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RUST ENGINEERING/CHAMPION INTERNATIONAL
QUINNESEC, MICHIGAN

NIOSH INVESTIGATORS:
RONNIE J. CORNWELL,CIH
JOHN PARKER, M.D.

I. SUMMARY

On October 27, 1989, the Division of Respiratory Disease Studies, National Institute for Occupational Safety and Health (NIOSH), received a request for a health hazard evaluation from the Building and Construction Trades Department. NIOSH was requested to evaluate possible health effects due to chlorine dioxide emissions from the Champion International Corporation (CIC) pulp mill in Quinnesec, Michigan. The request stressed that several construction workers employed by Rust Engineering adjacent to the Quinnesec operation had reported health concerns they felt were due to past exposure to toxic chemicals and exhaust gases from the pulp mill.

NIOSH investigators conducted an initial site visit and walk-through on November 1 and 2, 1989. A medical survey was conducted on December 11 through 14, 1989.

Two hundred fifty-two people completed a questionnaire and performed a pulmonary function test. For analyses, they were divided into groups according to their perceived exposure and nonexposure. Acute symptoms were reported more frequently among those workers who felt they had been exposed to chemical fumes. Shortness of breath was more common among workers with reported perceived exposures. No difference was seen in the prevalence of chronic cough with perceived exposure. Wheeze was reported by more workers who indicated an exposure only in the nonsmoking group.

There did not appear to be an effect of perceived exposure group on pulmonary function, however a smoking effect was seen when looking at mean FEV_1, mean FEV_1/FVC ratio, and the mean difference of the FEV_1/FVC ratio from Knudson's predicted values. Thirty-seven subjects showed an obstructive ventilatory function and ten had a restrictive pattern. Without baseline spirometry to compare with these results, however, we cannot say when these impairments occurred or whether they were present prior to working at the Champion Mill site.

All parties concerned have acknowledged that toxic process gases were released on more than one occasion at the mill in the vicinity of the construction work, however, there is no way to determine at this time the type and severity of any individual worker's exposure. Forty-seven subjects showed an abnormal ventilatory function when compared to Knudson's predicted values, but without baseline spirometry to compare with these results, we cannot say when these impairments occurred or whether they were present prior to working at the Champion Mill site. It is recommended that health and safety procedures be established and enforced to reduce future possible exposures and injuries. In particular, the requirements of the Hazard Communication Program of the State of Michigan needs to be effectively implemented.

KEYWORDS: SIC Code 1541: (Construction) pulp mill, hydrogen sulfide, organic mercaptans, dimethyl sulfide, dimethyl disulfide, sulfur dioxide, chlorine,

chlorine dioxide.

II. INTRODUCTION

On November 1 and 2, 1989, a NIOSH physician, industrial hygienist, and pulmonary function technician met with CIC and Rust officials and union officials representing Rust employees and conducted a walk-through survey of the pulp mill and construction site. During the November visit, health and safety records and procedures of both companies were reviewed, and spirometry testing was done on 29 construction workers identified by the union as having respiratory health concerns they felt were due to exposures at the construction site.

On December 11 through 14, 1989, a medical survey was conducted. It consisted of a Medical Research Council (MRC) questionnaire on respiratory symptoms, smoking habits, demographic information and work history; and pulmonary function tests. Employees previously identified from first aid records with respiratory complaints were asked to report for the examination.

Individual results were mailed to participants in November 1989 and January 1990. An interim report summarizing the walk-through survey with some initial recommendations was sent out on September 6, 1990. This report offers findings on the medical survey conducted in December, 1989.

III. BACKGROUND

Champion International Corporation, Quinnesec Mill is a pulp mill located in Quinnesec, Michigan. It employs approximately 400 individuals who are not represented by a union. The mill employs the kraft or sulfate process of pulp production.

Chipped wood is digested with steam in tanks using a solution of sodium sulfide and sodium hydroxide (white liquor). Relief gases periodically vent from the digester to relieve the pressure buildup. When the digestion is complete, the load is dumped to a blow tank and the gases vented from the pulp and digestion liquid. The spent cooking liquid (black liquor) is drained off, and the pulp is washed, screened, and bleached. The chemicals are recovered. The chemicals are dissolved in water in the smelt tank, and quicklime is added to convert the sodium to sodium hydroxide. The calcium carbonate formed is converted to calcium oxide in the lime kiln. This product is slaked with water to produce calcium hydroxide for the causticizer.

