on individuals who enter the pouring stations, areas for which respiratory protection is required for entry. Seventy-four percent (180/242) of all the personal exposures to TDI were below the limit of detection which was 0.1 ppb as calculated for the average sample time and flow rate. The remaining exposures ranged from 0.2 to 4.7 ppb.

The personal samples collected for toluene diamine were also analyzed for 2,4 Diaminotoluene, N,N-Dimethylethanolamine, N-Methylpyrrolidine, N-Methylmorpholine, and 1,4-Diazobicyclo[2.2.2]octane. None of the above compounds were detected. An unidentifiable, nitrogen containing, polyester (presumed) was found and quantitated in TDA equivalents for purposes of pulmonary function dose-response analysis. Foam line operations and other activities where there was a potential for aerosolized polyurethane seemed to have the highest concentrations of the unknown compound. It seems plausible that the "polyester" originated from either the B component of one of the urethanes or from the lactone ester utilized in the mold cleaning compound. The exposure data for the unknown did not correlate with the symptoms reported by questionnaire. Area samples for total reactive isocyanates, which were collected in impingers, were

unremarkable in that the addition of this data to the TDI results would not have greatly raised exposure estimates. The only areas in which levels were elevated above the limit of detection (and then only slightly) were the pack-out building and pouring booths. Particle size and total dust data from different areas of the plant are summarized in Table 5B and Figure 4. Respirable dust was less than 0.2 mg/m^3 except for areas D-23 and repair line D. Total dust levels ranged from 1.1 to 2 mg/m^3. Mean aerodynamic diameter of particles in all areas was quite large, ranging from 11.5 to 18 µm.

4. Observations and Conclusions

A review of existing environmental data from Ford, Michigan OSHA, and our own data failed to demonstrate excessive exposures to TDI or any other foam line process chemicals or dusts, with the exception of the pouring station enclosures (Tables 4, 5A, and 5B). The same was true for the sewing areas of the plant.

D. Recommendations

1. Current practices for control of spills should be continued.

2. Respiratory protection requirements for entry into the pouring stations should be continued and enforced.

3. Better dust control in the trimming and repair areas may serve to reduce complaints of eye and respiratory irritation.

IV. MEDICAL STUDY

In this HHE we examined workers at the Utica Trim Plant of Ford Motor Company (TDI exposure plant), and workers at the nearby Romeo tractor assembly plant (non-TDI comparison plant). The study was conducted on three successive Mondays and comprised measurements of two kinds of responses: 1) acute symptoms and changes in pulmonary functions over the shift, and 2) chronic symptoms and baseline pulmonary function. The questions addressed in this study were whether exposure to isocyanates being used at Utica Trim resulted in increased symptoms and/or decreased pulmonary function.

In the analysis to evaluate the association between isocyanate exposure and the response variables, and to make inferences about causation, we relied on two basic comparisons. One was to compare the responses of the TDI exposed workers to non-TDI exposed workers (external comparison). The other was to compare persons with high exposure to those with low exposure, i.e., to answer the question of where there is an association of exposure and response. This is the internal comparison.

This section discusses how we went about answering these questions, and what we found.

A. Methods

1. Sample Selection

The group of persons selected for the study from morning and afternoon shifts are defined as follows:

Group A (Current Exposure Group) - 104 men currently working on TDI foam lines (including maintenance) were selected at random from all such workers. These workers were divided into 5-year age groups. This was the initial high exposure group and subsequent selections were matched within the five year age interval. Only males were selected in Group A because mostly males worked on the foam lines.

Group B1 (Former Exposure Group) - All currently employed male employees at Utica Trim who formerly had worked on the foam lines but no longer worked there were divided into 5-year age groups. Random selection of men from each age group were made until the number was the same in each group as in Group A. This group matching on age was done to increase statistical power for the given sample sizes.

Group B2 (Never Exposed) - All currently employed male employees at Utica Trim who had never worked on TDI foam lines or who had a maintenance classification were divided into 5-year age groups. Random selections from each age group were made in the same fashion as Group B1.

Group C (External Comparison) - All male employees at the Romeo Tractor assembly plant working in assembly and related jobs, and not working in welding, painting, or other jobs with known exposure to dust or fumes, were divided into 5-year age groups. Two hundred seven were randomly selected in the same manner as in Groups B1 and B2 except there were twice as many men in each age group as there were in either Group B1 or Group B2. One-half in each age group were randomly selected to receive pre and post-shift pulmonary function tests; the other half were to be administered spirometry only once during the day. The only exception was that one age group contained only one subject, and he was assigned to the two-test group.

Group D (Symptomatic) - A list of all employees who had developed symptoms after one of two known TDI spills was supplied by the union. All 39 employees were selected for the study; 16 were currently employed at Utica Trim plant. The male subjects from this group were not excluded from selection into Groups A, B1, and B2.

Group E - Volunteers who wished to participate were administered the questionnaire and spirometry when it was possible to do so. Groups D (except for subjects included in Groups A, B1, and B2) and E are not included in the analysis reported here.

2. Worker Examination

A questionnaire with questions relating to smoking history, chronic symptoms, acute symptoms at work, TDI exposure, and atopic status, was administered to each worker in the study by a trained NIOSH interviewer. Workers doing pre- and post-shift spirometry were asked that day about symptoms experienced during the shift and whether these symptoms were experienced on the previous day.

Height and weight were measured with shoes off. Flow volume curves from a minimum of 5 forced expirations were recorded on magnetic tape using an Ohio 800 rolling seal spirometer.* Maximum value for forced expiratory volume in 1 second (FEV_1) forced vital capacity (FVC) and peak flow (PF) were used. A maximum envelope curve was used to obtain flows at 50% and 75% of expired FVC (FEF50 and FEF75). After shift flow rates were obtained by lining up at total lung capacity, the after-shift maximum envelope with pre-shift maximum envelope, and measuring post-shift flows at pre-shift percentage of FVC. Changes in pulmonary function (ΔPFT) are recorded as after shift pulmonary function minus pre-shift pulmonary function, so that a negative value of ΔPFT indicates a mean reduction in function over the shift.

All workers at Utica in Groups A, B1, B2, and D were scheduled for pre- and post-spirometry and acute symptom questions. All pre-shift spirometry and pre-shift questionnaires were administered before entering the plant. These workers returned about 6 hours after beginning work for post-shift respiratory questionnaires and spirometry on the same spirometer and with the same technician. Most of these workers wore personal samplers during this time. In Group C, the pre-shift questionnaire and spirometry were administered in the first 2 hours of the shift, and the post-shift questionnaire and spirometry were administered about 6 hours later. The remaining workers in Group C were scheduled during the shift for questionnaires and baseline spirometry. All of these baseline tests were administered Tuesday through Friday of one week, and involved only the morning shift.

Information on work history was obtained from personnel records.

3. Analysis

Four kinds of response variables were used:

1. Acute or work-related symptoms. Each worker was asked at the beginning of the shift as to whether he had these symptoms yesterday, and again at the end of the shift as to whether he had any of the symptoms that day. These are generally reversible symptoms of an irritating nature that have (with the exception of numbness of the forehead) been associated with TDI exposure.

*Mention of brand names does not constitute endorsement by NIOSH.

2. Acute changes in pulmonary function. This was the difference between post-shift spirometry and pre-shift spirometry values, where both values were obtained using the same technician and spirometer.

3. "Chronic" symptoms. These are symptoms from the Medical Research Council respiratory questionnaire which were incorporated into the main questionnaire (e.g., chronic cough, chronic phlegm, shortness of breath).

4. Baseline pulmonary function (PFT). These are pre-shift spirometry values.

The questions we are answering are:

1. Are there increased risks of acute and/or chronic health effects (symptoms, pulmonary function) among TDI workers at Utica compared to workers at Romeo?

2. Is there an association between the response variables (symptoms, pulmonary function) and exposure estimates?

External and internal comparisons were used to answer these questions. In the external comparison, the 3 Utica groups (A, B1, B2) were compared with the control population (C). For symptoms, the observed prevalence or incidence was presented. An odds ratio (OR) was calculated using a logistic regression (Cox, 1970) and adjusting for potentially confounding variables, namely age and smoking. For pulmonary function, linear models analysis (Searle, 1979) was used to adjust for age, smoking, and shift. (Shift was excluded in the logistic models because non-continuous independent variables result in zero cell problems in small studies.) For the acute analysis, smoking was represented by cigarettes per day, and for the chronic analysis, smoking was represented by smoking status.

The external comparison addresses the question of whether or not there are greater prevalences of symptoms or reduced pulmonary function in the Utica Trim plant workers (TDI exposed group) compared to a similar working population (Romeo) not exposed to TDI. The major environmental difference between these plants is that Utica uses TDI, and Romeo does not. A difference between the health of the workers in the two plants does not prove that TDI has an adverse effect in group A, but it would implicate TDI, especially because we have controlled for some of the known factors (age, smoking) that could cause such a difference. However, other factors we have not measured could conceivably be important.

The internal comparison is between persons with high and low exposure within the Utica Trim plant, i.e., within groups A, B1, B2. Also, comparisons among these three groups were made because abnormal

health in B1 could indicate a survivor effect in group A, while abnormal health in group B2 could indicate exposures to substances other than TDI. The advantage of the internal control group is that the high and low exposure workers in the Utica Trim Plant are more likely to be from the same population, i.e., similar selection process, more similar in exposures we are not measuring, etc. The disadvantage is that the subjects in the "control" group within the plant may themselves be exposed to TDI, thereby reducing any health differences. It is in this internal analysis that dose-response relationships are evaluated.

For the acute analysis, exposure includes measured TDI levels, number of TDI spills each person was exposed to, the length of the longest exposure to a spill, and whether symptoms occurred following a spill. For the chronic analysis, measured TDI exposure is replaced with tenure as an exposure variable. Logistic and multiple regression techniques are used to adjust for potential confounders. For all tests, the probability of a type I error was set at 0.05. A more technical description of the testing procedure is given in the appendix.

B. Study Population

Tables 6 and 7 document participation rates and reasons for non-participation by exposure groups. Participation among the randomly selected exposed groups was 83-85% in terms of questionnaire completion. Participation of the comparison population was 70%. The most common reasons for non-participation were refusal (10%) and missed appointment (7%).

Group matching by age category resulted in mean ages of each group being within less than one year of each other (Table 8). The proportion of smokers is similar in each group (about 50%); in the comparison group the proportion of ex-smokers is somewhat higher (35% vs 25%), and the proportion of non-smokers lower (17% vs 25%) than in the exposed group. Smoking intensity as measured by packyears and cigarettes per day was similar in all groups.

Whites comprised 81-89% of each group (Table 9A). The largest differences among groups was for exposure to isocyanates. Only one person in group C said he had ever worked with or been exposed to isocyanate. Among the exposed groups, 75% of group A had been exposed to spills compared to 51% and 30% in groups B1 and B2, respectively. Group A had the longest exposure time to a spill and the shortest mean distance from the spill among the exposed groups. However, a higher proportion of workers in groups B1 and B2 said they had gone to the doctor because of breathing problems they believed were related to work. Table 9B shows the relationships of age and various internal exposures. Age has very little relationship with any exposure, but subjects with high values of one exposure tend to have high values for other exposures.

C. Results

1. External Comparison - Acute Analysis

a. Acute or Work-Related Symptoms (Table 10 and Table 11)

Each person in the acute study was asked at the beginning and end of the shift about the occurrence of respiratory symptoms. At the beginning of the shift each was asked if he had had the symptom the day before. Depending on the symptom, from 1-18% said yes; the only significant inter-plant difference was that the odds ratios (OR) for wheezing in the Utica plant, relative to the Romeo plant, was related to age, where older workers had an elevated OR, and younger workers had a reduced OR (Table 10). Thus, there was no great difference between Romeo and Utica in the prevalence of symptoms the day before.

Those having the symptoms on the day before were excluded from the analysis of acute symptoms over the shift (Table 11). The assumption here is that a symptom occurring on Sunday is not work-related. The incidence of symptoms occurring during the shift is generally less in Group C than in the exposure groups. However, none of the differences were statistically significant.

As a check on the assumption that Sunday symptoms were not work related, crude prevalences of Monday eye irritation were compared to the incidences in Table 11 (12.9%, 13.0%, 15.3%, and 3.4% for groups A, B1, B2, and C2 respectively). These prevalences were 13.8%, 12.5%, 19.0%, and 7.2% for groups A, B1, B2, and C2 respectively. The largest differences between the incidence and prevalence occurred in groups B2 and C2, where the prevalences were larger than the incidences. Larger prevalences indicate that Sunday symptoms tend to be followed by Monday symptoms. This would indicate that either Sunday symptoms are work related or that they reflect a general tendency to complain of symptoms. Because the larger prevalences were found in the low exposure groups it appears that the Sunday symptoms are not work related and our analysis of acute symptoms in terms of incidence appears more reasonable.

The proportion of workers with greater than a 10% reduction in FEV_1 over the shift was quite small (2%) overall. In short, there were no large differences among the exposure and control groups in the incidence of work-related symptoms or prevalence of workers with > 10% reduction in FEV_1 over the shift, after adjusting for age and cigarettes per day.

b. Acute Changes in Pulmonary Function (ΔPFT) (Table 12)

Changes in pulmonary function over the shift (ΔPFT) are given in Table 12. There were no apparent differences in ΔPFT between Utica and Romeo.

2. Internal Comparisons - Acute Analysis by Exposure

a. Acute or Work-Related Symptoms (Table 11 and Tables 13A-13E)

There were no detectable differences in the incidence of acute symptoms among Groups A, B1, and B2 (Table 11).

