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FOUR WHEEL DRIVE CORPORATION
CLINTONVILLE, WISCONSIN

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I. SUMMARY

On September 22, 1986, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Allied Industrial Workers Union, Local 816 to investigate employee exposures to welding fumes, paint, asbestos and complaints of respiratory and other health problems among workers at the Four Wheel Drive (FWD)/Seagrave manufacturing facility in Clintonville, Wisconsin.

Based on information collected during a walk-through survey of the plant on November 18-19, 1986, the NIOSH investigators determined that a medical and industrial hygiene survey of welders and an industrial hygiene survey of the asbestos brake shoe machining operation were indicated. These surveys were conducted from March 9 to March 12, 1987.

Personal samples were collected near the breathing zone of 33 welders and analyzed gravimetrically for total dust and analyzed by inductively coupled argon plasma-atomic emission spectroscopy for 28 metals. Total airborne welding fume concentrations ranged from 0.7 milligrams per cubic meter of air (mg/M^3) to 6.2 mg/M^3. Two samples exceeded the Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) of 5 mg/M^3 and 11 were greater than 50% of the OSHA PEL. Nickel concentrations ranged from 0.001 to 0.022 mg/M^3; one sample exceeded the NIOSH recommended exposure limit (REL) of 0.015 mg/M^3 and 4 were greater than 50% of the NIOSH REL. Silver was detected in 1 sample at a concentration of 0.015 mg/M^3 which exceeds the OSHA PEL of 0.01 mg/M^3. Production volume during the survey was lower than usual.

Airborne asbestos in personal and area samples in the brake shoe machining area was below the analytical limit of detection. Bulk samples of brake shoe shavings contaminating the floor and equipment in that area contained 10 to 20% chrysotile asbestos.

A questionnaire and spirometry were administered to 46 welders and 36 non-welding machine shop employees. Welders had higher prevalences than controls for 10 out of 12 work-associated symptoms of irritation of the upper and lower respiratory tract, and for two of these symptoms (eye irritation and throat irritation) the differences between welders and controls were statistically significant. Among welders who had ever smoked, there was a statistically significant association between longer tenure as a welder at FWD and poorer performance on spirometric measures of airflow (FEV1 and FEF 25-75) by multiple regression analysis.

Based on these results, the NIOSH investigators concluded that there was a health hazard from exposure to welding fume at the Four Wheel Drive Corporation, and that a potential for significant exposure to asbestos exists in the brake shoe machining area. Recommendations for engineering controls to reduce exposure to welding fume and to asbestos dust are included in Section IX of this report.

KEYWORDS: SIC 3711 (Motor Vehicles), welding fume, nickel, silver, asbestos, chromium

II. INTRODUCTION

On September 12, 1986, The National Institute for Occupational Safety and Health (NIOSH) received a request from The Allied Industrial Workers Union, Local 816 to investigate exposures to welding fumes, paints, asbestos, and complaints of respiratory and other health problems among workers at the Four Wheel Drive (FWD)/Seagrave manufacturing facility in Clintonville, Wisconsin.

NIOSH investigators conducted a walk-through survey of the plant on November 18-19, 1986. Based on observations made at that time, the NIOSH investigators made preliminary recommendations and reviewed these in the interim letter dated December 8, 1986. On March 9-12, 1987, NIOSH conducted an industrial hygiene survey and a medical evaluation of employees at Four Wheel Drive Corporation, Clintonville, Wisconsin. On April 20, 1987, a letter was sent to workers who participated in the medical survey, notifying them of their own pulmonary function test results. On July 27, 1987, the NIOSH investigators sent an interim letter to the company and union officials summarizing the results of the environmental survey.

During the initial walk-through visit, sixteen welders were interviewed informally. Several of these workers reported work-associated symptoms such as cough, sore throat and eye irritation, and nearly all expressed concern over long-term effects of repeated exposure to welding fume in areas they considered poorly ventilated. Five full-time spray painters in the paint/body shop were also interviewed. Some reported occasional eye irritation when using urethane paints. None reported work-associated symptoms suggestive of excessive solvent exposure, and all wore supplied-air respirators or half mask respirators equipped with an organic vapor cartridge while spray painting.