Bleaching of the pulp is accomplished with chlorine, followed by extraction with sodium hydroxide, then calcium or sodium hypochlorite, and finally a chlorine dioxide treatment. The major gases released into the atmosphere from the overall process include hydrogen sulfide, organic mercaptans, dimethyl sulfide, dimethyl disulfide, sulfur dioxide, chlorine, and chlorine dioxide. These gases are normally released in small quantities into the atmosphere through exhaust stacks into nonworker occupied areas outside the mill.

RUST Engineering had been contracted by Champion to construct a paper mill addition to the pulp mill. The paper mill construction began in June 1988. RUST Engineering employed approximately 1600 workers on site in the summer and fall of 1989. These workers were represented by various

construction unions. Construction crews were reportedly exposed to waste gases during mill upset conditions in the summer of 1989, prompting the request for a health hazard evaluation. CIC later instituted engineering controls to insure that the effluents would not be exhausted into areas occupied by the construction workers.

CIC and RUST Engineering retained consulting firms to conduct industrial hygiene/environmental monitoring at the pulp mill/construction site. The consulting firms conducted environmental surveys during September and October, 1989. Both consultants concluded that there were several sources for a variety of potentially hazardous chemical exposures, but that under normal working conditions the exposures to workers would be expected to be below established exposure limits. The consulting firm retained by RUST identified two major problem areas: an inadequate hazard communication program and the absence of a medical surveillance program for RUST Engineering employees.

IV. METHODS

NIOSH offered medical examinations (medical questionnaire and spirometry) to those individuals who had been identified from the first aid logs with any respiratory complaints. A large conference room on site was provided for the examinations. After each worker received an explanation of the tests to be performed and gave their consent to participate, each volunteer had his height and weight measured, performed spirometry, and was administered a questionnaire.

A modified version of the Medical Research Council (MRC) questionnaire on respiratory symptoms, supplemented with questions concerning smoking habits, demographic information, job information, and possible occupational exposures, was administered by trained interviewers (Appendix I). In addition, participants were asked to classify the frequency of ten acute symptoms experienced at work as "never/rarely", "sometimes", or "often". For purposes of this analysis, "chronic cough" was defined as a cough on most days for as much as three months each year. "Wheeze" was positive if the subject answered yes to "Does your chest ever sound wheezing or whistling?" A subject was considered to have "shortness of breath" if he/she became short of breath when walking with other people of the same age on level ground.[1] The participants were divided into three groups according to their perceived exposure. Each worker's grouping was determined by a series of questions in the questionnaire (Appendix I, Section E). The subjects in the "YES" group felt that during work he/she had been exposed to irritaing gas or chemical fumes (question E. 1) and provided a date of exposure within one year of the survey and answered "yes" to at least one of the following questions: Did you have to leave work?, Did you seek first aid?, Did you seek medical care?, Did you go to the emergency room?, or Were you hospitalized? The subjects in the "NO" group answered that during work they had not been exposed to irritating gas or chemical fumes. The "POSSIBLE" subjects felt that they had been exposed during work to irritating gas or chemical fumes, but they did not indicate that they had taken any of the actions listed.

Spirometry was performed using a dry rolling-seal spirometer interfaced to a computer terminal with tape and disk storing capabilities. At least five maximal expiratory maneuvers were recorded for each person. All values were corrected to body temperature, and ambient pressure, saturated with water vapor (BTPS). The largest forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) were selected for analysis regardlesss of the curves on which they occurred. The spirometer and methods met the quality control recommendations of the American Thoracic Society (ATS).[2] Percent predicted pulmonary function values were calculated using Knudson's predictive equations.[3] The observed lung volume or flow rate converted to BTPS was divided by the predicted value and multiplied by 100 to obtain the percentage. In the absence of airway obstruction, a restrictive ventilatory impairment is present when the FVC is less than 80% of predicted. An obstructive ventilatory impairment is defined as an FEV_1 of less than 80% of predicted or an FEV_1/FVC ratio less than 70%. However, an occasional individual may be slightly below the normal value and not have a respiratory disorder.

Medical records were collected on 78 employees who had visited the local hospital or physicians. Some of the reports were for employment physicals and a few were for minor nonrespiratory injuries. For the most part, the reports were on people who felt they had been exposed to chemicals at work and reported to the hospital or doctor's office for an examination. Most contained a pulmonary function report and one half had a chest x-ray interpretation. These records were reviewed and a synopsis will be given in the medical discussion.