The next analysis is answering the question, "What is the association between exposure and the incidence of symptoms where exposure is (a) number of times exposed to a spill, (b) longest time exposed to a spill, (c) cumulative TDI exposure, (d) number of symptoms following exposure to a spill, and (e) measured TDI exposure (in ppb) over the shift?" We will discuss these results by symptom. Many of the symptom variables had too few positive responses for analysis.

Eye irritation showed relationships with longest time exposed to TDI spills, cumulative TDI exposure, and number of symptoms following a spill. For this latter variable, the 5-8 symptom group had an OR of 4.5 compared 1.0 for the 1-4 and 0 symptom groups (Table 13D). See Tables 13B and 13C for OR relative to age, time exposed, and cumulative exposure.

The associations of exposure with chest tightness and headache could be analyzed only for symptom exposure and TDI exposure group (Tables 13D and 13E). There was no apparent increase in either symptom with increased exposure.

The incidence of breathlessness increased as the number of symptoms following a spill increased. The odds ratios were 2.4 and 5.6 for the 1-4 and 5-8 symptom exposure group. The only statistically significant difference was between the 0 symptom group and 1-8 symptom group. The risk of breathlessness tended to increase with number of spills and with cumulative exposure, but the differences were not statistically significant.

See Table 13D for relationship of sore throat, symptom exposure and age. For all other acute symptoms and for greater than 10% reduction in FEV_1 the incidence was too low to analyze for an exposure- response association.

In summary, only eye irritation and breathlessness had a high enough incidence to analyze for several exposure-response relationships. The association to particularly note is with the symptom exposure group, and is abstracted from Table 13D.

	Number of Symptoms Following Spill					
	0		1-4		5-8	
	%	OR	%	OR	%	OR
Eye Irritation	9.1	1.0	9.4	1.0	31.1	4.5
Breathlessness	4.7	1.0	10.5	2.4	21.4	5.6

b. Acute Changes in Pulmonary Function (ΔPFT) (Table 12 and Table 14)

This part of the analysis is answering the question, "What is the association between exposure and ΔPFT?" There were no apparent differences in ΔPFT among Groups A, B1, and B2 (Table 12).

Mean changes in pulmonary function by exposure category are given in Table 14. These values are adjusted for age, smoking, and shift. If there is a linear dose-response relationship between exposure and ΔPFT, then ΔPFT will be largest at low exposure, with decreasing mean values as exposure increases. Such a relation does not occur for any pulmonary function parameter nor any exposure variable (number of spills, longest time exposed to spill, cumulative spill exposure, symptomatic after spill, measured TDI exposure).

The only non-linear dose-response relationships were as follows: Peak flow showed a large mean reduction in those exposed to 10 or more spills. Groups exposed to the lowest and highest measured TDI ($\leq$ 0.05 ppb and < 0.8 ppb respectively) generally had large reductions in all parameters but peak flow. For ΔFVC and ΔFEV_1 the reductions in the high TDI exposure groups were significantly greater than the intermediate TDI exposure group. However, there was no statistically significant difference between the low and high exposure groups. Basically there were no apparent associations between acute changes in pulmonary function and exposure to measured TDI on the day tested, nor to past exposure to TDI spills whether measured as number of spills, time exposed to spill, or whether symptomatic following a spill.

3. External Comparison - Chronic Analysis

a. Chronic Respiratory Symptoms (Table 15)

Workers in the exposure groups A, B1, and B2 had higher prevalences and odds ratios for chronic respiratory symptoms compared to Romeo workers (Group C), but the only comparison which was significant was that Group B2 had more shortness of breath than Group C.

b. Baseline Pulmonary Function (Table 16)

Romeo (Group C) generally had ventilatory function values similar to groups B1 and B2. Group A tended to have the largest mean values. After adjusting for age, height, race, smoking status, and shift, no differences were significant.

4. Internal Comparison - Chronic Analysis

a. Chronic Respiratory Symptoms - (Table 15 and Tables 17A-17E)

In Table 15, the only statistically significant internal comparison was that Group B2 had more shortness of breath than Group A. Tables 17A-E summarize the crude prevalences and age and smoking adjusted odds ratios of chronic respiratory symptoms by exposure category. The exposure categories are the same as in the acute analysis except

tenure is used rather than measured TDI.

1) Number of Spills (Table 17A)

Workers exposed to 4 or more spills tended to have the highest odds ratios. The only significant difference was for shortness of breath, where those exposed to 4 or more spills had an elevated odds ratio for young subjects and a reduced odds ratio for old subjects relative to those exposed to less than 4 spills.

2) Longest Time Exposed to Spill (Table 17B)

Workers whose longest exposure to a spill was > 15 minutes had a greater risk of asthma than those whose longest exposure was 6 to 15 minutes. Otherwise there was no apparent overall association of increased risk of chronic respiratory symptoms and longest time exposed to a spill except that young subjects exposed from 1-5 minutes had a greater risk of phlegm than young subjects with no exposure.

3. Cumulative Exposure (Table 17C)

No associations were statistically significant.

4. Symptoms Following Spill (Table 17D)

An increased risk of chronic respiratory symptoms (cough, phlegm, wheezing, asthma, and for young subjects, chest illness) was significantly associated with the occurrence of symptoms following exposure to a spill, particularly when more than 5 symptoms were experienced following a spill. Old subjects with symptoms had a reduced OR for chest illness. The odds ratio for shortness of breath also increased as the number of symptoms following a TDI spill increased. However, this was not statistically significant.

5. Tenure (Table 17E)

Tenure exposure categories were divided into 4 groups:

1. The highest tenure group consisted of subjects who had already worked 2 or more years at the time TDI began to be used (a total of 18 or more years).

2. The second highest tenure group began working at the time the polymerized system was being used from 1963 to 1970-71 (a total of 13 to 17 years). These two groups have had both a longer exposure to TDI and exposure to higher TDI concentrations than the other two groups.

3. The third highest tenure group worked for 10-12 years and only with the currently used isocyanate system.

4. The lowest tenure group worked for less than 10 years while only the current isocyanate system has been used.

The only variable showing a statistically significant relationship related to tenure was cough. For this variable, the 13 to 17 year group had more cough than the 0 to 9 year group. While the OR was generally increased in the longer tenure groups compared to the < 10 year group, no consistent pattern is obvious.

b. Baseline Pulmonary Function - Internal Comparison (Table 16 and Table 18)

There were no statistically significant overall differences in baseline PFT among Groups A, B1, and B2 (Table 16). However FVC declined faster with age in Group A than in Group B1.

The association of reduced baseline pulmonary function with exposure is estimated in linear regression models (Table 18). The exposure variables are the same as for respiratory symptoms, and are put in the model separately. Least square means for such exposure category are reported and are adjusted for race, age, height, smoking status, and shift. There were no statistically significant associations of reduced pulmonary function with increased exposure.

c. Association of Symptoms and Pulmonary Function (Table 19)

The statistically significant results of comparing the pulmonary function of those with and without symptoms are summarized in Table 19. There is no apparent association between acute symptoms and acute changes in pulmonary function. The only statistically significant association is between sore throat and ΔFEF50.

Chronic symptoms of cough, shortness of breath, and wheezing showed some association with reductions in pulmonary function. Persons with cough showed a larger reduction in volumes and flow rates per year of age than those without cough. Persons with shortness of breath, and persons with wheeze showed a reduced baseline lung volume and flow rates compared to those with those symptoms.

The relationships between acute changes in pulmonary function over the shift and chronic phlegm and wheezing were tested separately by smoking status. Phlegm had three categories of respondents: none, less than three months per year, and three or more months per year. The categories for wheezing were none, worse on weekends, the same on weekends, and better on weekends. Mean acute changes in pulmonary function of each symptom category were adjusted for differences in age, shift, and cigarettes/day and were compared. There was no association between symptoms and acute changes in pulmonary function in any smoking category, except for ΔFVC and wheezing among smokers. Those whose wheezing was better on weekends had a larger reduction (-104ml) than those without wheezing (-3ml). Differences between smoking categories were not significant.

V. DISCUSSION

In the acute part of this study we were seeking to determine if workers exposed to TDI were at increased risk of acute (over-the-shift) symptoms and reductions in pulmonary function. The response variables were symptoms occurring at work (determined by questionnaire) and changes in ventilatory function (FEV_1, FVC and flow rates).

Two kinds of comparisons or controls were used to determine if exposure was associated with changes in the response variables. In the external comparison, exposure groups A, B1, and B2 from Utica Trim, were compared with non-TDI exposed workers from Romeo (C). Sample sizes were too small and incidences too low for some analyses to be made. The incidence of acute symptoms of chest tightness and itching, burning, or watering eyes was 1% and 3% at Romeo (C) and 8% and 14% respectively at Utica, but the differences between these rates were not statistically significant (Table 11). Otherwise, there were no remarkable differences in acute symptoms or over-the-shift changes in lung function between the Utica TDI populations and the non-TDI Romeo population.

The second kind of control was an internal comparison of health effects at the Utica Trim plant only, comparing workers with high and low exposure. One such comparison was among workers who currently, in the past, or never worked on the foam lines. Exposure variables examined for dose-response relations included the number of TDI spills, the longest time exposed to the spill, cumulative spill exposure (number of spills x time), number of developed symptoms following exposure to a spill, and measured TDI exposure the day of the study. The internal comparison showed results which were similar to the external comparisons, in that itching, burning eyes was the symptom showing an association with exposure, and that among persons having had five or more symptoms following exposure to a TDI spill, sore throat and breathlessness also occurred more often among those experiencing symptoms following spill exposure (Tables 13A-13E). The significant relationships often involved age in such a manner that a large OR appeared to exist for young subjects, while for older subjects, low prevalences corresponded to high exposure. Usually one would assume this indicates a hazard together with a survivor effect. However, in this case, the estimated odds ratios are so extreme that they are difficult to believe. Another possibility is that the sample sizes are too small for the test to be valid, or if the test is valid, the sample sizes are too small for the equation to be accurately estimated. The latter, at least, appears to be true based on the standard errors of the coefficients (not shown). The over-the-shift changes in FVC and peak flow occasionally had different age slopes for different exposures, but none were consistent with a health hazard (Table 14). Also, since only three of 25 tests had a significant difference in slopes, it is likely to be a non-repeatable result.

There were two purposes of the chronic part of this study. The first was to determine if there was an increased prevalence of chronic respiratory symptoms (e.g. cough, phlegm, shortness of breath, wheezing) and reduced

pulmonary function (spirometry) among workers at Utica Trim compared to Romeo. The second purpose was to examine the association of these health measures with estimates of exposure (e.g. tenure, plus other estimates used in the acute part of the study).

The risk of having chronic symptoms was consistently higher among Utica Trim workers (more so in group B_2) compared to those at Romeo (Table 15). The strength of the associations were weak (e.g. cough, wheezing) to moderate (phlegm, shortness of breath, asthma, chest illness), and only shortness of breath was statistically significant.

Because few differences were found, we examined the statistical power by fitting the models, subtracting off the observed group effects from the predicted values, and replacing them with the difference desired to detect. For comparing Utica and Romeo, those were difference = 0.02, OR = 1.5, difference = 0.05, and OR = 1.5 for ΔFEV_1, incidence of irritated eyes, baseline FEV_1, and chronic cough respectively. Random numbers were generated to simulate data, and 20 runs were made for each variable. This method takes into account the unbalanced nature of the data. The respective powers of 0.10, 0, 0.25, and 0.15 were very low. Thus, the failure to find significant differences for these variables may be due to small sample size.

In the internal comparison, there were weak to moderately strong tendencies for chronic symptoms to increase with increased exposure (Tables 17A-17E). The occurrence of chronic symptoms showed a statistically significant increase among workers who said they had been symptomatic following exposure to a TDI spill. Those with 5 or more acute symptoms generally, had a greater risk of chronic symptoms. The risk of chronic cough increased with tenure up to 17 years of exposure. Other types of exposure had odds ratios related to age, but the estimated equations are once again unbelievable. In the external comparisons, pulmonary function showed, if anything, a relationship just the reverse of that seen for symptoms (Table 16). That is, pulmonary function measures were higher (but not statistically significant) among Utica Trim workers (especially Group A) than the comparison group. In the internal comparison there were no statistically significant associations of reduced baseline pulmonary function with any exposure variable (Tables 16 to 18).

In order to determine if pulmonary function was related to chest symptoms, shift changes in pulmonary function were compared for those having acute symptoms and those not having those symptoms (Table 19). Adjustment was made for confounders as in Tables 13A-13E. Similarly, baseline pulmonary function was compared for those having and not having chronic symptoms. The occurrence of acute symptoms related to exposure was not predictive of an effect on acute changes in PFT. The chronic symptoms with any association with reduced PFT were cough, dyspnea, and wheezing.

Reports of acute respiratory symptoms, primarily of asthma and bronchitis,

among workers exposed to toluene diisocyanate (TDI) first appeared in the published literature in the early 1950's. Concurrently, from experimental animal data, the question of more severe and perhaps irreversible pulmonary damage following TDI exposure was raised (Zapp, 1957). This and subsequent studies, led to a number of epidemiological studies of both the acute and chronic effects of TDI exposure on the respiratory system of humans as manifested in symptoms and pulmonary function changes. These results are described here and are also summarized in two NIOSH Criteria Documents on the Toluene Diisocyanates (NIOSH, 1973; NIOSH, 1978).

