U.S DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
CINCINNATI, OHIO 45202

HEALTH HAZARD EVALUATION DETERMINATION
REPORT NO. 73-30-90

KING SEELEY THERMOS COMPANY
MACOMB, ILLINOIS
NOVEMBER 1973

TOXICITY DETERMINATION

It has been determined that toluene diisocyanate (TDI) is potentially toxic to some employees at the concentrations found during this study of the King Seeley Thermos Company in Macomb, Illinois. This determination is based upon extensive environmental sampling coupled with medical testing.

Without exception, all airborne concentrations (breathing zone and work area) of TDI measured in this plant during this study were far below the present occupational health standard of ceiling value of 0.14 mg/M^3 or 0.02 ppm promulgated by the U.S. Department of Labor. Measured airborne concentrations were also below the recently recommended 8-hour time-weighted-average exposure standard of 0.035 mg/M^3 or 0.005 ppm contained in NIOSH's criteria document for toluene dissocyanate.

These low airborne concentrations are judged to be potentially toxic in this case because several of the workers exposed to foaming operations, and thus to TDI, are believed to be sensitive to TDI. Medical histories and clinical tests have shown that these sensitive individuals are experiencing adverse health effects from exposure to TDI. Sensitive individuals were found during this evaluation to experience mild asthma and hay fever-like symptoms which in general did not result in reduced pulmonary function test results over the course of one workshift's exposure. Only one sensitive individual experienced more severe symptoms including difficulty in breathing, chest tightness and conjestion, and was demonstrated to have a significant decrement in pulmonary function test results after one workshift's exposure to low levels of TDI.

It must be stated that it is not known how the sensitive employees acquired their sensitivity to TDI. Although past exposures to transient high levels of TDI resulting from spills of foam materials are considered to be an important cause for employee sensitivity, sensitivity in some cases may be the result of chronic exposures to low levels of TDI. Thus, presently unaffected employees may possibly become sensitive in the future as the result of chronic low level exposure.

Individuals who were found to have medical problems or abnormal clinical findings have been privately contacted by mail, as have their private physicians.

The following recommendations are made in the interest of controlling adverse health effects from exposure to TDI.

1. The plant should institute a medical monitoring program similar to the one outlined in the NIOSH "criteria for a recommended standard ... Occupational Exposure to Toluene Diisocyanate." This program includes comprehensive preplacement physical examinations for all workers, annual physical exams to include chest X-rays, pulmonary function tests, etc. for workers exposed to isocyanates.

2. Once employees have been examined following the above guidelines, those individuals found to be adversely reacting to exposure to TDI (experiencing symptoms of respiratory irritation, reduced pulmonary function, etc.) should be moved to jobs as far away from isocyanates as possible.

3. In the event of a spill of foam material, all employees should be evacuated from the immediate area of the spill and workmen equipped with U.S. Bureau of Mines approved respirators and protective equipment should move in to clean up the spill.

4. Foam technicians should wear approved respirators during maintenance and servicing of foam equipment when exposure to the isocyanate containing component is possible.

5. Foam machines should be equipped with improved local exhaust ventilation in conjunction with more complete enclosure of the foam dispensing process.

II. DISTRIBUTION AND AVAILABILITY OF DETERMINATION REPORT

Copies of this Determination Report are available upon request from the Hazard Evaluation Services Branch, U.S. Post Office Building, Room 508, 5th and Walnut Streets, Cincinnati, Ohio 45202. Copies have been sent to:

a) King Seeley Thermos Company - Macomb, Illinois
b) Authorized Representative of Employees
c) U.S. Department of Labor - Region V
d) NIOSH - Region V

For purposes of informing the approximately 200 "affected employees" the employer will promptly "post" the Determination Report in prominent places near where affected employees work for a period of 30 calendar days.

III. INTRODUCTION

Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6), authorizes the Secretary of Health, Education, and Welfare, following a written request by 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 National Institute for Occupational Safety and Health (NIOSH) received such a request from an authorized representative of employees regarding exposure to toluene diisocyanate (TDI) found in polyurethane foam materials in use at the King Seely Thermos Company. The request was precipitated by cases of employee symptomatology which necessitated movement of affected employees to new jobs.