V. TOXICOLOGY

Hydrogen sulfide gas is a rapidly acting systemic poison which causes respiratory paralysis with consequent asphyxia at high concentrations. It irritates the eyes and respiratory tract at low concentrations. Inhalation of high concentrations of hydrogen sulfide, 1000 to 2000 ppm, may cause coma after a single breath and may be rapidly fatal; convulsions may also occur. Exposure to concentrations of hydrogen sulfide above 50 ppm for one hour may produce acute conjunctivitis with pain, lacrimation, and photophobia; in severe form this may progress to keratoconjunctivis and vesiculation of the corneal epithelium. In low concentrations, hydrogen suldife may cause headache, fatigue, irritability, insomnia, and gastrointestinal disturbances; in somewhat higher concentrations it affects the central nervous system, causing excitement and dizziness. Prolonged exposure to 250 ppm of hydrogen sulfide may cause pulmonary edema. Prolonged exposure to concentrations of hydrogen sulfide as low as 50 ppm may cause rhinitis, pharyngitis, bronchitis, and pneumonitis. Repeated exposure to hydrogen sulfide results in increased susceptibility, so that eye irritation, cough, and systemic effects may result from concentrations previously tolerated without any effect. Rapid olfactory fatigue can occur at high concentrations.[4]

Mercaptan compounds are typically flammable liquids except methyl mercaptan which is a gas. A strong unpleasant odor is the most characteristic property of mercaptans and may be detected at very low levels, i.e. less than 0.5 ppm. They are used as gas odorants to serve as a warning property for hazardous odorless gases. Mercaptans are irritating to the skin, eyes, and mucous membranes of the upper respiratory tract. Liquid may cause contact dermatitis and vapor may cause irritation to the nose and throat. Methyl mercaptan acts toxicologically like hydrogen sulfide and may depress the central nervous system resulting in respiratory paralysis and death. Victims who survive severe exposures may suffer from headache, dizziness, staggering gait, nausea, and vomiting.

Respiratory tract irritation may lead to pulmonary edema and possibly renal and hepatic damage. The above effects are based primarily on animal experimentation. In a recent case of acute methyl mercaptan exposure, a worker developed acute anemia and methemoglobinemia 24 hours following coma.[5]

Dimethyl sulfide is a colorless liquid with a disagreeable odor. The sulfide appears to be of low toxicity when inhaled and in contact with the skin, but is a moderate eye irritant.[6]

Dimethyl disulfide is an odorous liquid often accompmanying the other C-1 and C-2 sulfur compounds. Disulfides occur in the atmosphere, stemming from livestock excretions, human bacteria, improperly stored fish and industrial processes. Normally it is photochemically oxidized by ozone. It is of moderate toxicity. In the mammal, it is capable of inhibiting erythrocyte carbonic anhydrase.[7]

Sulfur dioxide is a colorless gas at ambient temperatures with a characteristic strong suffocating odor. It is soluble in water and organic solvents. It is used in the manufacture of many products and in the bleaching of wood pulp. It is also a by-product of paper manufacturing. It enters the body by inhalation of the gas or by direct contact of the gas or liquid phase on the skin and mucous membranes. Gaseous sulfur dioxide is particularly irritating to mucous membranes of the upper respiratory tract. Chronic effects include rhinitis, dryness of the throat, and cough. Conjunctivitis, corneal burns, and corneal opacity may occur following direct contact with liquid. Acute over-exposure may result in death from asphyxia. Survivors may later develop chemical bronchopneumonia with bronchiolitis obliterans. Bronchoconstriction with increased pulmonary resistance, high-pitched rales, and a tendency to prolongation of the expiratory phase may result from moderate exposure, though bonchoconstriction may be asymptomatic. The effects on pulmonary function are increased in the presence of respirable particles. Chronic exposure may result in nasopharyngitis, fatigue, altered sense of smell, and chronic bronchitis symptoms such as dyspnesa on exertion, cough, and increased mucous excretion. Transient stimulation of erythropoietic activity of the bone marrow has been reported. Slight tolerance, at least to the odor threshold, and general acclimatization are common. Sensitization in a few individuals, particularly young adults may also develop following repeated exposures. Animal experimentation has also indicated that sulfur dioxide may be a possible co-carcinogenic agent.[8]