In the first part of the report we are focusing on acute, over-the-shift health effects. An important question is whether there are sensitized workers who show a response at very low exposures. Since sensitization may occur as a result of high exposures, we used all measures of spill exposures (including whether symptoms occurred following a spill) to examine the possibility of sensitization. Measures of sensitization or increased susceptibility could include a large reduction in FEV_1 (we used greater than 10%), acute symptoms (such as wheezing, chest tightness, feeling breathless), or irritation. There were only 6 workers in the entire study population with a greater than 10% reduction in FEV_1, and 2 were in the control population. This suggests that in the study population, if sensitization had occurred, it is not affecting over-the-shift ventilatory function.

Headache is a nonspecific symptom, and it shows no meaningful association with any exposure variable.

Eye irritation and sore throat have been observed to occur at odor threshold exposure levels (Zapp, 1957). These symptoms appear to be more sensitive indicators of exposure than changes in pulmonary function, and certainly more sensitive than chest symptoms. Eye irritation and sore throat tended to have a higher incidence among men with more spill exposures, cumulative spill exposure, and 5 or more symptoms following a spill. The incidence of eye irritation was also associated with increasing TDI exposure. Most of these differences were not statistically significant, however. The dose-response association is stronger for eye irritation than other symptoms, with about twice as many experiencing the eye irritation if TDI exposure was 0.051 ppb or greater than if non-detectable. While there is a suggestion of dose-response relationship, the occurrence of eye irritation appears almost as high over the weekend as at work. It is of course possible (although unlikely) that eye irritation over the weekend is a result of work exposure during the week. Sore throat, on the other hand, showed no association with any of the exposure variables.

Although not directly comparable to this study because of differences in methodology, other studies of TDI exposed workers in general show eye irritation and sore throat to be more sensitive than lower respiratory tract symptoms. Only one study (Holness et al., 1984), other than the one reported here, has examined both acute symptoms and changes in pulmonary

function. That study suggests changes in PFT are more sensitive than symptoms.

Bruckner, et al. (1968) found that eye, nose and throat symptoms were the most sensitive symptoms among workers involved in research, development, and production of isocyanates and other components of urethane plastics.

Belin et al. (1983) compared symptoms of 48 workers exposed to isocyanates and amines with 2 control groups. In the exposed group, 52% reported occasional eye symptoms, and 27% reported wheezing and shortness of breath compared to 17% and 0% among the 2 control groups. Because the amine concentrations were 1000-10,000 times higher than the isocyanate concentrations, amines were considered the main causative agents.

Elkins et al. (1962) reviewed the health experience of workers at 15 plants where polyurethane operations were involved. They concluded that exposures to around 10 ppb TDI can result in irritation of eyes, stuffy nose, and dry or sore throat. Higher exposures resulted in conjunctivitis, bronchitis, nausea, and chest tightness.

The results of the study reported here are somewhat at variance with those of Holness et al. (1984). In their exposed group, mean isocyanate level by area ranged from 0.1 ppb to 1.8 ppb. When exposure groups were divided into those with greater and less than 1 ppb isocyanate exposure, both groups had mean acute reductions of about 1.6% in FVC and 1% in FEV_1. These reductions were small but significantly greater than the control group with no isocyanate exposure. Rates of eye irritation were high (26% & 19% for exposed and controls respectively), but not statistically different. The study reported here showed lower eye irritation rates (13%-15% at Utica and 22% in the group with greater than 0.05 ppb exposure). However, there were no meaningful reductions in pulmonary function. In fact, the control workers reduction in pulmonary function in the Holness study was similar to the change in the exposed groups in this study. TDI and respirable dust exposures were similar in the two studies.

On May 11-12, 1982, a respiratory questionnaire was administered to all employees on the TDI foam line at the Utica Trim Plant (Abrons, Jankovic, Hodgson, 1983). The prevalence of similar symptoms are summarized in Table 20. The comparable group comparison is with Group A. The prevalence of phlegm, wheezing, and occupational wheezing during the 1983 survey was about 50% that of the 1982 survey. Wheezing away from work and asthma rates were similar. The prevalence of irritation appears to be reduced in the 1983 survey by 1/4 to 1/2, depending on the definition of "frequent." Frequent occupational wheezing is not the same question in the two surveys. The highest prevalence is in the comparison group.

The occurrences of wheezing (especially at work) appears to be less in the later survey compared to the earlier one at Utica, but there are no

consistent differences in prevalence among the groups in the later survey. Wheezing away from work is somewhat elevated among Groups B1 and B2. If these symptoms are related to exposure, these data suggest environmental controls may be effective for reducing the incidence of wheezing and phlegm, but possibly less so for irritation. At any rate the differences cannot be completely accounted for by differences in the questionnaire.

The higher incidence at Utica and the association with exposure suggest that TDI is acting as an eye irritant in this population. The severity would appear to be slight because the percentage of subjects with eye irritation at work is similar to the percentage for subjects not at work, and there is no apparent association of eye irritation and acute reductions in pulmonary function.

Most of the epidemiological studies of TDI exposed workers have focused on measurements of baseline pulmonary function. TDI exposures were generally reported as higher than what we measured at the time of our study, and there was generally a reduction in baseline pulmonary function (FEV_1, FVC). Relevant aspects of these studies are described.

One of the first epidemiological investigations was a cross-sectional study of twenty men working in a small factory where isocyanates were used to produce polyurethane foams (Gandevia, 1963). The reason for the study was that the exposed workers complained of respiratory symptoms. While no direct measurements of TDI air levels were done during the study, the odor of TDI was apparent, indicating a TDI level of 0.1 ppm or greater. Measurements taken about one month after the conclusion of the study were found to be 0.9 ppm in the spraying areas. The plant studied had a very high turnover with an average duration of employment of sixteen weeks, and only two men worked longer than one year. All but one of the twenty had no respiratory complaints prior to this work, and none had any prior history of wheezing or asthma. Fifteen of the twenty workers completed the data collection process (Gandevia notes that these were probably the "fittest" workers).

FEV_1's and FVC's in workers were measured over a 3 week period and the following observations were made: the workers showed a mean FEV_1 drop over a normal working day of about 0.182 liters; the mean pre-shift FEV_1 at the beginning of the work week (4.10 liters) remained depressed over night (3.94 liters on 2nd day) and over the weekend (3.96 liters on the 1st day after the weekend). These results seem to indicate that exposure to TDI at levels above the current TLV of 0.02 ppm does cause work-shift declines in FEV_1. While the high turnover rate among these workers may result in selection of sensitive workers out of the study, the 3 week duration of the study, may have included TDI sensitive workers.

From October 1962 through November 1963, Williamson (1965) studied 15 workers prior to and following their exposure to toluene diisocyanate. All TDI air samples were below 0.02 ppm except for one reported spill at

which time the odor of TDI was detectable; 10 minutes after the spill the level was 0.03 ppm and 20 minutes later was not detected. There was no mean FEV_1 declines over the one year study; mean FEV_1 in October 1962 was 3.19 liters and in November 1963 was 3.18 liters. In terms of the significance of this study, it should be noted that the actual post exposure follow-up measurements were one and six months, the measured TDI exposures were low, and only a small number of workers (15) were studied. It is interesting that a statistically significant drop in mean FEV_1 of workers was noted between the October 1962 and February 1963 measurements (3.19 liters to 2.97 liters); Williamson attributed the lower February readings to the effects of an acute episode of respiratory illness among the workers during the February measurements.

The next major epidemiological study of the respiratory health effects of TDI exposure was done by Peters et. al. (1970). They studied a small group of from 38 to 50 workers in a factory using TDI to produce polyurethane foams. Environmental and worker measurements were carried out at 6 month intervals over a period of 18 months. All of the TDI air environmental measurements were reported to be below 0.014 ppm.

Acute reductions in FEV_1 over Monday work shifts occurred in each of the 4 successive surveys (0.22 L, 0.16 L, 0.05 L, and 0.17 L drops for $n = 38$, 34, 43, and 50, respectively). Longer term FEV_1 declines for workers common to the first and subsequent surveys were 0.14 L ($p < 0.02$) at 6 months, 0.12 L ($p < 0.02$) at one year, and 0.22 L ($p < 0.02$) at 18 months. The chronic FEV_1 changes were calculated for only those workers in each follow-up survey who had been present at the first survey -- 28, 25, and 19 for 6, 12, and 18 months, respectively. While no information is reported on those workers dropping out of the study between follow-up surveys, if one compares the mean FEV_1's for the total first survey group of 38 with those for the survey repeater groups at the first survey ($n = 38$:$FEV_1 = 3.79$ L; $n = 28$:$FEV_1 = 4.07$ L; $n = 25$:$FEV_1 = 4.07$ L; and $n = 19$:$FEV_1 = 4.12$ L), it appears that the workers remaining in the study had higher FEV_1's to start with and are perhaps a more fit group than those workers dropping out.

In addition, Peters demonstrated that those workers with cough or sputum at the first survey had higher reductions in FEV_1 over the shift and after six months. A positive correlation was found between over shift FEV_1 declines and the 6, 12, and 18 month FEV_1 declines, i.e., those workers with the larger over shift FEV_1 declines were the same workers with larger chronic FEV_1 declines. However, when smoking status was considered, the correlation coefficient dropped from 0.72 to 0.60. The correlation coefficient also dropped with each successive follow-up study (0.72 at six months, 0.71 at 12 months, and 0.66 at 18 months).

From 1962 to 1970, Adams (1975) carried out a prospective study of workers at 2 plants manufacturing toluene diisocyanate. While well over 50% of the TDI air measurements (by the Mercali method) taken prior to 1965 were above 0.02 ppm, most of those taken after 1965 were below the 0.02 ppm level. (The TLV changed from 0.05 ppm to 0.02 ppm during this time

period.) This study consisted of 2 parts. In the first part Adams studied annual declines of FEV_1's in 180 asymptomatic subjects and found no relationship between rate of decline of FEV_1 over the nine year study period and the duration of workers' exposures to TDI.

In the second part of the study, annual FEV_1's for 61 workers who developed symptoms during the study and transferred away from TDI work were studied. Predicted FEV_1 values were derived from a community group living in the same geographic area.The mean difference between predicted and actual FEV_1's was -261 ml ($p \leq 0.05$).

The results from this study seem comparable to those of others in that those workers with symptoms appear to have larger declines in FEV_1 than do workers who remain asymptomatic. Forty-six men who had been removed from TDI plants because of sensitization had a higher prevalence of breathlessness and wheezing than controls. The prevalence of cough and phlegm were also elevated but the differences were not statistically significant.

Wegman (1974) did a cross-sectional study of over shift changes in FEV_1 in 111 workers exposed to TDI in a plant using TDI to manufacture polyurethane foam mattresses and seat covers. TDI air levels ranged from 0.002 ppm to 0.013 ppm (by the Marcali method). Based on the mean TDI exposures for jobs, each worker was assigned to one of 4 exposure categories. FEV_1 measurements were done on Monday, following 3 days away from work, and included both AM (pre-shift) and PM (postshift) measurements. Data on chronic respiratory symptoms were also obtained. Workers with any one of 4 respiratory symptoms (wheezing, breathlessness, cough, or phlegm) had greater over shift declines in FEV_1 than those workers without any one of these 4 symptoms; these differences in FEV_1 declines between symptom groups were not statistically significant. Mean FEV_1 declines over shift were found in all 4 dose categories, and the larger the dose, the greater the mean decline in FEV_1 (0.002 ppm to 0.003 ppm: $\Delta FEV_1 = 0.078$; 0.004 ppm: $\Delta FEV_1 = 0.112$; 0.006 ppm: $\Delta FEV_1 = 0.106$; 0.006 - 0.013 ppm: $\Delta FEV_1 = 0.180$). Differences in age, height, years smoking, number of cigarettes smoked, and duration of exposure in months did not account for reduction in FEV_1.

In addition to the cross-sectional study, Wegman (1982) also followed these 111 workers prospectively over four years with workplace surveys at 2 and 4 years. All TDI exposure measurements were below 0.02 ppm. Over the 4 year study period, the mean change in FEV_1 for the 48 study subjects participating in both the first and fourth year surveys was 119 ml; the mean FEV_1 decline for the 63 subjects participating in both the first and second year surveys was 92 ml. In addition, exposure categories and chronic 4 years FEV_1 declines were related as follows: < 0.0020 ppm: $\Delta FEV_1 = -2$ ml; 0.0020 - 0.0034 ppm: $\Delta FEV_1 = 133$ ml; and > 0.0035 ppm : $\Delta FEV_1 = 242$ ml. The FEV_1 annual declines of about 60 ml in the > 0.0035 group was almost twice the expected annual decline of 32 to 47 ml found in cross-sectional and longitudinal studies of normal populations as well as the lower exposure TDI groups. Information

on the workers not participating in successive surveys was not available.

Diem (1982) followed 277 TDI exposed workers in a new toluene diisocyanate manufacturing plant prospectively over 5 years; the first survey was done 5 months prior to the workers' TDI exposure and subsequent surveys were done at 6 month intervals over the next 5 years. Exposure was based on cumulative job exposures. Workers were categorized into one of two exposure categories: greater than 68.2 ppb months and equal to or less than 68.2 ppb months; changes in FEV_1's were compared for these two internal exposure subgroups. For the non-smoking group, the FEV_1 annual declines in the higher TDI exposure category was 38 ml/year larger than in the lower exposure category. Among the previous and current smoking groups, the differences were smaller (previous smokers ΔFEV_1 = 3 ml/yr, and current smokers ΔFEV_1 = 11 ml/yr) and not statistically significant.