IV. HEALTH HAZARD EVALUATION

A. Description of Process - Conditions of Use

The King Seeley Thermos Company is engaged in the manufacture of insulated ice chests, picnic jugs, and metal vacuum bottles. These containers are produced with shells and liners made from styrene plastic and metal. Compressed styrene beads, fiberglass, and polyurethane foam are employed as insulating materials. The polyurethane foam used in this application is based on toluene diisocyanate (TDI). The foam material is dispensed into the shells of containers in a liquid state (components A and B). A liner is then placed inside the shell over the foam and held in place by a form. The urethane foam then expands to fill the space between the container shell and liner.

Approximately 200 employees are exposed to airborne TDI which is generated by the foaming process. The purpose of this health hazard evaluation was to determine whether potentially toxic concentrations of TDI exist in this plant during near normal operating conditions.

B. Study Progress and Design

On April 25, 1973 an initial environmental-medical survey of the Macomb Plant was conducted by Mr. Robert Vandervort, Dr. Steven K. Shama, and Dr. Lawrence Handelsmann. A walk-through survey was conducted and preliminary air samples for TDI as well as bulk samples of the foam components were gathered. A preliminary medical evaluation was conducted involving interviews with 8 workers active on foam lines and 18 workers who had been transferred away from foam lines because of alleged intolerance to foam operations. Interviews

revealed that although the 8 present foam line workers were not symptomatic, 14 of the 18 transferred workers had symptoms consistent with intolerance to foam (TDI) at the time they were transferred. Most workers gave histories of being unable to work near foaming operations because of the onset within minutes to hours of a productive cough, chest heaviness, and wheezing. All had been working close to foaming operations, most having been foam machine operators or maintenance men.

Because of the finding that many workers had apparently developed sensitization to TDI, an in-depth evaluation of exposures and workers was planned. Due to the large number of employees and variety of exposure possibilities, it was apparent that a representative group of employees would have to be selected for study.

A second visit was made to the plant on June 5 and 6, 1973 by NIOSH representatives Messrs. Vandervort, Ruhe, Eddleston, Kurimo, and Drs. Shama and Handelsmann. Extensive air sampling was conducted in Departments 56, 73 and 75-A. In addition, several air samples were obtained from points scattered throughout the plant. Almost all of the samples were analyzed at the plant by a NIOSH chemist. A few samples were returned to Cincinnati for analytical comparative purposes. Results of this sampling showed that TDI levels were well below federal standards in all departments sampled. (See Section IV, D and E.)

During this visit all employees in the plant (290), regardless of job description or exposure to TDI were asked to fill out a questionnaire designed to elicit a history of TDI exposure and any symptoms that may have resulted from such exposure. Questionnaires were screened for major chest symptoms associated with foaming operations (i.e., cough, chest tightness, and wheezing) and minor irritative symptoms (i.e., eyes, nose, and throat irritation). Cohorts of workers were classified as either symptomatic or asymptomatic. Symptomatic workers were those reporting coughing and chest tightness with conjestion, or coughing, chest tightness and wheezing in association with foaming operations. Asymptomatic workers were those noting either minor non-specific irritative symptoms or no symptoms as related to foaming operations. Twenty-nine exposed workers were selected for study; 13 symptomatic and 16 asymptomatic workers. The exposed study population was then subdivided into moderate and low dose exposure groups on the basis of environmental TDI measurements made on June 5, 1973. The low exposure group contained those workers who were transferred because of alleged sensitization and whose exposure to TDI would be incidental. The exposed population of 29 workers was matched with a control population of 7 individuals with respect to age, sex, and smoking history. Thus, the total study population contained 36 individuals and could be subdivided into 5 groups.

A third visit to the plant was made during June 17 to 19, 1973 by NIOSH environmental and medical investigators. On June 18, 1973 each member of the study population was given pre- and post-shift pulmonary function tests. Exposed workers were asked to wear personal sampling equipment for the entire period between morning and afternoon pulmonary function tests. The study population was asked to complete; #1 an extensive medical and occupational questionnaire; three shorter questionnaires #2, #3, and #4. The shorter questionnaires were administered before, after, and the morning after the monitored shift, respectively. The shorter questionnaires allowed better correlation of symptoms with exposure levels and pulmonary function data. (Data collected via the short questionnaires along with average exposure data are presented in Table IV.)

Serum samples were obtained from 35 of the 36 individuals in the study population. An additional 47 serum samples were obtained from other workers who were not involved in the complete study.