Chlorine gas is a severe irritant of the eyes, mucous membranes, and skin. The odor threshold for chlorine has been reported at various concentrations and appears to be between 0.02 and 0.2 ppm for most subjects. Nasal irritation and coughing occur at about 0.5 ppm. There is evidence that olfactory fatigue develops at these low concentrations and that some tolerance is built up in chronic industrial exposures. A report in the literature of an accidental exposure of humans to unmeasured but high concentrations for a brief period caused burning of the eyes with lacrimation, burning of the nose and mouth with rhinorrhea, cough, choking, choking sensation and substernal pain. These symptoms were frequently accompanied by nausea, vomiting, headache, dizziness, and sometimes syncope. Of 33 of the victims who were hospitalized, all suffered tracheobronchitis, 23 progressed to pulmonary edema, and of those, 14 to pneumonitis. Respiratory distress and substernal pain generally subsided within the first 72 hours; cough increased in frequency and severity after 2 to 3 days and became productive of thick mucopurulent sputum; cough disappeared by the end of 14 days. Prolonged or repeated exposure to 5 ppm may cause respiratory complaints, corrosion of the teeth, and inflammation of the mucous membranes of the nose. It has been reported that chronic exposure may increase susceptibility to respiratory infections. In high concentrations, chlorine irritates the skin and causes sensations of burning and prickling, inflammation, and vesicle formation. Liquid chlorine causes eye and skin burns on contact.[9]

Chlorine dioxide gas is a severe respiratory and eye irritant. Delayed deaths occurred in animals after exposure to 150 to 200 ppm for less than 1 hour. Rats repeatedly exposed to 10 ppm died after 10 to 13 days of exposure; there was nasal and ocular discharge and dyspnea; autopsy revealed purulent bronchitis. Exposure of a worker to 19 ppm for an

unspecified time period was fatal. Repeated acute exposure of workers to undetermined concentrations is stated to have caused eye and throat irritation, nasal discharge, cough, wheezing, bronchitis, and delayed onset of pulmonary edema. Repeated exposure may cause chronic bronchitis.[10]

VI. RESULTS AND DISCUSSION

A. Environmental

The following observations are based on the walk-through survey, discussions with RUST employees, CIC and RUST officials, review of CIC and RUST health and safety procedures, and review of RUST records of injuries and illnesses.

OBSERVATIONS

1. RUST Construction workers began reporting chemical odors and chemical exposures in May 1989.

2. The work area of most concern (most reports of odors and exposures) was the construction site outside and adjacent to the southern side of the mill (lime kiln area).

3. It was evident to the NIOSH survey team that RUST employees had not received appropriate health and safety training and were not aware of the mill processes and the potential hazardous chemical exposures. CIC has a well established health and safety program for the mill employees. The mill employees are informed about the mill processes, potential dangers, safety precautions, and emergency procedures. Prior to the construction, CIC provided RUST's safety department information about the potential exposures in the mill and offered to provide the same type of safety training for the construction workers as they provide their mill employees. RUST reportedly declined the offer by CIC to provide training and NIOSH learned that the health and safety information provided RUST management was never disseminated to the workers.

4. RUST Engineering hired a consulting firm to provide health and safety hazard communication training for its construction workers. The training is important but if safety procedures and hazard communication requirements are not enforced by management there will continue to be unanticipated exposures.

For example, review of RUST's first aid log covering a 6-week period, November 1, 1989 to December 12, 1989, indicated there were approximately 40 eye injuries reported. This is highly unusual especially since all workers are "required" to wear safety glasses with side shields. It appears that safety procedures are not being enforced. Also, during our worker interviews, no workers reported the use of mandatorily issued disposable mouth-bite respirators, which are to be used to evacuate the work area in case of accidental releases, even though they thought possible gaseous overexposures were occurring.

5. The pulp mill has sensors and alarms to alert personnel of chemical leaks. The detectors appeared to be properly located and are calibrated monthly and checked electrically approximately every two weeks. RUST construction employees are not normally in the operational areas where leaks triggering these detectors might occur. Contract workers must be informed of the proper precaution to take when these alarms sound.