From 1971 to 1976 Musk (1982) studied a group of workers from three polyurethane plastic manufacturing plants. There were 259 workers in the original group, but due to the closure of one of the plants and a high turnover, in 1976 the number had dropped to 107 workers, only 17 of whom had TDI exposures. Approximately 2500 TDI air samples were taken during the study period, and all TDI measurements were well below the TLV of 0.02 ppm. FEV_1's were measured pre and post shift and at the beginning and conclusion of the 5 year period. The mean decline over shift was 0.06 L $\pm$ 0.21. The 5-year decline was 0.13 L $\pm$ 0.25 or an annual decline of 0.02 L. The mean FEV_1 at the initial survey was 3.34 L for the 152 workers who left the cohort and 3.46 L for the 107 workers remaining in the study over the 5 year time period. This difference suggests that those who stayed had better baseline pulmonary function than workers who left.

Gee and Morgan (1985) determined ventilatory capacity in 68 workers exposed to isocyanates in two plants, 42 of whom were part of the cohort studied by Musk. TDI and MDI mean annual concentrations were less than 5 ppb from 1973 to 1981 (only MDI was being used at the time of the study). Baseline FVC and FEV_1 were over 100% of predicted. No worker had more than a 10% decrement in FEV_1 over the shift. Gee and Morgan tried to calculate annual declines using the 1971 values, but were unable to do so because most of these data were unreliable. They conclude that there was no discernible effect on pulmonary function in this population.

In 1982 Holness et. al. (1984) did a cross-sectional study of a group of workers exposed to toluene diisocyanate used in foaming operations. Initially 161 workers were examined, however, 29 were subsequently excluded (7 with confounding exposures; 3 with concurrent illness; 15 with technically unacceptable PFT's; and 4 with incomplete data). The final group consisted of 95 TDI exposed workers and 37 controls. (The controls consisted of technical/clerical staff for the Ministry of Labor and nonexposed employees of TDI plants.) Health questionnaires were administered, and PFT's were done at the beginning and end of workshifts

on Mondays, Wednesdays, and Fridays. Both area and personal sampling was done (Marcali); the mean TDI personal sampling level was 2.50 ppb and the area sampling mean was 1.54 ppb; less than 3% of personal or area TDI values were above the TLV of 5 ppb. An exposure-effect relationship between TDI exposure and FEV_1 declines over a work shift was demonstrated when doses were categorized as control, low, or high (> 1 ppb); however, a regression analysis of doses and FEV_1 declines over shift did not demonstrate an exposure-effect relationship. The exposed group of workers had lower levels of all pulmonary function measures on Monday and showed significantly larger FEV_1 and FVC declines over the workshift than did the control group.

In 1983 Belin et al. (1983) published his findings of a study of workers in a factory producing polyurethane foam. The study subjects included 48 TDI exposed workers and two control groups. The 30 subjects in the first control group were selected from a workforce involved with plastic molding injections in a plant adjacent to the foam production factory. The second control group was non-smoking healthy subjects associated with the author's laboratories. All TDI levels were below 5 ppb, while amine levels were 1000 to 10,000 times as high as the TDI levels. A medical questionnaire was administered to all study subjects. Methacholine inhalation tests were used to classify subjects into low, intermediate, or high airway reactivity categories. The prevalence of increased methacholine reactivity was higher in the exposed group than in control group 1. In addition, reports of blurred vision, associated with amine exposures, were more frequent in the high reactivity group as compared with the other 2 lower reactivity groups. This finding, together with the low TDI and increased amine environmental measurements, led the authors to speculate that the eye and respiratory symptoms may have been the result of amine, rather than TDI exposures.

The findings of Belin's study, that eye and respiratory symptoms may result from amine rather than TDI exposures, are not supported by the results of a recently published report by Candura and Moscatu (1984). Twelve subjects with respiratory work-related symptoms of wheezing and breathlessness and exposure to polyurethane foams were all found to be reactive to methacholine and TDI but not to toluendiamine.

These studies confirm that pulmonary function declines when exposures to TDI are high enough. Below some level (20 ppb in 2 studies, 14 ppb and 3.5 ppb in two others) the excess reductions in PFT are not observed. This study is in agreement with these earlier studies because no reduction in PFT was observed for any exposure group. However, there were only 5 personal TDI samples that were more than 3.5 ppb. Thus, TDI levels appear to be sufficiently low so there is no appreciable effect on either baseline pulmonary function, or acute changes in PFT over a workshift.

Previous studies of TDI workers (Peters et. al. (1970); Wegman et. al. (1974); Adams (1975)) have shown that symptomatic or sensitized workers may have reductions in baseline pulmonary function and greater reduction

in FEV_1 over the shift. In this study, workers who were symptomatic following exposure to a spill (particularly those with more than 5 symptoms) had excess rates of acute and chronic symptoms.

This study also suggests that symptoms are the more sensitive indicator of isocyanate exposure. The occurrence of excess symptom rates occurred in the absence of any detectable reduction in pulmonary function. Not surprisingly, the workers most affected appear to be workers who earlier had been exposed to TDI spills and experienced several symptoms as a result of that exposure.

VI. CONCLUSIONS

These results suggest the following conclusions:

1. Exposure levels were generally below NIOSH recommendations.

2. At the TDI concentrations measured at the time of the study there are possible slight acute irritation symptoms, but no apparent acute adverse effects on pulmonary function.

3. Past exposures have had no observable adverse effect on baseline pulmonary function of the examined workers. The prevalence of chronic respiratory symptoms is increased among the Utica Trim workers, with workers who had previously experienced symptoms following exposures to a TDI spill being at increased risk for these symptoms.

VII. RECOMMENDATIONS

We recommend particular care be taken to avoid TDI spills. If spills cannot be prevented, then a good health promotion practice would be to follow workers with spill exposures very closely. Specifically, all workers with spill exposures, and particularly those who experience symptoms following such exposures, should be followed on a regular basis with both clinical examinations and pulmonary function studies to detect any exposure-related symptoms or declines in pulmonary function.

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IX. APPENDIX

Details of the Testing Procedure

For either logistic or linear models analysis, the first step was to test for an interaction between age and exposure group. If this test was significant ($p \leq 0.05$), then orthogonal contrasts were used to determine which groups had differing age coefficients. When comparing Groups A, B1, B2, and C1 or C2, the contrasts were Utica vs Romeo, (A, B1,) vs B2, and A vs B1. When comparing groups based on exposure

variables within Utica, the high exposure groups were compared to the low exposure groups, and then the low exposure groups were compared to each other, and the high exposure groups were compared with each other. (When there were 3 total groups, 2 were considered high, and thus there was no comparison among the low groups. When there were 5 total groups, 3 were considered high.) When interactions with age were not significant, main effects were tested in an analogous manner. Hierarchical testing was also performed at intermediate levels. For example, (A, B1) were compared to B2 only if an overall test of A vs B1 vs B2 was significant. No tests were run unless the number of positive responses averaged at least 5 per group.

X. ORIGINATING OFFICE:

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XI. DISTRIBUTION AND AVAILABILITY OF REPORT

Copies of this report are currently available upon request from NIOSH Division of Standards Development and Technology Transfer, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through the National Technical Information Service (NTIS), 5285 Port Royal, Springfield, Virginia 22161. 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:

1. Ford Motor Company, Utica, Michigan
2. United Auto Workers of America, Detroit, Michigan
3. United Auto Workers of America, Local 400
4. NIOSH, Region V
5. OSHA, Reg. 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.

XII. ACKNOWLEDGMENTS

We are appreciative of the cooperation and help given by the participants in the survey, as well as union, plant, and company persons involved in the planning, execution, and analysis of the study. The scheduling of workers for the acute part of the study was a huge task that was done competently, pleasantly, and often at odd hours. The help we received not only made this survey possible, but pleasant. Thank you.

Table 1

Compounds Sampled

Compound	Standard Analytical Method	Limit of Detection For Collection Procedure
Total Reactive Isocyanates	P&CAM 366	0.90 millimole
Total Dust	Gravimetric	0.01 mg
2,4-Diaminotoluene (TDA)		0.14 µg/sample
TDI	P&CAM 326	0.10 ppb
MDI	P&CAM 347	0.24 ppb
N,N-Dimethylethanolamine (DMEA)		2.35 µg/sample
N-Methylpyrrolidine (N-MP)		
N-Methylmorpholine (N-MM)		0.33 µg/sample
1,4-Diazobicyclo[2.2.2]octane (DABCO)		2.46 µg/sample

Table 2

Summary of
Ford TDI Data

1969 and 1967

1 to 2 ppb all areas and operations in foaming.

1972

Pour	Foam
n = 3	n = 7 ppb
X = 40 ppb*	X = 2.4 ppb
SE = 17.3 ppb**	SE = 1.4 ppb

1973

Pour
< 3.0 ppb

1978

Pour	Foam	Other(Sew)	Floor Painting
n = 12	n = 65	n = 41	n = 18
X = 46.9 ppb	X = 1.2 ppb	X = 0.8 ppb	X = 3.8 ppb
SE = 22.6 ppb	SE = 0.2 ppb	SE = 0.5 ppb	SE = 0.2 ppb

1980

Pour	Foam	Other(Sew)
n = 6	n = 26	n = 5 ppb
X = 21.8 ppb	X = 2.9 ppb	X = 0.1 ppb
SE = 10.8 ppb	SE = 0.9 ppb	SE = 0.05 ppb

1981

Foam
n = 15
X = 0.4 ppm
SE = 0.1

*X = Mean
** SE = Standard error of the mean

Table 3

Michigan Department of Public Health Sampling Results

Compound	Mean Concentration	Std Error of the Mean	Number of Measurements
Acetone	4.5 ppm	2.5 ppm	2
Diethyl Ether	18.5 ppm	7.5 ppm	2
MEK	46.0 ppm	21.9 ppm	2
Methylene Chloride	45.5 ppm	37.5 ppm	2
Petroleum Distillates	10.3 ppm	4.8 ppm	4
Toluene	3.3 ppm	1.1 ppm	4
Oil Mist	N.D.	--	2
Toluene Diisocyanate	0.002 ppm	0.0006 ppm	38

N.D.: Not Detected

Table 4

Summary of NIOSH and Ford Motor Company Sampling
Utica Trim Plant - 1982 Survey

Ford's Data: Line A - 14 ppb inside enclosure

Line G - 23 ppb inside enclosure

All else ≈ 5 ppb inside enclosure
Sewing area 0

MDI Limit of Detection 120 Min Sample ≈ 0.24 ppb 0.3 µg/Sample
TDI Limit of Detection 60 Min Sample ≈ 0.70 ppb 0.3 µg/Sample

Sample No.	Location	Time(Min)	Vol(l)	Conc (ppb) MDI	TDI
1	Repair Oper(G)	319	319	< 0.1	N.A.
2A	Near Demold Oper(G)	60	60	N.A.	1.6
2B	Near Demold Oper(G)	71	71	N.A.	2.4
3A	Trimmer Line G	57	57	N.A.	1.2
3B	Trimmer Line G	72	72	N.A.	2.1
3C	Trimmer Line G	46	46	N.A.	1.5
3D	Trimmer Line G	62	62	N.A.	1.6
4A	Inside Injection Enclosure Line G	50	50	N.A.	13.5
4B	Inside Injection Enclosure Line G	51	51	N.A.	33.1
5	Inside Injection Enclosure Line G	283	283	< 0.1	N.A.
11	Inside Injection Enclosure Line A	112	112	< 0.3	N.A.
12	Inside Injection Enclosure Line A	112	112	N.A.	21.3
17	Sewing Area West	100	100	< 0.3	< 0.4
18	Escort Base Sew	85	85	< 0.4	< 0.5

Table 5A

1983 TDI Results by Job Category

Job Category	Mean TDI(ppb)	SE	n
Maintenance	0.16	0.05	34
All Foam	1.38	0.46	48
Sewing	< 0.1	--	8
Other Plant (In)	< 0.1	--	149
Other Plant (Out)	< 0.1	--	3

SE: standard error of the mean

Table 5B

Mean Plant Aerosol Characterization by Area

Area	Respirable Dust(mg/m^3)	Total Dust (mg/m^3)	Particle Size MMAD(μm)	GSD
Cafeteria	0.06	--	--	--
D-23	0.60	1.1	11.5	3.0
Foam Line H	0.13	--	--	--
Pouring Booth H	--	1.2	11.5	3.0
Repair Line H	--	1.3	16.5	3.3
Repair Line D	0.52	--	--	--
Trimming Line H	--	1.4	12.5	2.5
Pack Out	0.18	--	--	--
Facia Trim	0.11	1.6	13.5	2.5
Facia Trim	--	2.0	18.0	2.8

*See Figure 2

MMAD: Mass median aerodynamic diameter
GSD: Geometric standard deviation

Dust samples collected for particle sizing were examined by polarized and phase contrast light microscopy to qualitatively identify the particulates present on the impactor surfaces. The predominant particles by area were as follows:

Panel Lines:	Fiber glass and synthetic fibers
Sewing Lines:	Synthetic fibers
Foam, Repair, Trimming Lines:	Polyurethane dust
Typical Components-General Plant:	Polyurethane dust, blue chalk dust, fungal spores, plant fibers, pollens, and silicate/carbonate minerals

TABLE 6

Participation Rates

Group	N Selected	% Completion Questionnaire N	%	Spirometry & Acute Qx N	%	Personal Samples N	%
A	104	86	(83%)	80	(77%)	70	(67%)
B1	104	88*	(85%)	80**	(77%)	74	(71%)
B2	104	87	(84%)	84	(81%)	77	(74%)
C-two test	104	75	(72%)	70***	(67%)	--	
one test	103+	70	(68%)	69	(67%)	--	
D	39	15*	(38%)	11++	(28%)	10	(26%)

*One subject in Group D was also in Group B1.