Copies of previous investigations conducted by the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA), Appleton Area Office during March 1985 and September 1986 were obtained from the company and reviewed. During the March 1985 inspection, personal air samples for selected employees in the paint and body shop indicated exposures exceeding the OSHA permissible exposure limit (PEL) for cadmium (spray painter), chromate (two spray painters and one body shop worker), nuisance dust (body shop worker), and lead (body shop worker). Additionally, FWD was cited for deficiencies in their respiratory protection program and medical surveillance program for lead-exposed workers. During the September 1986 OSHA investigation, personal breathing zone air samples collected from four painters indicated exposures in excess of the OSHA PEL of 50 micrograms per cubic meter (mcg/M^3) for lead. One body shop worker was exposed to total nuisance dust in excess of the OSHA PEL of 15 milligrams per cubic meter (mg/M^3).

Results from semi-annual blood lead monitoring of workers with potential lead exposure were retrieved and reviewed. These included blood lead tests from 27 employees on December 10, 1985, and from 23 employees on July 22, 1986. No blood lead level exceeded 20 micrograms per deciliter (mcg/dl) (The OSHA action level is 40 mcg/dl). An inquiry to the OSHA office which approves laboratories for OSHA - mandated blood lead monitoring revealed, however, that in December 1985, the test lab was not approved, based on performance on quarterly proficiency tests. The lab was approved in July 1986. It is thus possible that true blood lead levels may have differed from the reported results in December.

During the initial walk-through, a potential for hazardous exposure to asbestos during a brake shoe machining operation was observed. This potential hazard was described and recommendations made regarding its abatement in the interim letters to the company dated December 8, 1986 and July 27, 1987.

Based on information obtained during the walk-through visit and other information gathered, it was decided to conduct a medical and industrial hygiene survey focusing on welding operations and an industrial hygiene assessment of the brake shoe machining operation at the FWD/Seagrave manufacturing facility.

III. BACKGROUND

A. Plant Production and Workforce:

FWD Corporation manufactures heavy duty, multiple-axle drive trucks and firetrucks at the FWD/Seagrave facility in Clintonville, Wisconsin. Four hundred and thirty-five persons were employed there at the time of our initial visit, 313 of these being union shop employees. Major processes at the plant include machining of purchased forged and cast metal parts, cutting and stamping of sheet metal, welding of various frame and body assemblies, painting, and final assembly.

B. Process Description and Employee Duties:

Most welding operations occur in three departments: fabrication (32 welders), cab assembly (8 welders), and ladder shop (13 welders). Most welding is MIG welding (metal inert gas) on mild steel, with some galvaneal, stainless steel and aluminum also being welded. A small amount of SMA (shielded metal arc, or "stick") welding is also done in the fabrication department. Six welders work in other areas of the plant (mostly assembly), including two part-time welders in the machine shop.

C. Engineering Controls:

Local exhaust ventilation (LEV) systems were available at some welding stations in the fabrication department, but these were not used routinely.

IV. EVALUATION DESIGN AND METHOD

A. Environmental:

Air samples for welding fumes were collected on pre-weighed polyvinyl chloride (PVC) filters. Personal samples were collected by placing the filter cassettes near the breathing-zone of the workers. The filter media were connected via tygon tubing to battery operated sampling pumps operating at an air flow rate of 1.5 liters per minute (LPM). The pre-weighed PVC filters were analyzed gravimetrically for total dust and were analyzed via inductively coupled argon plasma-atomic emission spectroscopy (ICP-AES) according to NIOSH Method No. 7300[1], a technique that provides for the simultaneous analysis of 28 metals of toxicological importance. A list of these elements and their corresponding analytical limits of detection is presented in Table 1.

Sampling for asbestos was conducted at the brake shoe operation to evaluate employee exposures to airborne asbestos fibers. Personal samples were collected near the breathing zone of the employee responsible for assembling brake shoes and general area air samples were collected in an area where employees were likely to enter. Both personal and general area air samples were collected on AA 25 millimeter filters connected via tygon tubing to battery powered sampling pumps operating at 3.0 (LPM). All asbestos samples were analyzed via phase contrast microscopy according to NIOSH method #7400.[1] Additionally, a bulk material sample of shavings from the brake shoe pads was collected and analyzed via polarized light microscopy.