B. Medical

Prior to the medical survey, NIOSH personnel obtained and reviewed the OSHA first aid logs to identify all workers who had reported with any respiratory symptoms. Two hundred thirty-seven workers were identified and targeted for inclusion in the medical survey. Once on site, there were other workers who reported for the exam either self or supervisor-referred. There was also an attempt made to select a random sample of workers from the various trade groups working on site. A total of 253 people were examined. Of these, 140 had previously been identified as being symptomatic through the OSHA logs. Seventy-nine fell into the referred group and 34 were in the randomly selected group.

One of the workers did not complete the questionnaire and was excluded from the analyses. Two hundred forty-three of the participants were male and nine were female. Two hundred thirty-seven (94%) were white (one of Hispanic origin), one (<1%) black, and fourteen (6%) were American Indian. Sixty-one workers reported never having smoked cigarettes, while 114 were current smokers, and 77 were former smokers. The mean age of the group was thirty-eight.

Since the chemical exposures were unanticipated and had occurred several weeks before our visit, there were no definitive records of the exposures or which workers were exposed. Thus, we divided the participants into three groups according to their perceived exposure. When divided this way, there were 128 or 51% in the "YES" group, 71 (28%) in the "POSSIBLE" group, and 53 (21%) in the "NO" group (TABLE I).

1. Questionnaire

Chronic symptoms by perceived exposure group and smoking status are shown in Table II. There appeared to be no difference in the prevalence of chronic cough with perceived exposure within the smoking categories. Shortness of breath was more common among workers with reported exposures. Wheeze was reported by more workers who indicated an exposure in the nonsmoking group. When asked about acute symptoms related to their work, the responses for "Often" were quite similar among all groups for cough, headache, and fever. The remainder of the acute symptoms were reported more frequently among the "YES" group (TABLE III).

2. Spirometry

Mean pulmonary function measures are reported by smoking status and perceived exposure in TABLE IV. Perceived exposure had no apparent relationship on

mean FVC, FEV_1 or FEV_1/FVC ratio. Differences from Knudson's predicted values are shown in TABLE V. There are no obvious differences along the perceived exposure gradient within each smoking category. Thirty-seven subjects showed an obstructive ventilatory function and ten had a restrictive pattern (TABLE VI). However, without baseline spirometry to compare with these results, we cannot say when these impairments occurred or whether they were present prior to working at the Champion Mill site. In another study of four young healthy adults who were studied physiologically after accidental inhalation of chlorine gas, all lung function impairment was temporary and cleared entirely within one month.[11]

3. Medical Records

According to the 78 medical records, the majority of suspected chemical exposures occurred during September and October, 1989. The workers sometimes waited a few days before seeing a physician, but this would not be unexpected in that some symptoms of toxic gas exposures do not appear until a few days later--this is particularly true of chlorine dioxide. The most frequently recorded diagnosis was bronchitis with 23 cases, fifteen were listed as having an inhalational injury, and there were 5 cases of asthma. It is not known when asthma developed in these subjects though it is known that at least one had asthma previous to this.

The physical examination revealed most to have normal chest sounds. There were ten cases with chest wheezing and five with rales.

All but six had performed a pulmonary function test. The physician reported 22 as having obstructive lung disease, however when the same ITS criteria used by NIOSH was applied to the results, only 7 cases were identified. One case was reported as restrictive lung disease. NIOSH performed spirometry on 51 of the individuals for whom medical records were obtained. In this group, six were found with obstructive lung function and two with restrictive function.

Thirty-nine of the individuals had chest x-rays taken. Diagnoses reported in these workers included three with emphysema, two with atelectasis and one case of fibrosis. NIOSH personnel did not review these films.

VII. CONCLUSIONS

It has been acknowledged by all parties that toxic process gases were released on more than one occasion at the mill in the vicinity of the construction work. There is no way at this time to determine the type and severity of any individual worker's exposure.

Most acute symptoms were reported more often among those subjects with perceived exposure. The reporting of chronic symptoms was less clearly associated with perceived exposure. Shortness of breath was reported more often in workers with perceived exposure, while wheeze was reported more only in nonsmokers. There tended to be a high prevalence of wheezing among all groups of workers, whether this indicates that workers in the so-called nonexposed group had been exposed without their knowledge is unknown.

There did not appear to be a relationship on pulmonary function from perceived exposure, but the NIOSH tests were done about two months after the exposures. Of the workers tested, 14.7% showed an obstructive disease pattern as compared to 8.1% in a group of nonexposed blue-collar workers.