**Eighty-one had before shift spirometry.

***Seventy-four had before shift spirometry.

+One age group only contained one subject, and he was assigned to the two-test group.

++Twelve had before shift spirometry.

TABLE 7

Reasons for Non-Participation*

	Groups						
				C		Sub-Total	
	A	B1	B2	Two-Test	One-Test	A-C	D
Selected:	104	104	104	104	108	519	39
	%	%	%	%	%	%	%
Refused	10	5	7	12	17	10	0
Medical Leave	5	4	3	7	1	4	3
Not on Roster	4	3	8	1	0	3	49
Missed Appointment (absent, forgot, overslept, vacation, etc)	1	10	1	8	14	7	13
Other	4	2	1	5	0	2	8
Total Non-Participation By Group	23%	23%	19%	33%	33%	26%	72%

*Based on complete spirometry.

TABLE 8

Demographic Characteristics of Exposure Groups

	Exposure Groups			Comparison Groups		
	A	B1	B2	C2	C1	C
N	86	88	87	75	70	145
Mean Age(S.D.)	40.5(9.1)	40.3(9.8)	40.0(9.8)	40.7(10.2)	39.5(9.6)	40.1(9.9)
Mean Height-cm						
Standing(S.D.)	173.8(7.1)*	171.5(7.5)**	172.4(7.0)	173.3(8.7)	173.9(6.9)	173.6(7.9)
Sitting(S.D.)	82.2(4.2)*	82.0(4.4)**	82.4(4.3)	83.0(3.9)	82.4(3.6)	82.7(3.8)
Mean Weight-kg (S.D.)	82.9(13.5)*	80.6(13.6)**	82.9(16.5)**	84.3(14.2)	82.5(13.9)	83.4(14.0)
Mean Grade(S.D.)	11.3(2.2)	11.7(2.1)	11.7(1.6)	11.3(1.8)	11.8(1.7)	11.6(1.8)
Non-Smokers-N(%)	19(22.1)	20(22.7)	25(28.7)	12(16.0)	13(18.6)	25(17.2)
Ex-Smokers-N(%)	25(29.1)	21(23.9)	21(24.1)	27(36.0)	24(34.3)	51(35.2)
Mean Cig/Day (S.D.)	23.3(17.4)	28.6(15.0)	21.0(11.6)	24.4(14.0)	23.6(15.5)	22.4(14.0)
Mean Pack Years (S.D.)	20.6(24.5)	22.2(19.4)	21.8(15.7)	18.6(20.2)	20.2(24.3)	18.6(20.2)
Smokers-N(%)	42(48.8)	47(53.4)	41(47.13)	36(48.0)	33(47.1)	69(47.6)
Mean Cig/Day (S.D.)	24.3(9.9)	23.2(11.9)	25.6(14.8)	25.9(13.3)	25.1(13.7)	25.9(13.3)
Mean Pack Years (S.D.)	25.4(16.2)	25.7(23.4)	22.0(17.8)	27.1(20.4)	27.9(24.6)	27.1(20.4)

*2 missing value
**1 missing value

TABLE 9A

Characteristics of Acute Exposure Groups-External Comparison*

	Exposure Groups			Comparison Groups		
	A	B1	B2	C2	C1	C
	80	80	84	70	70	140
Race-N(%)						
White	66(82.5)	71(88.8)	68(81.0)	58(82.9)	62(88.6)	120(85.7)
Black	13(16.2)	7(8.8)	14(16.7)	12(17.2)	7(10.0)	19(13.6)
Other	1(1.2)	2(2.5)	2(2.4)	0	1(1.4)	1(0.7)
Worked with Isocyanates-N(%)	68(85.0)	66(82.5)	40(47.6)	0(0.0)	1(1.4)	1(0.7)
Times Exposed to a Spill-N(%)						
0 Times	20(25.0)	39(48.8)	59(70.2)	70(100)	69(98.6)	139(99.3)
1-3 Times	21(26.2)	25(31.2)	13(15.5)	0	0	0
4-10 Times	18(22.5)	6(7.5)	9(10.7)	0	0	0
> 10 Times	21(26.2)	10(12.5)	3(3.6)	0	1(1.4)	1(0.7)
Longest Time Exposed to a Spill(minutes) N(%)						
0	20(25.0)	39(48.8)	59(70.2)	70(100)	69(98.6)	139(99.3)
1-5	16(20.0)	14(17.5)	5(6.0)	0	1(1.4)	1(0.7)
6-15	17(21.2)	9(11.2)	7(8.3)	0	0	0
16-60	13(16.2)	7(8.8)	5(6.0)	0	0	0
>60	14(17.5)	11(13.8)	8(9.5)	0	0	0
Mean Distance To Spill(ft)(S.D.)	9.7(27.0) (N=60)	10.5(23.1) (N=41)	34.8(84.3) (N=25)	-- (N=0)	2(--) (N=1)	-- (N=0)
Qx F16-Have you ever been to a doctor because of breathing trouble you believe is related to work?(%)	6(7.5)	13(16.2)	16(19.0)	2(2.9)	2(2.9)	4(2.9)
Mean TDI (S.D.) (ppb)	10.9**(82.7) (N=70)	.01(0.2) (N=73)	.01(0.0) (N=77)	-- (N=0)	-- (N=0)	-- (N=0)

*Contains only subjects with appropriately complete spirometry.
**Includes a single value of 693 ppb. Without this value, the mean and S.D. would be 1.0 and 2.7 respectively.

TABLE 9B

Demographic Characteristics of Exposure Categories for Acute TDI Study Internal-Comparison (Utica Trim Plant Only)*

	Degree of Exposure**				
	1	2	3	4	5
Exposure Based On	Low		To		High
1. Times Exposed to Spills					
N	118	59	33	34	
Age	40.7(10.0)	40.4(9.8)	40.5(9.3)	39.4(7.5)	
Mean Time Exp-Min	0(0.0)	22.4(25.3)	31.1(25.6)	39.1(29.0)	
Mean Cum Exp-Min	0(0.0)	44.9(50.7)	217.6(179.2)	468.7(347.7)	
Mean TDI - ppb	0.3(1.9)	0.3(0.6)	0.7(1.7)	23.7(126.4)	
	(N=109)***	(N=53)	(N=28)	(N=30)	
Mean Spills+	0	2	7	12	
2. Longest Time Exposed to a Spill					
N	118	35	33	25	33
Age	40.7(10.0)	41.3(10.2)	39.3(8.4)	40.4(8.0)	39.6(9.4)
Mean # Spills	0(0.0)	3.6(3.2)	7.3(4.1)	5.4(3.7)	7.8(4.4)
Mean Cum Exp-Min	0(0.0)	8.9(7.9)	76.7(43.4)	205.2(142.2)	539.2(302.
Mean TDI - ppb	0.3(1.9)	0.4(0.7)	0.7(1.7)	0.43(1.0)	22.7(124.
	(N=109)	(N=31)	(N=28)	(N=21)	(N=31)
Mean Time+	0	2.5	10.5	38	69.5
3. Cumulative Exposure [(# of Spills) x (Time Exposed)]++					
N	118	45	45	36	
Age	40.7(10.0)	40.3(9.9)	40.6(9.1)	39.4(8.0)	
Mean # Spills	0(0.0)	3.2(2.9)	5.9(4.2)	9.6(2.5)	
Mean Time Exp-Min	0(0.0)	4.3(3.4)	30.9(23.9)	58.1(15.3)	
Mean TDI - ppb	0.3(1.9)	0.4(0.6)	0.5(1.5)	22.2(122.4)	
	(N=109)	(N=39)	(N=40)	(N=32)	
Mean Cum Exp-Min	0(0.0)	11.6(8.6)	102.7(29.2)	572.8(238.1)	
4. Number of Symptoms Following a Spill					
N	134	58	52		
Age	40.5(10.0)	41.0(9.4)	39.6(8.1)		
Mean # Spills	0.4(1.4)	5.3(4.0)	7.7(4.1)		
Mean Time Exp	2.3(10.2)	24.6(25.5)	37.2(28.2)		
Mean Cum Exp-Min	5.9(23.6)	149.0(232.8)	314.0(304.7)		
Mean TDI	0.3(1.9)	0.4(1.2)	16.3(104.4)		
	(N=122)	(N=54)	(N=44)		
Mean # of Symptoms	0(0.0)	2.5(1.1)	6.0(1.0)		
5. TDI Measured					
N	162	38	20		
Age	40.9(9.6)	41.3(9.9)	36.8(5.9)		
Mean # Spills	1.9(3.4)	6.4(4.9)	5.2(4.6)		
Mean Time Exp-Min	11.8(22.5)	24.4(28.0)	24.0(29.0)		
Mean Cum Exp-Min	65.8(168.4)	211.6(283.5)	231.3(338.7)		
Mean TDI - ppb	0.0(0.0)	0.3(0.2)	37.8(154.3)+++		

*Contains only subjects with complete before and after shift spirometry. (see Tables 8A-8E for specific quantification of exposure groups.)

**Standard deviations are in parentheses.

***N = number of subjects with TDI measurements.

+Class midpoints

++Note that time is maximum time rather than average time so that values will be larger than if average time had been used.

+++Includes single value of 693 ppb. Without this value, the mean and standard deviation for the 5 exposure variables (Times exposed, ..., TDI measured) would be 0.6(1.0), 0.3(0.7), 0.5(1.0), 0.5(1.0), and 3.3(4.4), respectively.

TABLE 10

Prevalence of Symptoms on Previous Day, by Exposure Group
Answer Yes to the Question: Did You Have (The Symptom) Yesterday?*

	Exposure Groups								
	A		B1		B2		C2		
N	80		80		84		70		
Symptom	%	OR**	%	OR	%	OR	%	OR	Significance
Eyes itch, burn, water	12.5	0.85	3.8	0.23	14.3	0.97	14.3	1.00	N.S.
Sore throat	15.0	***	5.0	***	7.1	***	7.1	***	***
Numbness in forehead	0	N.A.	2.5	N.A.	0	N.A.	1.4	N.A.	N.A.
Chest tightness	6.2	4.61	11.2	8.79	9.5	7.30	1.4	1.00	N.S.
Headache	16.2	1.47	11.2	0.97	17.9	1.59	11.4	1.00	N.S.
Chest sound wheezing or whistling	6.2	+	13.8	+	11.9	+	10.0	+	+
Feel breathless	7.5	1.35	6.2	1.12	8.3	1.52	5.7	1.00	N.S.
Have a Cold Yesterday	8.8		6.2		4.8		15.7		
Have a Cold Today	10.0		3.8		7.1		13.0++		

N.A.: Not analyzed due to less than 20 positive responses.
N.S.: $p > .05$

*Includes only subjects with complete spirometry.

**Odds ratio relative to C2, adjusted for age and cigarettes per day.

***The odds ratio for A, relative to B1 was related to age by the equation OR = Exp(11.15 - .233 Age). For example, among subjects 30 and 50 years old, the estimated OR is 64.1 and 0.6 respectively. The odds ratio for B2 and the combined group of A and B1, relative to C2 was not significantly different from 1.

+The odds ratio for the Utica groups (A, B1, B2) relative to the Romeo group (C2) was related to age by the equation OR = Exp(-5.73 + .157 Age). At age 30 and 50 the OR's are .4 and 8.3 respectively. The odds ratios for A and B1 relative to B2 were not significantly different from 1.

++ 1 missing value.

TABLE 11

Incidence of Symptoms During the Workshift: External Comparison
Q: Did You Have (Symptom) During Work Today?

Exposure Groups*

Symptom	A N	A %	A OR**	B1 N	B1 %	B1 OR	B2 N	B2 %	B2 OR	C2 N	C2 %	C2 OR	Significance
Eyes itch, burn, water	70	12.9	4.20	77	13.0	4.24	72	15.3	5.14	59	3.4	1.00	N.S.
Sore throat	68	7.4	N.A.	76	6.6	N.A.	78	6.4	N.A.	64	6.2	N.A.	N.A.
Numbness in forehead	80	1.2	N.A.	78	0.0	N.A.	84	0.0	N.A.	68	0.0	N.A.	N.A.
Chest tightness	75	6.7	N.A.	71	8.5	N.A.	76	7.9	N.A.	68	1.5	N.A.	N.A.
Headache	67	4.5	0.66	71	14.1	2.33	69	7.2	1.04	61	6.6	1.00	N.S.
Chest sound wheezing or whistling	75	1.3	N.A.	69	4.3	N.A.	74	4.1	N.A.	62	1.6	N.A.	N.A.
Feel Breathless	74	10.8	1.48	75	8.0	1.04	77	9.1	1.25	65	7.7	1.00	N.S.
>10% reduction in FEV_1	80	1.2	N.A.	80	3.8	N.A.	84	0.0	N.A.	70	2.9	N.A.	N.A.

N.A.: not analyzed due to less than 20 positive responses.
N.S.: $p > .05$

*Includes only subjects with complete spirometry, and excludes those who had the symptom on the previous day.