B. Medical:

A structured questionnaire and a spirometry test (a type of lung function test) were administered to study participants. The questionnaire was administered by NIOSH interviewers, and contained questions about respiratory and other symptoms, smoking history, demographic variables, and occupational history. The respiratory symptom portion of the questionnaire was a modified version of one used in previous NIOSH studies.[2] For the purpose of this report, a symptom which a worker indicated to be "better on days away from work" is referred to as a "work-associated symptom."

Spirometry was measured with an Ohio Medical Instruments Model 822 dry-rolling seal spirometer connected to a Spirotech dedicated computer. The following spirometric measurements were recorded for each participant: the forced vital capacity (FVC), the forced expiratory volume in 1 second (FEV1), FEV1/FVC ratio ((FEV1/FVC)%), and the FEF 25-75%. For a detailed explanation of the interpretation of individual spirometry results, see Appendix A.

All current welders at the FWD/Seagrave facility, as determined by company personnel lists, were invited to participate in the study. Current machine shop employees who were not welders (two machine shop employees performed welding on a part-time basis and are included in the welding group) were used as a comparison or "control" group for the welders. On the basis of the walk-through inspection, the machine shop work environment was considered relatively free of respiratory irritants, and it was assumed that welders and machine shop workers would be similar in terms of other factors that might affect reporting of symptoms.

Forty-six current welders and 36 controls completed both the questionnaire and spirometry, and one welder and one control completed the questionnaire, but declined spirometry. Participation rates were 80% for welders and 95% for controls.

Six other workers who participated in the study are not included in the data analysis. Two of these workers worked in welding areas but were not themselves welders and four had been machine shop employees when the initial list of study participants was created but had been transferred to other departments when the study was performed.

For each symptom a prevalence ratio, the proportion of welders reporting a symptom divided by the proportion of controls reporting the same symptom, was calculated. The prevalence ratio was adjusted for the proportion of current smokers in each group to compute a "smoking-adjusted prevalence ratio" (PR) with a 95% confidence interval (95% CI), using the Mantel-Haenzel estimate and test-based method, respectively.[3] For explanations of the prevalence ratio, smoking-adjusted prevalence ratio, and 95% confidence interval, see Appendix B.

For analysis, symptoms were grouped into 4 categories: 1) lower respiratory tract irritative symptoms; 2) work-associated lower respiratory tract symptoms - i.e., symptoms which improved on days away from work; 3) work-associated mucous membrane irritation symptoms - symptoms related to irritation of the eyes, nose, and throat that improved on days away from work; 4) other work-associated symptoms-other symptoms, "constitutional" in nature, that improved on days away from work.

To analyze the pulmonary function data, the spirometry results of welders and controls were compared, using t-tests and analysis of covariance[4], and an assessment was made of whether, among welders, pulmonary function was associated with the total time worked as a welder at FWD/Seagrave, using multiple linear regression.[4] "Residual"[6] spirometry values (observed minus predicted), rather than percent of predicted values (observed/predicted times 100), for study participants were used throughout the analysis to adjust for age and height (see Appendix C). Because previous studies have suggested that welding fume may affect smokers and non-smokers differently, spirometry data were analyzed separately for ever-smokers and never-smokers.

V. EVALUATION CRITERIA

A. Environmental Evaluation Criteria:

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy).

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the levels set by the evaluation criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: 1) NIOSH Recommended Exposure Limits (RELs), 2) the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs)[6], and 3) the U.S. Department of Labor/Occupational Safety and Health Administration (OSHA) occupational health standards. Often, the NIOSH RELs and ACGIH TLVs are lower than the corresponding OSHA standards. Both NIOSH RELs and ACGIH TLVs usually are based on more recent information than are the OSHA standards. The OSHA standards also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH RELs, by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that industry is required by the Occupational Safety and Health Act of 1970 (29 USC 651, et seq.) to meet those levels specified by an OSHA standard.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8 to 10-hour workday. Some substances have recommended short-term exposure limits (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high, short-term exposures.