VIII. RECOMMENDATIONS

1. RUST Engineering should include an industrial hygienist in its safety department.

2. Establish and maintain a health and safety/hazard communication training program for Rust employees. This construction site is located in an Occupational Safety and Health Administration approved state-plan state. Therefore, RUST must comply with the Hazard Communication requirements of the state. The state requirements are "at least as effective" as the federal rule (29 CFR 1910, 1200), but they may differ in some respects. For specific Michigan requirements, contact Michigan Department of Labor, 309 N. Washington, P.O. Box 30015, Lansing, Michigan 48909 (517/373-9600).

3. RUST Engineering should enforce its health and safety requirements.

4. Improve health and safety communication between RUST Engineering and CIC.

5. Rust Engineering needs to establish a health surveillance program for its employees, particularly when those employees have a potential for respiratory exposures to hazardous gases and dusts. The following is recommended:

--A complete history and physical examination to detect pre-existing conditions that might place the exposed employee at increased risk, and to establish a baseline for future health monitoring. The examination should include the eyes, teeth, respiratory tract, and cardiac status. The skin should be examined for evidence of chronic disorders. Simple tests of olfactory ability should be carried out.

--A 14" x 17" chest roentgenogram.

--Pulmonary function testing to measure FVC and FEV_1.

The aforementioned medical examinations should be repeated on an annual basis, except that an x-ray is considered necessary only when indicated by the results of pulmonary testing, or by signs and symptoms of respiratory disease.[4-10]

IX. REFERENCES

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X. AUTHORSHIP AND ACKNOWLEDGEMENTS

Report prepared by: Elizabeth B. Knutti, R.N.

Statistical analysis by: Kathleen B. Kinsley

Originating Office: Respiratory Disease Hazard Evaluations and Technical Assistance Program
Division of Respiratory Disease Studies, NIOSH
Morgantown, West Virginia

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Copies of this report have been sent to:

1. Rust Engineering
2. Champion International Corporation
3. Building and Construction Trades Department
4. NIOSH Regional Office
5. OSHA

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

TABLE I

DEMOGRAPHIC CHARACTERISTICS BY PERCEIVED EXPOSURE GROUP

Rust Engineering
Quinnesec, MI
December 11-14, 1989
RDHETA 90-030

	"Yes" N=128 Mean	SD	"Possible" N=71 Mean	SD	"No" N=53 Mean	SD
Age	37	10.6	40	10.5	39	12.4
Height (In)	69	2.6	70	2.4	69	2.9
	N	%	N	%	N	%
Sex						
Male	122	95	71	100	50	94
Female	6	5	0	0	3	6
Smoking Status						
Never Smoker	28	22	16	22	17	32
Former Smoker	40	31	24	34	13	25
Current Smoker	60	47	31	44	23	43

TABLE II

PREVALENCE OF CHRONIC SYMPTOMS REPORTED BY SMOKING STATUS AND PERCEIVED EXPOSURE GROUP

Rust Engineering
Quinnesec, MI
December ll-l4, l989
RDHETA 90-030

	Never Smoker		Former Smoker		Current Smoker	
	N	% AFFECTED	N	% AFFECTED	N	% AFFECTED
Chronic Cough						
"Yes"	5/28	18	8/39	2l	25/60	42
"Possible"	4/l6	25	2/24	8	l4/3l	45
"No"	3/l7	l8	2/l3	l5	l0/22	45
Wheeze						
"Yes"	l3/28	46	22/39	56	44/60	73
"Possible"	6/l6	38	l3/24	54	l7/3l	55
"No"	4/l7	24	6/l3	46	l6/22	73
Shortness of Breath- Grade II or Higher						
"Yes"	6/28	21	l0/39	26	l6/60	27
"Possible"	2/l6	l2	7/24	29	7/3l	23
"No"	2/l7	l2	l/l3	8	3/22	14

TABLE III

PREVALENCE OF JOB RELATED ACUTE SYMPTOMS
REPORTED "OFTEN" BY PERCEIVED EXPOSURE GROUP

Rust Engineering
Quinnesec, MI
December 11-14, 1989
RDHETA 90-030

SYMPTOMS	"YES" N=128		"POSSIBLE" N=71		"NO" N=53	
	Often %	N	Often %	N	Often %	N
Cough	34	27	15	21	12	23
Tight/Constricted Chest	22	17	6	8	1	2
Chest Wheezing/Whistling	19	15	7	10	1	2
Difficult/Labored Breathing	19	15	6	8	1	2
Nose Tickled/Irritated/Sneezing	39	30	14	20	7	13
Eyes Itch/Burn/Tear	21	16	9	13	3	6
Sore Throat	32	25	8	11	8	15
Headache	22	17	11	15	6	11
Fever	3	2	2	3	0	0
Joint Pain/Muscle Aches	21	16	16	23	2	4