**Odds ratio relative to C2, adjusted for age and cigarettes per day.

TABLE 12

Mean Acute Changes In Pulmonary Function Over the Shift (ΔPFT)
By Exposure Group

	Exposure Groups*			
	A	B1	B2	C2
N	80	80	84	70
ΔFVC (ml)	- 12(23)	- 2(18)	- 23(18)	- 6(21)
ΔFEV_1 (ml)	- 24(25)	- 3(19)	6(15)	- 21(15)
ΔPeak Flow (ml/sec)	153(83)	97(99)	161(66)	78(92)
ΔFEF50 (ml/sec	- 13(84)	10(73)	18(65)	- 76(68)
ΔFEF75 (ml/sec)	- 51(45)	- 15(45)	- 41(32)	- 29(30)
Mean Δ PFT, Adjusted For Age, Cigarettes/Day, And Shift				
ΔFVC (ml)	- 15(20)	- 5(21)	28(21)	- 15(25)
ΔFEV_1 (ml)	- 34(19)	- 17(20)	- 9(20)	- 53(24)
ΔPeak Flow (ml/sec)	117(86)	53(87)	112(87)	- 19(105)
ΔFEF50 (ml/sec)	- 47(74)	- 36(75)	- 27(75)	-182(90)
ΔFEF75 (ml/sec)	- 62(39)	- 32(40)	- 51(40)	- 63(48)

*Standard errors of the means are given in parenthesis. A negative value indicates a decline over the work shift. There are no differences among the groups.

TABLE 13A

Incidence of Acute Symptoms by Number of TDI Spills*

Number of TDI Spills

	0			1-3			4-10			> 10			
Symptom	N	%	OR**	N	%	OR	N	%	OR	N	%	OR	Significance
Eyes itch,burn, water	106	9.4	1.00	54	14.8	1.68	30	13.3	1.49	29	27.6	3.69	N.S.
Sore throat	110	5.5	N.A.	54	5.6	N.A.	31	12.9	N.A.	27	7.4	N.A.	N.A.
Forehead numb	116	0.0	N.A.	59	0.0	N.A.	33	0.0	N.A.	34	2.9	N.A.	N.A.
Chest tightness	113	8.0	N.A.	54	7.4	N.A.	27	7.4	N.A.	28	7.1	N.A.	N.A.
Headache	102	6.9	N.A.	50	12.0	N.A.	28	10.7	N.A.	27	7.4	N.A.	N.A.
Chest wheezing or whistling	109	1.8	N.A.	51	3.9	N.A.	28	7.1	N.A.	30	3.3	N.A.	N.A.
Breathless	112	5.4	1.00	54	9.3	1.80	30	13.3	2.75	30	20.0	4.51	N.S.
>10% Reduction in FEV	118	0.8	N.A.	59	1.7	N.A.	33	3.0	N.A.	34	2.9	N.A.	N.A.

N.A.: Not analyzed due to less than 20 positive responses.
N.S.: $p > .05$

*Includes only subjects with complete spirometry, and excludes those who had the symptom on the previous day.

**Odds ratio relative to 0 spills group, adjusted for age and cigarettes per day.

TABLE 13B
Incidence of Acute Symptoms by Longest
Exposure Time to TDI Spills*

Longest Time Exposed to TDI Spill (Min)

	0			1-5			6-15			16-60			> 60			
Symptom	N	%	OR**	N	%	OR	N	%	OR	N	%	OR	N	%	OR	Significance
Eyes itch, burn,water	106	9.4	***	32	21.9	***	30	16.7	***	24	16.7	***	27	14.8	***	***
Sore throat	110	5.5	N.A.	32	9.4	N.A.	29	6.9	N.A.	22	0.0	N.A.	29	13.8	N.A.	N.A.
Forehead numb	116	0.0	N.A.	35	0.0	N.A.	33	0.0	N.A.	25	0.0	N.A.	33	3.0	N.A.	N.A.
Chest tightness	113	8.0	N.A.	32	9.4	N.A.	30	6.7	N.A.	21	9.5	N.A.	26	3.8	N.A.	N.A.
Headache	102	6.9	N.A.	31	9.7	N.A.	30	13.3	N.A.	19	5.3	N.A.	25	12.0	N.A.	N.A.
Chest wheeze,whistle	109	1.8	N.A.	31	9.7	N.A.	30	3.3	N.A.	22	0.0	N.A.	26	3.8	N.A.	N.A.
Breathless	112	5.4	N.A.	32	15.6	N.A.	32	12.5	N.A.	22	9.1	N.A.	28	14.3	N.A	N.A.
> 10% Reduction in FEV	118	0.8	N.A.	35	2.9	N.A.	33	3.0	N.A.	25	0.0	N.A.	33	3.0	N.A.	N.A.

N.A.: Not analyzed due to less than 25 positive responses.
N.S.: $p > .05$

*Includes only subjects with complete spirometry, and excludes those who had the symptom on the previous day.

**Odds ratio relative to 0 time exposed, adjusted for age and cigarettes per day.

***The odds ratio for those exposed for 1 to 5 minutes relative to those not exposed was related to age by the equation OR = Exp(7.77 - .177 Age). The ORs are 11.7 and 0.3 at ages 30 and 50 respectively. There were no significant differences among the 3 highest exposed groups, nor between those exposed for 5 or less minutes compared to those exposed for 60 or more minutes.

TABLE 13C

Incidence of Acute Symptoms by Cumulative TDI Exposure*

Cumulative TDI Exposure (Number of Spills x Longest Time Exposed)

	0			1-30			30.5-262.5			> 262.5			
Symptom	N	%	OR**	N	%	OR	N	%	OR	N	%	OR	Significance
Eyes itch,burn, water	106	9.4	***	42	19.0	***	40	12.5	***	31	22.6	***	***
Sore throat	110	5.5	N.A.	42	7.1	N.A.	39	7.7	N.A.	31	9.7	N.A.	N.A.
Forehead numb	116	0.0	N.A.	45	0.0	N.A.	45	0.0	N.A.	36	2.8	N.A.	N.A.
Chest tightness	113	8.0	N.A.	42	7.1	N.A.	38	7.9	N.A.	29	6.9	N.A	N.A.
Head ache	102	6.9	N.A.	40	12.5	N.A.	39	7.7	N.A.	26	11.5	N.A.	N.A.
Chest wheezing, whistling	109	1.8	N.A.	40	7.5	N.A.	38	2.6	N.A.	22	3.2	N.A.	N.A.
Breathless	112	5.4	1.00	42	11.9	2.37	41	12.2	2.52	31	16.1	3.40	N.S.
>10% Reduction in FEV	118	0.8	N.A.	45	2.2	N.A.	45	2.2	N.A.	36	2.8	N.A.	N.A.

N.A.: Not analyzed due to less than 20 positive responses.
N.S.: $p > .05$
*Includes only subjects with complete spirometry, and excludes those who had the symptom on the previous day.
**Odds ratio relative to 0 cumulative exposure, adjusted for age and cigarettes per day.
***The odds ratio for the 1 to 30 group relative to the 0 group was related to age by the equation OR = Exp(6.49 - .151 Age), while that for the > 262.5 group, relative to the 30.5 - 262.5 group was related to age by the equation OR = Exp(8.44 - 181 Age). Examples are given in the following subtable:

	OR by Age	
	30	50
1-30 vs 0	7.3	0.4
> 262.5 vs 30.5 - 262.5	20.9	0.6

TABLE 13D

Incidence of Acute Symptoms by Symptoms Following an Exposure to a Spill*

Symptom Exposure Groups

	0			1-4			5-8			
Symptom	N	%	OR**	N	%	OR	N	%	OR	Significance
Eyes itch.burn.	121	9.1	1.00	53	9.4	1.05	45	31.1	4.54	***

TABLE 13E

Incidence of Acute Symptoms by Measured TDI Exposure*

TDI Exposure Groups (ppb)

Symptom	≤ 0.05 N	≤ 0.05 %	≤ 0.05 OR**	0.06-0.80 N	0.06-0.80 %	0.06-0.80 OR	> 0.80 N	> 0.80 %	> 0.80 OR	Significance
Eyes itch,burn,water	147	11.6	1.00	33	21.2	2.15	17	23.5	2.23	N.S.
Sore Throat	150	7.3	1.00	34	2.9	.37	16	6.2	.89	N.S.
Forehead numb	160	0.0	N.A.	38	2.6	N.A.	20	0.0	N.A.	N.A.
Chest tightness	148	8.1	1.00	34	14.7	1.22+	20	0.0	1.22+	N.S.
Headache	137	8.8	1.00	32	3.1	.33	18	16.7	1.95	N.S.
Chest wheezing or whistling	145	4.1	N.A.	33	3.0	N.A.	20	0.0	N.A.	N.A.
Breathless	152	8.6	1.00	36	13.9	1.76	18	11.1	1.31	N.S.
> 10% Reduction in FEV_1	162	1.2	N.A.	38	5.3	N.A.	20	0.0	N.A.	N.A.

N.A.: Not analyzed due to less than 15 positive responses.
N.S.: $p > .05$

*Includes only subjects with complete spirometry, and excludes those who had the symptom on the previous day.
**Odds ratio relative to ≤ 0.05 group, adjusted for age and cigarettes per day.

+The two highest exposure groups were combined due to zero incidence in the > 0.8 group.

Table 14

Mean Acute Changes in Pulmonary Function Over the Work Shift by Exposure Category, Adjusted for Age, Cigarettes/Day, and Shift*

	N	ΔFVC (ml)	ΔFEV_1 (ml)	ΔPeak Flow (ml/sec)	ΔFEF50 (ml/sec)	ΔFEF75 (ml/sec)
Number of Spills						
0	118	-30(17)**	-23(18)	173(70)***	-65(65)	-48(36)
1-3	59	-14(24)**	-16(24)	-51(95)***	-30(87)	-33(49)
4-10	33	18(32)**	-4(32)	403(129)***	61(118)	-43(66)
> 10	34	-6(31)**	-28(32)	-160(127)***	-148(116)	-76(65)
Longest Time Exposed to a Spill-Minutes						
0	118	-29(17)	-23(18)	172(72)	-64(65)	-48(36)
1-5	35	3(31)	-4(31)	148(128)	28(115)	-90(64)
6-15	33	-41(31)	-10(32)	25(130)	102(117)	-25(65)
16-60	25	-18(36)	-36(36)	-70(149)	-149(113)	-64(74)
> 60	33	42(32)	-18(33)	13(133)	-50(119)	- 8(66)
Cumulative Exposure (# Spills x Longest Time)-Minutes						
0	118	-30(17)	-23(18)	169(72)	-65(65)	-48(36)
1-30	45	-17(27)	-12(27)	59(112)	53(100)	-48(56)
30.5-262.5	45	0(27)	-12(28)	37(113)	-18(101)	-53(56)
> 262.5	36	10(31)	-26(31)	1(126)	-78(113)	-39(63)
Symptoms Following a Spill						
0	134	-24(17)	-23(17)	159(69)	-63(63)	-44(34)
1-4	58	15(29)	-19(29)	95(119)	-15(108)	-19(59)
5-8	52	-17(26)	-6(26)	-2(106)	21(97)	-79(53)
TDI Exposure - ppb						
≤ 0.05	162	-28(15)+	-23(16)+	96(65)	-44(50)	-54(31)
0.06-0.80	38	45(30)+	13(31)+	262(129)	82(114)	7(62)
>0.80	20	-76(41)+	-127(42)+	120(177)	-341(156)	-202(85)

*Standard errors of the means are given in parentheses.
**The slope with age was .005 for the 1 to 3 group and -.002 for the 0 group. No other differences were found.
***The > 10 group had lower values than the 4 to 10 group.
+The > 0.80 group had lower values than the 0.06 - 0.80 group.

TABLE 15

Prevalence and Adjusted Odds Ratios of
Chronic Symptoms

	Exposure Groups								
	A		B1		B2		C		
N	86		87		87		145		
Symptom	%	OR*	%	OR	%	OR	%	OR	Significance
Cough	16.3	0.99	21.8	1.39	23.0	1.61	16.6	1.00	N.S.
Phlegm	20.9	1.30	26.4	1.74	29.9	2.20	17.2	1.00	N.S
Shortness of breath	7.0	1.30	8.1	1.52	17.2	3.71	5.5	1.00	**
Wheezing	4.7	0.62	6.9	0.93	12.6	1.97	7.6	1.00	N.S.
Asthma	17.4	2.07	11.5	1.29	14.9	1.80	9.7	1.00	N.S.
Chest illness	12.8	1.79	10.3	1.43	12.6	1.85	8.3	1.00	N.S.

N.S.: $p > .05$

*Odds ratios relative to group C, adjusted for age and smoking status.

**At least one odds ratio was statistically different from 1.0. The test of Utica vs Romeo was not significant, and the test of differences within Utica was non-significant; however, in testing all pair-wise comparisons, B2 was different from both A and C.

Table 16

Mean Baseline Pulmonary Function (PFT) by Exposure

	Exposure Groups*			
	A	B1	B2	C
N	80	80	84	143
FVC (L)	5.00(.09)	4.71(.10)	4.80(.10)	4.82(.07)
FEV_1 (L)	3.86(.08)	3.66(.09)	3.67(.09)	3.72(.07)
Peak Flow (L/Sec)	9.71(.20)	9.34(.21)	9.26(.21)	9.55(.15)
FEF50 (L/Sec)	4.56(.17)	4.50(.18)	4.27(.14)	4.48(.13)
FEF75 (L/Sec)	1.47(.08)	1.41(.07)	1.36(.06)	1.41(.06)
Mean PFT Adjusted for Age, Race, Height, Smoking Status, and Shift				
FVC (L)	4.73(.16)**	4.53(.16)**	4.59(.16)**	4.50(.17)**
FEV_1 (L)	3.73(.14)	3.59(.14)	3.58(.14)	3.56(.15)
Peak Flow (L/Sec)	9.29(.42)	9.02(.42)	8.91(.41)	9.04(.45)
FEF50 (L/Sec)	4.73(.34)	4.58(.34)	4.40(.34)	4.53(.37)
FEF75 (L/Sec)	1.49(.13)	1.46(.13)	1.37(.13)	1.40(.14)

*Standard errors of the means are given in parentheses.