C. Evaluation Methods

1. Toluene Diisocyanate (TDI) Air Sampling

Employee exposures to TDI were measured via personal air sampling equipment. Both work area and breathing zone samples were obtained using midget impingers. Reagents and analytical procedures followed the "modified" Marcali method as reported by Grim and Linch.[1] Samples were analyzed within hours of collection by a NIOSH chemist in the field at the plant.

2. Pulmonary Function Testing

Each pulmonary function test required the employee to make two forced expiratory volume practice maneuvers after which three forced expiratory volume maneuvers (reproducible within 5%) were recorded as flow volume loops. A waterless, high fidelity spirometer equipped with an air temperature probe was used. Flow volume loops were displayed on a storage oscilloscope and recorded on magnetic tape. Computer analysis of the flow volume loops provided the following parameters (corrected to body temperature and pressure, saturated with water vapor-BTPS): forced expiratory volume in one second (FEV_1), and forced vital capacity (FVC). For the purposes of calculating A.M./P.M. differences in group mean FEV_1 and FVC values, each individual's best FEV_1 and best FVC of his A.M. and P.M. trials were used.

3. Immunologic Assay - Serum Antibody Tests

Each employee serum sample was subjected to a battery of six immunologic test procedures.[2] These tests included those specifically designed to detect various types of antibodies resulting from specific isocyanate antigens (i.e. PK = Prausnitz-Kustner and PCA = passive cutaneous anaphylaxis).

D. Evaluation Criteria

The occupational health standard promulgated by the U.S. Department of Labor (Federal Register, October 18, 1972, Title 29, Chapter XVII, Subpart G, Table G-1) applicable to the individual substance of this evaluation is as follows:

Substance	p.p.m.[b]	mg/M3[c]
C[a] Toluene-2,4-diisocyanate	0.02	0.14

[a] C - Ceiling Value: Employee exposures are not to exceed this level.
[b] p.p.m. - Parts of vapor or gas per million parts of contaminated air by volume.
[c] mg/M^3 - Approximate milligrams of particulate per cubic meter of air.

Recently the National Institute for Occupational Safety and Health (NIOSH) has gathered criteria for the recommendation of a new standard to the Department of Labor.[3] This recommendation calls for an eight-hour time-weighted-average exposure of level of 0.005 p.p.m. or 0.035 mg/M^3 in addition to the present ceiling value of 0.02 p.p.m. or 0.14 mg/M^3 for occupational exposure to toluene diisocyanate (TDI).

Occupational health standards for individual substances are established at levels designed to protect workers occupationally exposed on an 8-hour per day, 40-hour per week basis over a working lifetime. However, with respect to TDI, the standard may not be protective to workers already sensitive to TDI.

E. Evaluation Results

1. Toluene Diisocyanate (TDI) Air Sampling

Table I contains the results of air sampling for TDI which was conducted on June 5, 1973. A total of 34 samples were collected and analyzed at the plant. All sample results were far below the present occupational health standard of 0.14 mg/M^3 or 140 $\mu g/M^3$. Highest results were obtained from the breathing zones of foam machine operators and from one area sample collected near foam supply drums in department 75-A.

Table II contains the results of air sampling for TDI which was conducted on June 18, 1973 in conjunction with medical studies. The data are grouped by department and employee. A total of 88 samples were collected and analyzed at the plant. Again all sample results were far below the present occupational health standard with highest results obtained near foaming operations.

Table III contains individual time-weighted-average exposures; changes in pre- and post-shift pulmonary function test results; and symptoms reported by employees before, during and after the June 18, 1973 monitored workshift.

Table IV contains mean exposure values and mean changes in pulmonary function test results for the five study subgroups. Subgroup mean exposure values were obtained by averaging the individual time-weighted-average exposures in each subgroup. An exposure value of 0 to 0.2 $\mu g/M^3$ was assigned to the control group based on environmental levels measured in the conference room.

It is important to mention that work operations where employees can be exposed to TDI in this plant are highly repetitive. Under normal conditions foam machine operators and other assembly personnel should be exposed to relatively constant levels of TDI which should be well reflected by the air sampling conducted during this study. However, according to employee and employer representatives, there have been incidents when foam machines and associated equipment have malfunctioned and "spills" of foam material have occurred. These incidents undoubtedly have produced transient elevated levels of airborne TDI in the plant. During the days of this evaluation an incident such as this did not occur.