Information on possible health effects of excessive exposure to welding fume and selected metals that may be found in welding fume are provided below:

1. Total Welding fume, not otherwise classified[6,7]

   The health effects associated with exposure to welding fumes are dependant on the toxicity of individual component metals. This classification applies to welding environments where concentrations of toxic metals (i.e., chromium, cadmium, zinc) are not in excess of their respective exposure criteria. Usually in these situations the major component of the fume is iron oxide or aluminum oxide, depending on whether the base metal is carbon (mild) steel or aluminum. Oxides of these metals are considered nuisance particulates based on their 5 mg/M3 criteria.

2. Chromium[7,8,9]

   Chromium compounds can act as allergens in some workers to cause dermatitis to exposed skin. Acute exposure to chromium dust and mist may cause irritation of the eyes, nose and throat. Chromium exists in chromates in one of three valence states 2+, 3+, and 6+. Chromium compounds in the 3+ state are of a low order of toxicity. In the 6+ state, chromium coumpounds are irritants and corrosive. This hexavalent form may be carcinogenic or non-carcinogenic depending on solubility. The less-soluble forms are carcinogenic. Workers in the chromate-producing industry have been reported to have an increased risk of lung cancer. The known health hazards from excessive exposure to chromium welding fumes are dermatitis, ulceration and perforation of the nasal septum, irritation of the mucous membranes of the larynx, pharynx, conjuctiva and chronic asthmatic bronchitis.

3. Iron oxide fume[7,8]

   Inhalation of iron oxide fume or dust causes an apparently benign pneumoconiosis termed siderosis. Iron oxide alone does not cause fibrosis in the lungs of animals, and the same probably applies to humans. Exposures of 6 to 10 years are usually considered necessary before changes recognizable by x-ray can occur; the retained dust gives x-ray shadows that may be indistinguishable from fibrotic pneumoconiosis.

4. Nickel [7,8,10]

   Metallic nickel and certain soluble nickel compounds as dust or fume can cause sensitization resulting in dermatitis and/or asthma. Nickel fume in high concentrations is a respiratory irritant. Nickel is carcinogenic in animals, and several epidemiologic studies have shown an increased incidence of cancer of the paranasal sinuses and lungs among workers in nickel refineries and factories. Suspicion of carcinogencity has been focused primarily on respirable particles of nickel, nickel subsulfide, nickel oxide, and on nickel carbonyl vapor.

5. Silver[11]

Inhalation or ingestion of soluble silver compounds over many years may cause a generalized bluish-black discoloration of the skin known as argyria. Silver deposits (argyrosis), in the conjunctiva, cornea, and lens of the eye have also resulted from silver exposure, and decreased night vision was reported by some affected workers, but no objective functional deficits could be demonstrated.

B. Effects of Arc Welding on Respiratory Symptoms and Lung Function

Previous studies have noted a variety of acute and chronic health problems associated with arc welding, which have not clearly been attributable to any single metal fume or gas exposure, but which may be related to the combined effects of different exposures created by arc welding. Some metal fumes and gasses generated by welding are respiratory irritants, and symptoms of eye, nose, and throat irritation as well as cough, and phlegm production have been reported by welders in association with their work shift.[12] Welders have been reported to have an increased prevalence of chronic bronchitis.[13,14,15] Some studies have also shown welders to have lower pulmonary function values than non-welders, including lower total lung capacity (TLC)[16] and lower FVC and FEV1.[13,16] However, it has not been possible to attribute changes in pulmonary function to specific exposures, and not all studies have found lower pulmonary function in welders.[15] In addition, it is not known whether changes in lung function associated with welding can, in the absence of smoking or other exposures, lead to clinically significant abnormalities in lung function. Exposures encountered by welders vary with the type of welding process, the material welded, and the use of local ventilation and personal protective equipment. Therefore, it is not possible to make reliable generalizations about health effects of welding in all workplaces. Differences in exposures may explain why various studies of welders have not produced consistent results.