**The slope with age was -0.918 for Group A and - 0.041 for Group B1. No other differences were found.

TABLE 17A

Prevalence of Chronic Symptoms by Number of TDI Spills

Number of TDI Spills

	0		1-3		4-10		> 10		
N	124		65		36		35		
Symptoms	%	OR*	%	OR	%	OR	%	OR	Significanc
Cough	16.9	1.00	15.4	0.98	30.6	1.98	31.4	2.21	N.S.
Phlegm	21.8	1.00	23.1	1.16	30.6	1.47	40.0	2.4	N.S.
Shortness of breath	8.1	**	12.3	**	11.1	**	17.1	**	**
Wheezing	8.1	1.00	4.6	0.97	13.9	1.83	8.6	1.47	N.S.
Asthma	13.7	1.00	13.9	1.02	11.1	0.86	22.9	2.01	N.S.
Chest illness	8.1	1.00	12.3	1.58	13.9	3.07	13.5	2.39	N.S.

N.S.: $p > .05$

*Odds Ratios relative to 0 spills, adjusted for age and smoking status.

**The odds ratio for those exposed to 4 or more spills relative to those exposed to less than 4 spills was related to age by the equation OR = Exp(5.86 - .132 Age). The ORs were 6.7 and 0.5 for ages 30 and 50 respectively. There were no significant differences between the two highest categories or between the two lowest categories.

TABLE 17B

Prevalence of Chronic Respiratory Symptoms by Exposure Time to TDI Spills

Longest Time Exposed to a TDI Spill (Min)

	0		1-5		6-15		16-60		> 60		
N	124		37		38		26		35		
Symptoms	%	OR*	%	OR	%	OR	%	OR	%	OR	Significance
Cough	16.9	1.00	18.9	1.30	26.3	1.79	19.2	1.11	28.6	1.87	N.S.
Phlegm	21.8	**	21.6	**	34.2	**	30.8	**	31.4	**	**
Shortness of breath	8.1	1.00	8.1	0.91	18.4	2.97	15.4	2.32	11.4	1.64	N.S.
Wheezing	8.1	1.00	5.4	0.61	7.9	1.03	7.7	0.98	11.4	1.52	N.S.
Asthma	13.7	1.00	16.2	1.06	2.6	0.19	11.5	0.91	31.4	3.29	***
Chest illness	8.1	1.00	21.6	2.87	7.9	1.02	15.4	2.24	17.1	2.55	N.S.

N.S.: $p > .05$

*Odds ratios relative to 0 time, adjusted for age and smoking status.

**The odds ratio for those exposed for 1 to 5 minutes relative to those not exposed was related to age by the equation OR = Exp(6.78 - .170 Age). The ORs were 5.4 and 0.2 for ages 30 and 50 respectively. There were no significant differences among the 3 highest exposed groups, nor between those exposed for 5 or less minutes compared to those exposed for 6 or more minutes.

***The odds ratio for $\geq$ 16 minutes relative to 6-15 was significantly greater than 1. There were no significant differences between those exposed for > 60 minutes compared to those exposed for 16-60 minutes, those exposed for 1-5 minutes compared to those never exposed, and those exposed for 6 or more minutes compared to those exposed less than 6 minutes.

TABLE 17C

Prevalence of Chronic Respiratory Symptoms by Cumulative TDI Exposure

Cumulative TDI Exposure (Number of Spills x Longest Time Exposed)

	0		1-30		30.5-262.5		>262.5		
N	124		50		57		29		
Symptoms	%	OR*	%	OR	%	OR	%	OR	Significance
Cough	16.9	1.00	20.0	1.39	21.1	1.26	34.5	2.42	N.S.
Phlegm	21.8	1.00	24.0	1.24	29.8	1.49	37.9	2.11	N.S.
Shortness of breath	8.1	1.00	10.0	1.24	17.5	2.60	10.3	1.51	N.S.
Wheezing	8.1	1.00	6.0	0.73	5.3	0.65	17.2	2.38	N.S.
Asthma	13.7	1.00	12.0	0.81	12.3	0.96	27.6	2.82	N.S.
Chest illness	8.1	1.00	16.0	2.02	14.0	2.05	17.2	2.53	N.S.

N.S.: $p > .05$

*Odds ratios relative to 0 cumulative exposure, adjusted for age and smoking status.

TABLE 17D

Prevalence of Chronic Respiratory Symptoms by Symptoms Following an Exposure to a Spill

Number of Symptoms Following Spill Exposure

	0		1-4		5-8		
N	142		62		56		
Symptoms	%	OR*	%	OR	%	OR	Significance
Cough	16.2	1.00	14.5	0.83	37.5	3.06	**
Phlegm	19.7	1.00	27.4	1.50	39.3	2.58	***
Shortness of breath	8.5	1.00	11.3	1.42	16.1	2.30	N.S.
Wheezing	7.0	1.00	3.2	0.43	16.1	2.54	**
Asthma	12.7	1.00	9.7	0.75	25.0	2.55	**
Chest illness	8.5	+	9.7	+	23.2	+	+

N.S.: $p > .05$

*Odds ratios relative to 0 symptoms, adjusted for age and smoking status.

**The odds ratio for those with 5 or more symptoms relative to those with 1 to 4 symptoms was significantly greater than 1. Those with 1 or more symptoms did not differ significantly from those with 0 symptoms.

***The odds ratio for those exposed to 1 or more spills, relative to those exposed to no spills, was significantly greater than 1. Those exposed to 5 or more spills were not significantly different from those exposed to 1 to 4 spills.

+The odds ratio for those exposed to 5 to 8 spills, relative to those exposed to 1 to 4 spills, was related to age by the equation OR = Exp(12.52 - .287 Age). The ORs were 49.9 and 0.2 for ages 30 and 50 respectively. Also, the odds ratio for 1 to 8 relative to 0 symptoms was significantly greater than 1.

TABLE 17E

Prevalence of Chronic Respiratory Symptoms by Tenure

Tenure (Years)

	0-9		10-12		13-17		≥ 17		
N	71		90		62		37		
Symptoms	%	OR*	%	OR	%	OR	%	OR	Significa
Cough	14.1	1.00	22.2	1.97	30.7	2.93	10.8	0.83	**
Phlegm	18.3	1.00	25.6	1.65	30.7	2.07	32.4	2.43	N.S.
Shortness of breath	5.6	1.00	12.2	2.34	9.7	1.69	18.9	3.06	N.S.
Wheezing	2.8	1.00	7.8	3.10	12.9	5.84	10.8	5.89	N.S.
Asthma	14.1	1.00	14.4	1.06	19.4	1.36	8.1	0.38	N.S.
Chest illness	7.0	1.00	15.6	2.50	14.5	2.62	8.1	1.66	N.S.

N.S.: $p > .05$

*Odds ratios relative to 0-9 years, adjusted for age and smoking status.
**Prevalence of cough was significantly related to tenure, but the rates were not different for those with 13 or more years compared with those with less than 13, years, those with 18 or more years compared to those with 13 to 17 years, or those with 10 to 12 years compared to those with 0 to 9 years. All pair-wise comparison showed only that the 13 to 17 group had a higher prevalence of cough than the 0 to 9 group.

TABLE 18

Mean Pulmonary Function by Exposure Category
(Adjusted for Age, Race, Height, Smoking Status, and Shift)*

	N	FVC	FEV_1	Peak Flow	FEF50	FEF75
Number of Spills						
0	118	4.55(.15)	3.56(.14)	8.85(.40)	4.44(.33)	1.37(.13)
1-3	60	4.57(.17)	3.63(.15)	9.29(.45)	4.77(.37)	1.41(.14)
4-10	33	4.56(.19)	3.56(.17)	8.51(.50)	4.37(.42)	1.34(.16)
> 10	34	4.50(.19)	3.52(.17)	8.98(.49)	4.39(.41)	1.39(.16)
Longest Time Exposed to Spill-Minutes						
0	118	4.55(.15)	3.56(.14)	8.89(.40)	4.45(.33)	1.37(.13)
1-5	36	4.58(.18)	3.62(.17)	9.34(.49)	4.81(.41)	1.48(.16)
6-15	33	4.63(.19)	3.62(.17)	8.71(.50)	4.50(.41)	1.42(.16)
16-60	25	4.52(.19)	3.60(.18)	9.04(.52)	4.65(.43)	1.36(.17)
> 60	33	4.46(.19)	3.49(.17)	9.02(.50)	4.33(.42)	1.27(.16)
Cumulative Exposure (# Spills x Longest Time)-Minutes						
0	118	4.55(.15)	3.56(.14)	8.88(.40)	4.45(.33)	1.37(.13)
1-30	46	4.64(.18)	3.66(.16)	9.22(.47)	4.77(.39)	1.47(.15)
30-210	45	4.49(.18)	3.55(.16)	8.97(.47)	4.53(.39)	1.35(.15)
> 210	36	4.51(.18)	3.54(.17)	8.85(.49)	4.37(.41)	1.32(.16)
Symptoms Following a Spill						
0	134	4.56(.15)	3.57(.14)	8.89(.40)	4.48(.33)	1.37(.13)
1-4	59	4.60(.18)	3.65(.17)	9.07(.47)	4.82(.40)	1.37(.15)
5-8	52	4.52(.17)	3.54(.16)	8.98(.46)	4.45(.39)	1.42(.15)
Tenure-Years						
0-9	66	4.65(.16)	3.64(.15)	9.22(.43)	4.59(.36)	1.37(.14)
10-12	85	4.56(.16)	3.53(.15)	8.72(.43)	4.25(.36)	1.32(.14)
13-17	58	4.43(.16)	3.54(.15)	8.79(.43)	4.57(.36)	1.44(.14)
≥ 18	36	4.65(.19)	3.64(.17)	9.22(.50)	4.80(.41)	1.37(.16)

*Standard errors of the means are given in parentheses.
Pulmonary function was not significantly related to any exposure.

Table 19

Significant* Relationships Between Symptoms and Pulmonary Function

Acute Variables**

	Sore Throat (Slope with Age)	
	Without	With
Δ FEF50	.003	-.056

Chronic Variables***

	Cough (Slope with Age)		Shortness of Breath (Slope with Age)	
	Without	With	Without	With
FVC	-.027	-.049	--	--
FEV	-.034	-.055	--	--
Peak Flow	-.059	-.114	--	--
FEF50	-.046	-.094	-.058	-.004

	Shortness of Breath (Means)		Wheezing (Means)	
	Without	With	Without	With
FVC	4.63	4.35	4.59	4.25
FEV	3.67	3.35	3.62	3.35
Peak Flow	9.16	8.41	9.05	8.27
FEF75	1.48	1.26	--	--

*The symptoms in Tables 8A-8E were compared to the pulmonary function indices in Table 9, and the symptoms in Tables 12A-12E were compared to the pulmonary function indices Table 13. All comparisons for which values are not specifically listed in this table were not statistically significant.
**Adjusted for age, cigarettes per day, and shift.
***Adjusted for age, race, height, smoking status, and shift.

Table 20

Comparison of 1982 and 1983 Studies

Symptoms	1982		1983 A	1983 B1	1983 B2	1983 C
Chronic Bronchitis (Phlegm)	44.4		23.3	29.4	33.3	18.6
Wheezing	44.0		23.3	35.3	35.6	29.7
Occupational Wheezing	31.9		15.2	21.2	17.2	23.5
Frequent Occupational Wheezing*	18.9		8.1	10.6	18.4	19.2
Wheezing Away From Work	12.0		15.1	28.2	25.1	16.6
Frequent Eye or Throat Irritation**	58.8	Daily	23.3	18.8	23.0	12.4
		Weekly	12.8	15.3	14.9	6.9
Asthma	4.6		5.8	8.2	3.4	4.8

*Frequent occupational wheezing in 1982 survey = wheezing on most days during workweek but not weekend; in 1983 survey = wheezing most days.