2. Medical Evaluation

a. Pulmonary Function Testing

Individual A.M. to P.M. differences in FEV_1's and FVC's for the study population are included in Table IV. Table IV contains A.M. to P.M. mean differences in FEV_1's and FVC's for each of the subgroups.

Pulmonary function test results were evaluated using "paired t test" analysis of the A.M. to P.M. mean differences in FEV_1's and FVC's for each of the exposed subgroups (II through V) and for the control group (I). Refer to Table IV. Similar evaluations were performed for all symptomatic employees (subgroups II and III combined) and for all asymptomatic employees (subgroups IV and V combined). Refer to Table V. The A.M to P.M. mean differences in FEV_1's and FVC's were not significant at the 95% confidence level, except for subgroup III.

When the A.M. to P.M. mean differences in FEV_1 and FVC for subgroup III were compared with corresponding values for the control group (I) using the "student t test," a significant difference was found at the 95% confidence level.

These two statistically significant findings for subgroup III must be viewed with the knowledge that subgroup III contains only 4 individuals all of whom were transferred to new jobs because of intolerance to foaming operations. One of these individuals, believed to be exquisitely sensitive to TDI, recorded the greatest individual change in FEV_1 and FVC even though his time-weighted average exposure to TDI during the monitored shift was 0.2 $\mu g/M3$. (Refer to Table III)

Further evaluation of these pulmonary function results comparing symptomatic employees (subgroups II and III combined) with asymptomatic employees (subgroups IV and V) and each of these two combination groups with the control group (I) using the "student t test" produced no significant differences at the 95% confidence level.

b. Immunologic Assay - Serum Antibody Tests

Serum antibody tests were performed on 35 serum samples from the study population and on 47 serum from other production employees. It was hoped that these developmental tests would serve to positively identify individuals who should not be further exposed to isocyanates. The results of the serum tests (including split samples) were not entirely consistent, therefore strict interpretation of immunlogic data in the absence of other clinical findings cannot be made.

The PK (Prausnitz-Kustner) test was used to reveal the presence of reaginic antibody (IgE) indicating the capacity of an individual to react to isocyanate in an immediate manner with symptoms of asthma, hay fever, laryngospasm, etc. The PCA (passive cutaneous anaphylaxis) test was used to indicate the presence of a precipitating antibody (IgG) which in many cases appears to indicate immunity. This immunity probably is of sufficient degree to produce a protective effect, mitigating the adverse effects of an immediate type reaction. The third test, the agglutination reaction, was used to reveal the presence of complement medicated antibodies of a delayed or contact type. This reaction is sometimes associated with a delayed type allergy. The most common clinical problem associated with this form of allergy is contact dermatitis. Either isolated PK reactions or the combination of PK and PCA reactions can be significant.

Most individuals tested had either only a PCA reactive test or a PK and PCA reactive tests but with no symptoms. In only one case did an exposed worker show a reactive isolated PK test. This worker also related a history of symptoms. This latter combination of an isolated PK reactive test and symptoms strongly suggests that further exposure for this individual to isocyanates is ill advised. This individual was privately contacted and his immunologic potential explained.

In summary, the serum antibody tests revealed that many individuals have been sufficiently exposed to isocyanates to produce measurable levels of antibodies. Only one individual showed a reactive isolated PK reaction with symptoms. Several other employees were shown to have reactive PK and PCA tests but had not experienced symptoms.

Another group of individuals related histories of symptoms but tests were either non-reactive or difficult to interpret. In these cases one can only speculate that antibody levels have diminished to undetectable levels due to a lack of recent significant exposure or that possibly these individuals have developed blocking antibodies which were not detected by the test procedures.

c. Discussion and Conclusions

A number of workers were noted to be symptomatic on the day of clinical testing while airborne levels of TDI were considerably below recognized safe limits. (Refer to TableIII). These individuals may be sensitive and therefore experience mild symptomatology when exposed to low concentrations of TDI. It is not known how these individuals became symptomatic. We did discover that 9 of the 13 symptomatic employees were exposed to spills of foam material in the past and that 8 of these 9 experienced symptoms at the time of a spill. Unfortunately, we have no history as to whether the onset of symptoms coincided with the first spill, suggesting a pharmacologic overdose, perhaps sufficient to cause sensitivity. Despite the presence of symptoms on the day of testing no medically significant change in pulmonary function was found for the symptomatic group.