TABLE IV

FVC, FEV_1, AND FEV_1/FVC RATIO BY PERCEIVED EXPOSURE GROUP AND SMOKING STATUS

Rust Engineering
Quinnesec, MI
December 11-14, 1989
RDHETA 90-030

	Never Smoker N=61		Former Smoker N=77		Current Smoker N=114	
	Mean	SD	Mean	SD	Mean	SD
FVC(ℓ)						
"Yes"	5.35	0.80	5.00	0.78	5.13	0.90
"Possible"	5.59	0.95	4.91	0.72	5.22	0.82
"No"	5.26	0.80	5.10	1.03	4.86	0.81
FEV_1(ℓ)						
"Yes"	4.38	0.71	3.81	0.77	3.95	0.75
"Possible"	4.44	0.81	3.84	0.66	4.02	0.75
"No"	4.21	0.59	3.85	0.90	3.62	0.84
FEV_1/FVC (%)						
"Yes"	81.7	4.9	76.1	8.6	77.1	7.1
"Possible"	79.5	5.8	78.2	6.1	77.0	7.5
"No"	80.3	5.3	75.3	12.6	74.2	11.0

TABLE V
PERCENT AND ABSOLUTE DIFFERENCES FROM PREDICTED FOR FVC, FEV_1 AND RATIO BY PERCEIVED EXPOSURE GROUP AND SMOKING STATUS

Rust Engineering
Quinnesec, MI
December 11-14, 1989
RDHETA 90-030

	Never Smoker N=61		Former Smoker N=77		Current Smoker N=114	
	Mean	SD	Mean	SD	Mean	SD
*Percent of Predicted - FVC						
"Yes"	109.2	13.6	106.4	15.7	106.3	14.9
"Possible"	112.2	17.8	104.1	14.5	105.4	11.2
"No"	104.7	15.6	107.6	13.0	106.1	14.3
*Percent of Predicted - FEV_1						
"Yes"	106.7	13.0	97.9	16.6	98.9	16.4
"Possible"	107.2	15.2	99.5	17.1	98.2	14.0
"No"	101.1	15.6	99.0	19.5	95.1	17.3
+Absolute Difference from Predicted - FVC(ℓ)						
"Yes"	0.41	0.64	0.26	0.70	0.28	0.71
"Possible"	0.59	0.87	0.16	0.65	0.26	0.57
"No"	0.16	0.69	0.39	0.61	0.25	0.66
+Absolute Difference from Predicted - FEV_1(ℓ)						
"Yes	0.25	0.53	-0.09	0.63	-0.06	0.64
"Possible"	0.29	0.62	-0.05	0.64	-0.07	0.57
"No"	-0.03	0.59	-0.01	0.63	-0.20	0.70
+Absolute Difference from Predicted - FEV_1/FVC (%)						
"Yes"	-2.0	4.4	-6.5	7.9	-5.9	6.8
"Possible"	-3.5	5.6	-3.9	6.0	-5.8	6.9
"No"	-2.9	4.9	-6.8	12.3	-8.8	10.5

*Knudson's Prediction Formulae Were Used
+Difference = Actual-Predicted

TABLE VI

OBSTRUCTIVE AND RESTRICTIVE DISEASE BY PERCEIVED EXPOSURE GROUP AND SMOKING STATUS

Rust Engineering
Quinnesec, MI
December 11-14, 1989
RDHETA 90-030

	Never Smoker		Former Smoker		Current Smoker	
	N	% Affected	N	% Affected	N	% Affected
Obstructive Disease						
$\underline{FEV_1/FVC\ (\%) < 70.0}$						
"Yes"	1/28	4	10/40	25	7/60	12
"Possible"	2/16	12	1/24	4	5/31	16
"No"	1/17	6	4/13	31	6/23	26
Restrictive Disease						
FVC Percent of Predicted < 80.0						
"Yes"	1/28	4	2/40	5	4/60	7
"Possible"	0/16	0	0/24	0	1/31	3
"No"	1/17	6	0/13	0	1/23	4