**Only eye irritation for 1983 survey. Meaning of "frequent" in 1982 is not clear.

FIGURE 1

MOLDING STEPS ON A FOAM LINE

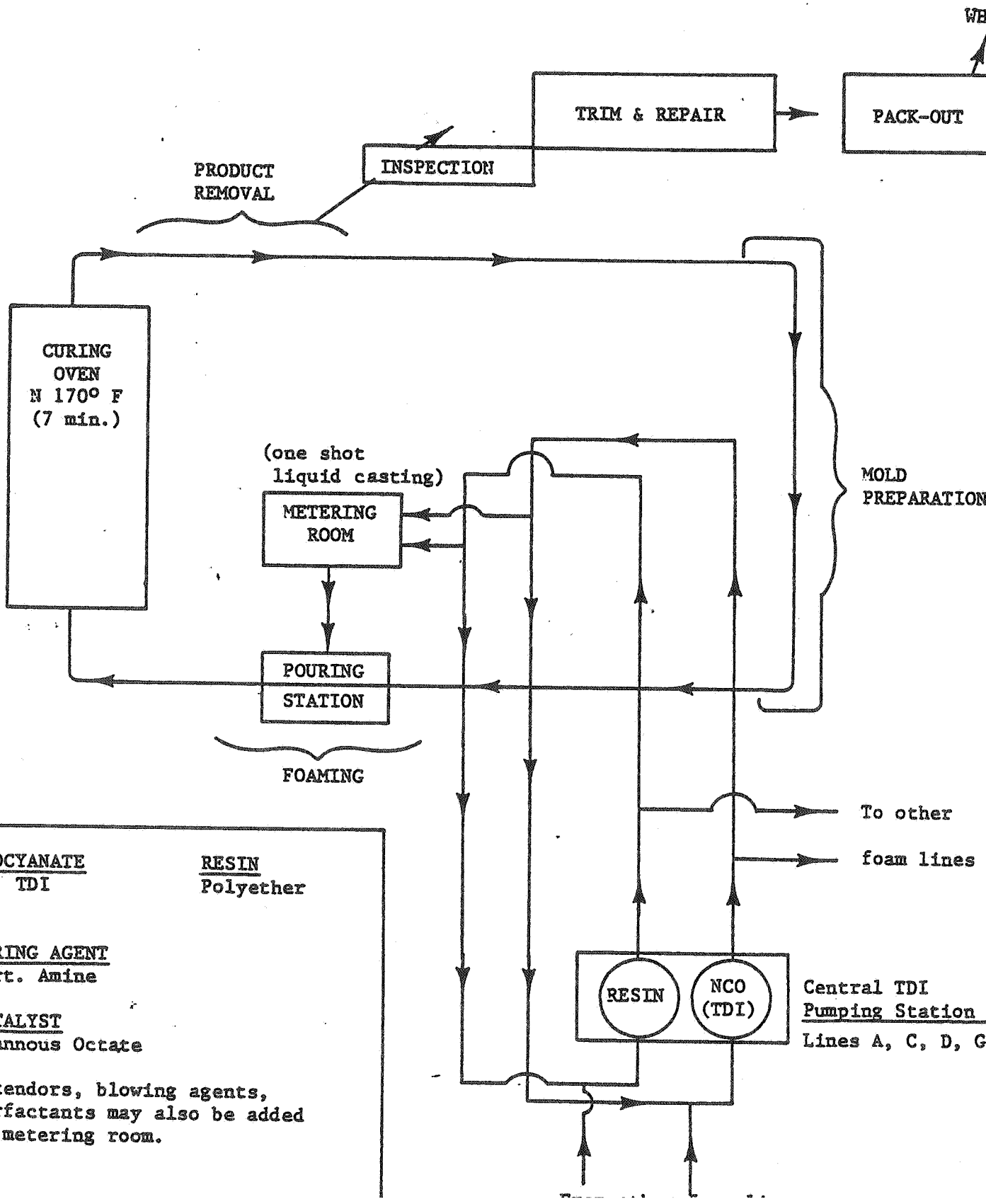


FIGURE 2

FLOOR PLAN

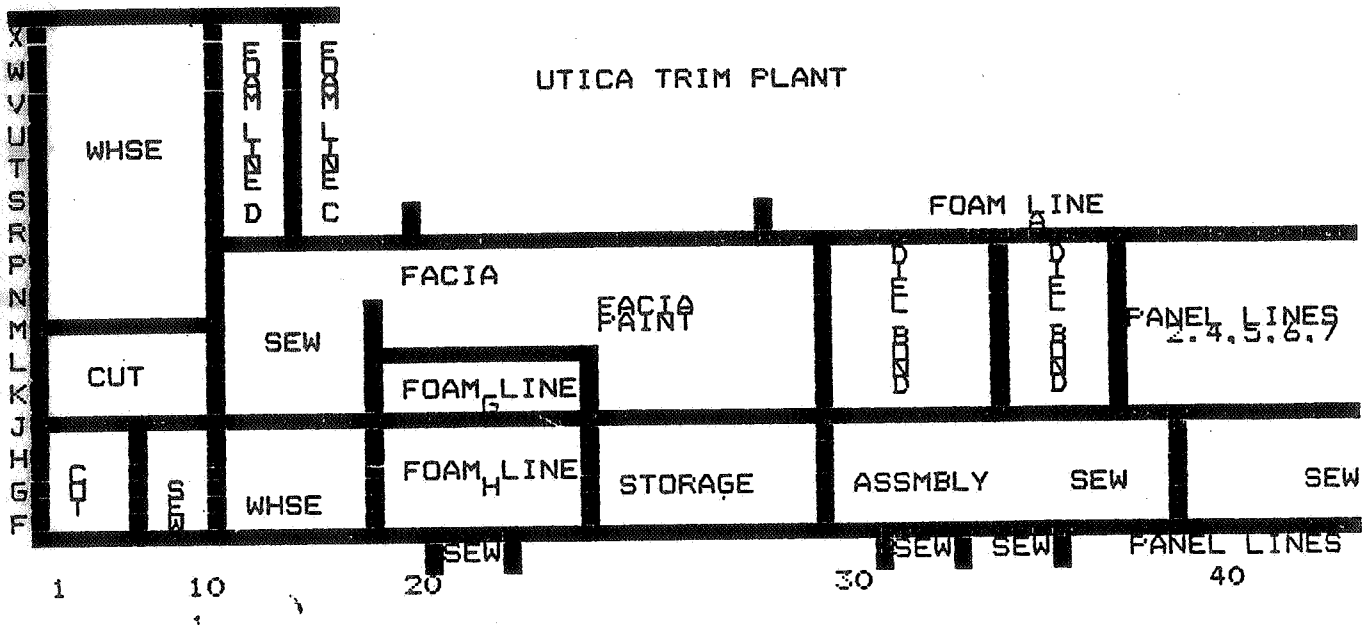
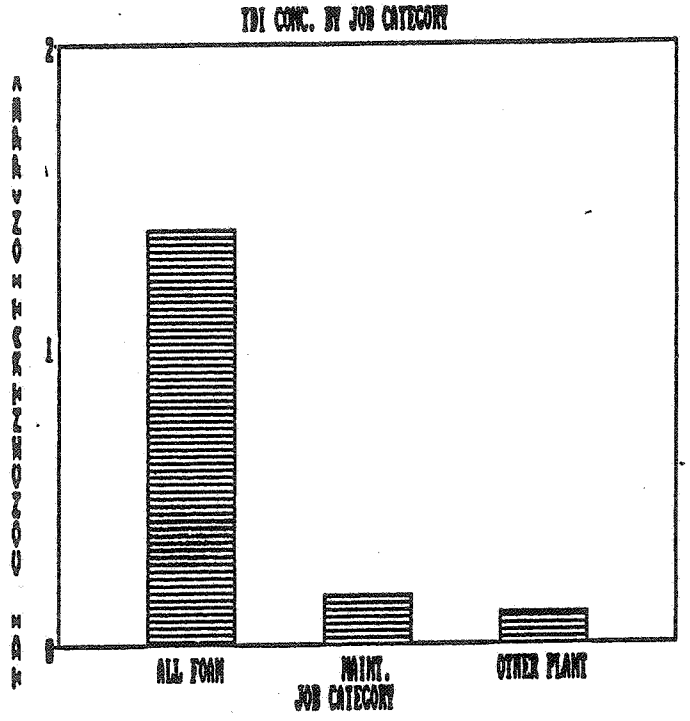


FIGURE 3

PERSONAL TDI SAMPLES - 1983 SURVEY



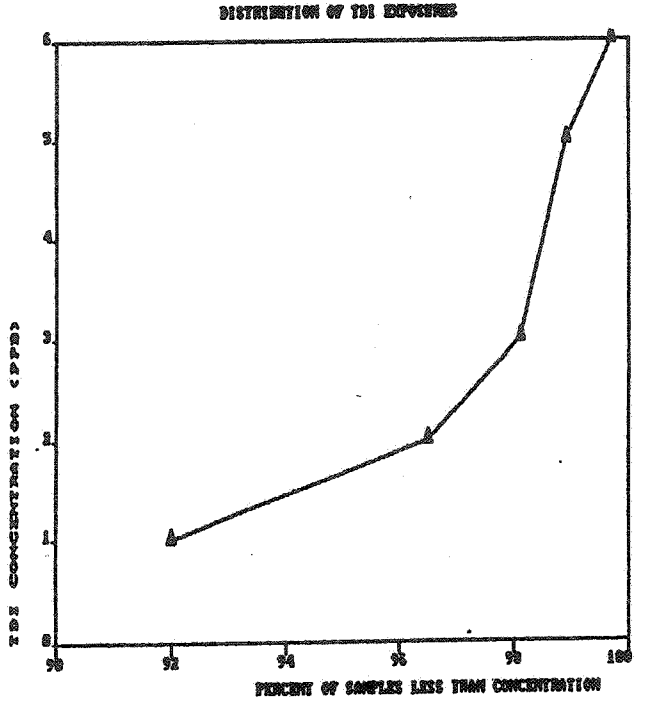
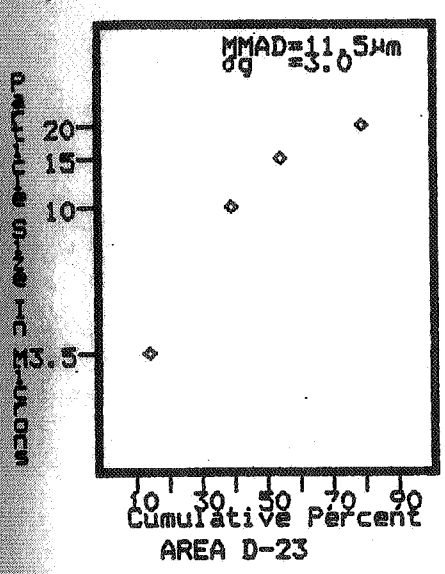
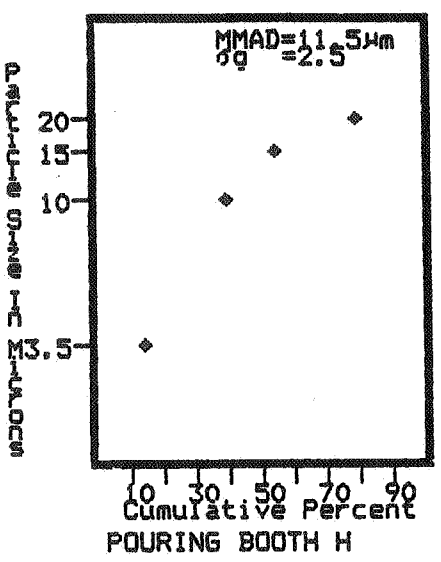


FIGURE 4

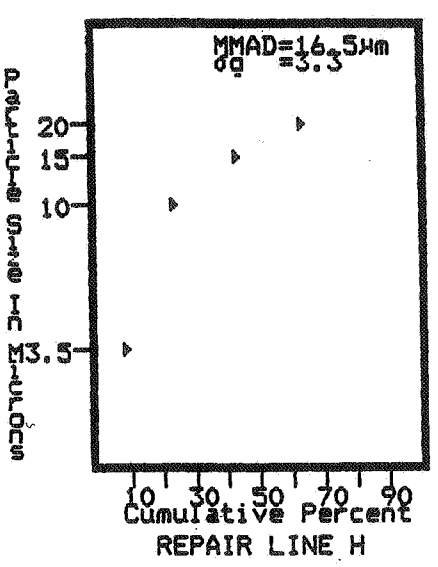
PARTICLE SIZE AND
TOTAL DUST DATA



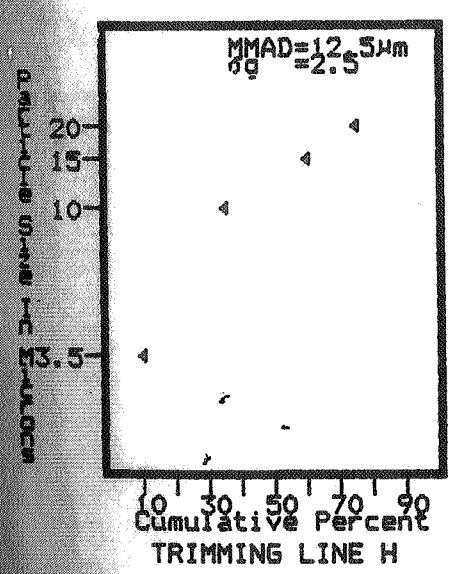
AREA D-23



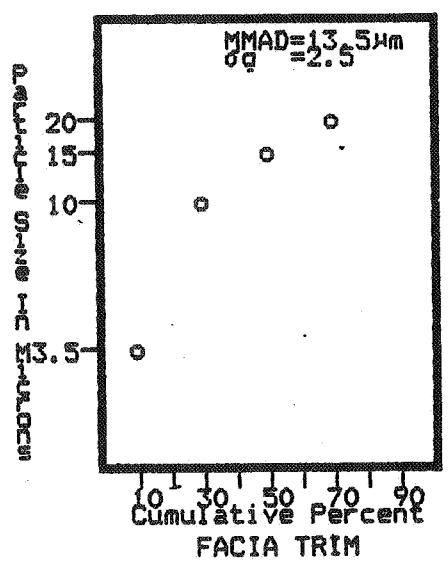
POURING BOOTH H



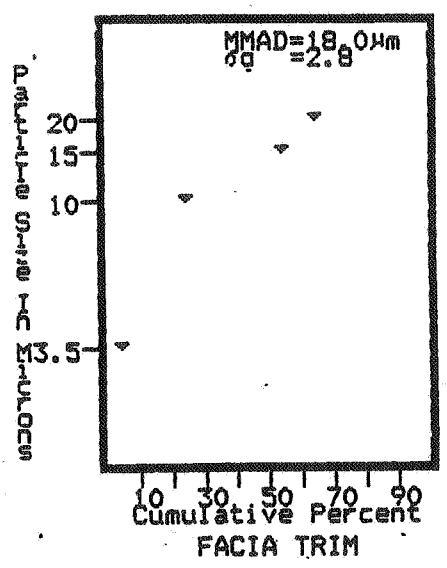
REPAIR LINE H



TRIMMING LINE H



FACIA TRIM



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