Objective medical evidence obtained during this evaluation suggests that several employees are adversely reacting to very low levels of TDI, but that with one exception their reactions do not include significant change in pulmonary function test results over a period of one workshift. One employee did show a significant decrement in pulmonary function, but this individual is believed to be exquisitely sensitive to TDI.

It appears that airborne levels of TDI found in this plant during this evaluation are not producing acute adverse health effects in plant employees who are not sensitive. It is not known whether chronic exposure to these levels of TDI are capable of producing sensitivity in employees or whether accelerated pulmonary function changes may be manifested after years of exposure.

It could not be disproved that the measured levels of TDI, which are believed to be representative of normal operating conditions, were responsible for the exquisite sensitization of some employees (necessitating transfer) or for the milder sensitization of other employees (as yet not transferred). Furthermore, it could not be established from this cross-sectional study, whether chronic exposures of symptomatic and asymptomatic individuals to these levels of TDI are capable of producing accelerated pulmonary function decrements after years of exposure. However, it is believe that continued exposure of symptomatic individual to these low levels of TDI is potentially hazardous to their health, in spite of the fact that acute pulmonary decrements were not observed for this group.

V. REFERENCES

1. Grim, K.E. and A.L. Linch. Recent Isocyanate-in-Air Analysis Studies. Am. Ind. Hyg. Assoc. J., Vol. 25, May-June 1965.

2. Scheel, L.D., R. Killens, and A. Josephson. Immuno-chemical Aspects of Toluene Diisocyanate (TDI) Toxicity. Am. Ind. Hyg. Assoc. J., Vol. 25, (179) 1964.

3. Criteria for a Recommended Standard.....Occupational Exposure to Toluene Diisocyanate. U.S. Department of Health, Education, and Welfare, Public Health Service, National Institute for Occupational Safety and Health, 1973.

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I. TABLES

TABLE I - TDI Air Sampling Data (Samples Collected 6/5/73)

Department No.	Sample No.	Type of Sample	Sampling Time(min)	µg[a] TDI in Sample	Concentration TDI in µg/M³
55	32	Area[b]	100	0.1	0.5*
56-Lid	12	B.Z.[c]	141	3.5	15.9**
56-Lid	13	B.Z.	141	4.0	14.2**
56-Lid	14	B.Z.	139	0.2	0.7*
56-Lid	15	Area	132	0.4	1.5
56-Lid	25	B.Z.	83	4.3	25.9**
56-Lid	26	B.Z.	81	2.2	13.6**
56-Lid	27	B.Z.	81	0.2	1.2*
56-Lid	28	Area	77	0.2	1.3*
56-Lid	29	Area	75	0.1	0.7*
73	1	B.Z.	98	0.3	1.5*
73	33	B.Z.	97	0.2	1.0*
75-A	2	B.Z.	124	2.5	10.1**
75-A	3	B.Z.	122	0.5	2.0
75-A	4	B.Z.	122	0.9	3.7
75-A	5	B.Z.	129	0.4	1.6
75-A	6	B.Z.	223	0.2	0.4*
75-A	7	B.Z.	227	1.1	2.4
75-A	8	B.Z.	214	N.D.[d]	0.0
75-A	9	B.Z.	210	0.2	0.5*
75-A	11	B.Z.	110	0.4	1.8
75-A	17	B.Z.	125	2.3	9.2
75-A	18	B.Z.	124	0.3	1.2*
75-A	19	B.Z.	124	0.8	3.2
75-A	20	B.Z.	112	0.6	2.7
75-A	22	B.Z.	111	0.7	3.2
75-A	23	B.Z.	107	0.5	2.3
75-A	24	B.Z.	97	N.D.	0.0
75-A	34	Area	98	6.2	31.6
Foam Tech.	10	B.Z.	211	0.8	1.9
Conf. Rm.	16	Area	336	0.5	0.7
Mach. Shop	21	Area	211	N.D.	0.0
Plant 2	35	Area	74	0.1	0.7*
Personnel Office	31	Area	----Broken Impinger--------		

[a] µg: 1 µg = 0.001 mg or 1,000 µg = 1 mg

[b] Area: Means that the sample was collected at a stationary location in a work area.

[c] B.Z.: Means that the sample was collected in the breathing zone of a worker.

[d] N.D.: Means that no TDI was detected in the sample.

*: TDI concentrations followed by an asterisk (*) may be interpreted as 0.0 or N.D. due to the variation seen in prepared blanks.

**: TDI concentrations followed by a double asterisk(**) came from samples collected in the breathing zones of workers operating or very near foam machines.

TABLE II - TDI Air Sampling Data (Samples Collected 6/18/73)

Department No.	Sample No.	Type of Sample	Sampling Time(min)	µg[a] TDI in Sample	Concentration TDI in µg/m³
55	102	B.Z.[b]	59	0.2	1.7*
55	122	B.Z.	183	1.9	5.2
55	147	B.Z.	238	0.8	1.7
55	106	B.Z.	214	1.0	2.3
55	144	B.Z.	181	1.2	3.3
55	175	B.Z.	60	0.4	3.3
55-Foam	118	B.Z.	126	6.9	27.4
55-Foam	130	B.Z.	155	5.8	18.7
55-Foam	161	B.Z.	149	7.3	24.3
55	119	B.Z.	185	0.2	0.4*
55	143	B.Z.	180	0.1	0.3* L
55	174	B.Z.	60	0.2	2.2
55	120	B.Z.	182	0.3	0.8
55	142	B.Z.	173	0.2	0.4* L
55	172	B.Z.	63	0.2	1.2*
55	123	B.Z.	172	0.1	0.3*
55	141	B.Z.	175	1.9	5.4
55	171	B.Z.	69	0.2	1.1*
55	124	B.Z.	230	0.4	0.9
55	159	B.Z.	110	0.1	0.5* L
55	170	B.Z.	79	0.2	0.9*
55	127	B.Z.	165	1.1	3.3
55	145	B.Z.	182	1.4	3.8
55	176	B.Z.	60	0.3	2.5
55-Foam	129	B.Z.	94	5.5	29.3
55-Foam	131	B.Z.	151	7.8	25.8
55-Foam	162	B.Z.	141	9.1	32.3
56 Chest F.	104	B.Z.	196	3.4	8.7
56 Chest F.	139	B.Z.	135	4.1	15.2
56 Chest F.	164	B.Z.	155	11.4	36.8
56 Chest F.	185	B.Z.	18	0.1	2.8*
56 Lid Foam	108	B.Z.	157	1.1	3.5
56 Lid Foam	133	B.Z.	73	1.2	8.2
56 Lid Foam	173	B.Z.	151	3.0	9.8
56 Lid Foam	177	B.Z.	89	0.7	3.9
56 Lid Foam	110	B.Z.	145	0.6	2.1
56 Lid Foam	132	B.Z.	146	1.1	3.8
56 Lid Foam	160	B.Z.	170	0.8	2.4 L
56 Lid Foam	195	B.Z.	13	0.1	3.9*

TABLE II - Continued

Department No.	Sample No.	Type of Sample	Sampling Time(min)	µg TDI in Sample	Concentration TDI in µg/M³	
56	111	B.Z.	207	0.8	1.9	
56	149	B.Z.	185	0.6	1.6	
56	179	B.Z.	82	0.1	0.6*	
56	112	B.Z.	207	0.3	0.7	
56	151	B.Z.	186	0.3	0.8	
56	181	B.Z.	72	N.D.[c]	0.0	
56	113	B.Z.	204	0.4	1.0	
56	150	B.Z.	184	0.2	0.5*	L
56	180	B.Z.	77	0.3	1.9	
56 Chest F.	126	B.Z.	126	9.8	39.9	
56 Chest F.	138	B.Z.	145	7.9	27.2	
56 Chest F.	163	B.Z.	174	6.9	19.8	L
75-A Foam	107	B.Z.	163	9.6	29.4	
75-A Foam	134	B.Z.	162	11.7	36.1	
75-A Foam	165	B.Z.	127	5.0	19.7	
75-A Foam	186	B.Z.	72	5.2	36.1	
75-A	114	B.Z.	147	0.5	1.7	
75-A	137	B.Z.	162	0.6	2.0	
75-A	168	B.Z.	200	0.3	0.8	
75-A	115	B.Z.	190	0.3	0.8	L
75-A	153	B.Z.	216	0.8	2.0	L
75-A	192	B.Z.	101	1.0	5.0	
75-A Foam	117	B.Z.	143	2.2	6.7	
75-A Foam	136	B.Z.	161	2.6	6.4	
75-A Foam	167	B.Z.	202	1.2	3.0	
75-A Foam	125	B.Z.	127	2.6	10.2	
75-A Foam	135	B.Z.	161	3.3	10.2	
75-A Foam	166	B.Z.	206	1.7	4.1	
75-A	128	B.Z.	183	5.0	13.7	
75-A	155	B.Z.	193	1.0	2.5	
75-A	193	B.Z.	103	1.0	4.9	
75-A	121	B.Z.	203	1.5	3.7	
75-A	154	B.Z.	188	0.5	1.3	L
75-A	191	B.Z.	102	0.5	2.5	
74	105	B.Z.	244	0.6	1.2	
74	152	B.Z.	244	0.5	1.0	

TABLE II - Continued

Department No.	Sample No.	Type of Sample	Sampling Time(min)	µg TDI in Sample	Concentration TDI in µg/M³	
WS	109	B.Z.	169	1.0	3.0	L
WS	140	B.Z.	166	4.8	14.5	
WS	169	B.Z.	118	1.2	5.1	
WS	100	B.Z.	79	1.1	7.0	L
63	101	B.Z.	298	0.3	0.5	
63	156	B.Z.	293	0.2	0.3*	
63	103	B.Z.	275	0.3	0.5	
63	158	B.Z.	290	N.D.	0.0	
52	116	B.Z.	188	0.3	0.8	
52	148	B.Z.	183	N.D.	0.0	
52	178	B.Z.	113	0.2	0.9*	
Conf. Rm.	500A	Area[d]	484	0.2	0.2*	
Personnel Office	500B	Area (Impinger solution carryover during sampling)	467	0.7	0.7	

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[a]ug: 1 µg = 0.001 mg or 1,000 µg = 1 mg

[b]B.Z.: Means that the sample was collected in the breathing zone of a worker.

[c]N.D.: Means that no TDI was detected in the sample.

[d]Area: Means that the sample was collected at a stationary location in a work area.

*: TDI concentrations followed by an asterisk (*) may be interpreted as 0.0 or N.D. due to the variation seen in prepared blanks.

L: TDI concentrations followed by an "L" are thought to be somewhat low. This is due to the fact that the vacuum pump pulling air through the impinger was observed to be running at a decreased flow rate during part of the sampling time. This error is not considered critical since flow rate checks were made approximately every 30 minutes.

Note: Sample results in this Appendix are grouped by employee. In other words, each group of samples represents one employee's exposure.

TABLE III: Individual time-weighted-average exposures; changes in pre- and post-shift pulmonary function test results and symptoms reported by employes on June [illegible] 1973

Group I control (7)	Sex	Dept.	Past Exposure to Spills	Symptoms with Spill	Smoker	Ex-Smoker	µg/M³-TDI Time-Weighted Average Exposure	Change FEV1	Change FVC	Symptoms Before Shift	Symptoms After Shift	Symptoms Ever After Shift
1	M	WS	NO		NO	YES	0.1	-.14	+.05			
2	F	WS	NO		NO	NO	0.1	-.14	-.25	a		
3	F	WS	NO		NO	YES	0.1	-.12	+.02			
4	F	WS	NO		NO	YES	0.1	+.10	+.11			
5	M	WS	YES	c	YES	----	0.1	+.05	+.02	a		
6	M	WS	NO		NO	NO	0.1	-.15	-.24			
7	F	WS	NO		NO	NO	0.1	-.03	+.02			
GROUP II symptomatic (9) Moderate Exposure												
8	M	55	NO		YES	----	2.8	-.16	-.06		a,c	
9	F	56	NO		YES	----	1.0	+.26	+.33	b	a,b,c	a,b,c
10	F	56	YES		NO	NO	0.6	-.12	-.17	a	a	a
11	M	75	YES	b,c	NO	YES	2.2	-.09	-.15	d,e	a,d,e,	a,b
12	F	75	NO		YES	----	7.7	+.07	+.08		a,b,c,e	a
13	F	55	YES	a,b,c	YES	----	0.7	-.19	-.10	a,d	d	a,b,c,d,e
14	F	55	YES		NO	NO	23.2	+.32	-.17		b,c,e	
15	F	55	NO		NO	NO	0.8	+.02	-.05	b,c		a
16	M	WS	YES	a,b,c	NO	NO	7.7	+.03	-.10	a	a,b,c	a,b,c,e
GROUP III symptomatic (4) Low Exposure (Transferred)												
17	M	63	YES	a,b,c	NO	NO	0.4	+.11	-.15	a,b,c	a,b,c,e	a,b,c,d
18	M	63	YES	a,b,c	NO	NO	0.2	-.53	-.61	a	b,c,e	a,b,c,d,e
19	M	74	YES	a,b,c	YES	----	1.1	-.09	-.09		a,e	a
20	F	52	YES	a,b,c	NO	NO	0.5	-.05	-.40	a,b,c d,e	a,d,e	a,c,d,e
GROUP IV asymptomatic (8) Moderate Exposure												
21	M	56	YES		YES	----	18.9	+.06	-.04		a	a
22	M	75	NO		YES	----	30.0	-.14	-.08		a	
23	M	56	YES	b,c	YES	----	6.3	+.02	+.14	a	a	a
24	F	56	NO		NO	NO	2.8	-.06	+.05	a	a	
25	M	75	NO		NO	NO	6.3	.00	-.10	a	a	a
26	F	55	YES		NO	YES	29.0	-.02	-.04	a		
27	F	75	NO		YES	----	6.2	-.12	-.05	a	a,c	a
28	F	73	NO		YES	----	0.5**	+.07	-.04			
GROUP V asymptomatic (8) Low Exposure												
29	M	55	YES		YES	----	3.0	-.04	-.17			
30	F	55	YES		YES	----	2.6	-.01	-.01	a	a	b
31	F	56	NO		NO	NO	1.6	-.05	-.03		a,b,c	
32	M	75	NO		YES	----	1.4	.00	-.11	a	a	a
33	F	75	NO		YES	-----	2.5	-.04	-.12	a	a	
34	M	56	YES		NO	YES	27.9	-.01	-.08	a		
35	M	55	NO		YES	----	3.4	-.06	-.05			
36	F	55	YES		YES	----	0.6	-.10	-.06	b		a,b,e

*Symptoms: a = Minor eye, nose, or throat irritation
b = Coughing
c = Chest tightness, soreness, or heaviness
d = Wheezing or whistling
e = Shortness of breath

**Employee refused to wear sampling equipment on day of testing. Exposure was estimated from air samples gathered in this work area on a previous day

TABLE IV Pulmonary Function Test Results with Time-Weighted-Average Exposure to TDI.

	Difference (AM to PM)		Paired t Test	Time-Weighted-Average Exposure to TDI (mean) ug/M^3
	Range	Mean		
Group I control (7)				
FEV_1 (liters)	-.15 to +.12	-.06	NS (p = .164)	0.0 to 0.2
FVC (liters)	-.25 to +.05	-.04	NS (p = .507)	(0.1)
Subgroup II - symptomatic (9) Moderate Exposure				
FEV_1 (liters)	-.19 to +.32	+.016	NS (p = .802)	0.6 to 23.2
FVC (liters)	-.17 to +.33	-.04	NS (p = .440)	(5.2)
Subgroup III - symptomatic (4) Low Exposure - Transferred				
FEV_1 (liters)	-.53 to +.11	-.16	S (p = .024)	0.4 to 1.1
FVC (liters)	-.61 to -.09	-.31	S (p = .004)	(0.55)
Subgroup IV - asymptomatic (8) Moderate Exposure				
FEV_1 (liters)	-.14 to +.07	+.02	NS (p = .417)	6.2 to 30.0
FVC (liters)	-.10 to +.14	-.02	NS (p = .492)	(17.0)
Subgroup V - asymptomatic (8) Low Exposure				
FEV_1 (liters)	-.10 to +.01	-.04	NS (p = .383)	0.6 to 3.0
FVC (liters)	-.17 to -.01	-.08	NS (p = .080)	(2.2)

NS = not significant at the 95% confidence level
S = significant at the 95% confidence level

TABLE V - Paired t Test Evaluation of Pulmonary Function Test Results

	Mean Difference AM to PM (liters)	Paired t Test
Group I - control (7)		
FEV_1	-.06	NS (p = .164)
FVC	-.04	NS (p = .507)
Subgroups II & III (13) All Symptomatic		
FEV_1	-.03	NS (p = .600)
FVC	-.13	NS (p = .061)
Subgroups IV & V (16) All Asymptomatic		
FEV_1	-.03	NS (p = .059)
FVC	-.03	NS (p = .106)

NS = not significant at the 95% confidence level