VI. RESULTS AND DISCUSSION

A. Environmental:

Qualitative and quantitative analytical results for metals via ICP-AES and total welding fume via gravimetric analysis are presented in Table 2. These results show the presence of aluminum, barium, calcium, chromium, copper, iron, magnesium, manganese, molybdenum, nickel, silver, titanium, and zinc. The range of airborne concentrations for each of these metals are presented along with their corresponding environmental criteria.

Individual air sampling results for the various departments are presented in Tables 3 to 6. Environmental concentrations are provided for total welding fume, iron oxide, and for those other metals (nickel and silver) that were present at concentrations greater than 50% of their respective most stringent occupational exposure limits. Additionally, results for total chromium are presented to illustrate the fact that higher concentrations of chromium are present in areas where welding of stainless steel was performed. The higher concentrations are most likely attributable to chromium VI, a form of chromium that is present in stainless steel.

Total welding fume levels ranged from 0.7 milligrams per cubic meter of air (mg/M^3) to 6.2 mg/M^3. One-third of the samples had quantities of total welding fume greater than 50% of the ACGIH TLV and OSHA PEL of 5 mg/M^3, and two of these samples exceeded these criteria. Nickel concentrations ranged from 0.001 to 0.022 mg/M^3; 1 of the 33 samples exceeded the NIOSH REL of 0.015 mg/M^3 and 4 of 33 were greater than 50% of their most restrictive occupational exposure limit; none exceeded the OSHA PEL of 1.0 mg/M^3. Silver was detected on 1 of 33 samples at an airborne concentration of 0.015 mg/M^3, which exceeded the OSHA PEL of 0.01 mg/M^3. All other detected metals did not exceed any of the environmental criteria.

Some welding on stainless steel was conducted during the collection of three samples. Total chromium in these samples ranged from 0.023 to 0.051 mg/m^3. Chromium concentrations were 0.010 mg/m^3 or less in all other samples.

Results of personal and general area air sampling for asbestos in the brake shoe assembly area indicated that airborne concentrations of asbestos were below the analytical limit of detection. However, a bulk sample of material shavings from the brake shoe pads were collected and submitted for analysis. This bulk sample showed that this material contained 10 - 20% chrysotile asbestos.

B. Medical

Table 7 summarizes a comparison of welders and controls with respect to sociodemographic characteristics. The welders were somewhat younger than the controls with 57.5% and 37.8%, respectively, being 45 years old or less. A higher proportion of welders (8.5%) had more than 12 years of education compared with controls (2.7%). Fewer welders (25.5%) than controls (40.5%) were current smokers, but welders had a higher proportion of ever-smokers and more pack-years of smoking. Controls had a slightly longer average length of employment at FWD. Among welders, the average number of years welding was 20.1, and a high proportion of those years (17.7, on average) was spent welding at FWD Corp. None of the controls had ever worked as a welder.

Table 8 shows a comparison of symptom frequencies in welders and controls, stratified by current smoking status, and the smoking-adjusted prevalence ratio for each symptom. Welders were slightly less likely than controls to have a usual cough (PR = 0.7, 95% CI 0.5 - 1.2) or usual phlegm (PR = 0.8, 95% CI 0.5 - 1.4) than controls. However, welders were more likely to report symptoms of chronic bronchitis (PR = 2.7 95%

CI = 0.7 - 9.9). As expected, chronic bronchitis was more frequent among current smokers than current non-smokers, but 14% of non-smoking welders reported chronic bronchitis compared with none of the non-smoking controls. Welders were also more likely to report having had a chest illness that kept them from their usual activities for as much as a week during the past three years (PR = 3.6, 95% CI 0.9 - 14.5). None of these differences was statistically significant, as shown by the 95% confidence intervals, which include 1.0.

Welders were more likely than controls to report lower respiratory tract symptoms that improved on days away from work. The PRs for this group of symptoms ranged from 1.2 for work-associated phlegm to 3.9 for work-associated dyspnea. None of these PRs differed significantly from 1.0.

Three work-associated mucous membrane irritation symptoms were more common in welders than in controls, irrespective of smoking status. For eye-irritation (PR = 6.4, 95% CI 1.7 - 23.9) and throat irritation (PR = 3.8, 95% CI 1.0 - 14.3), the differences between welders and controls were statistically significant. Work-associated nasal congestion was also more frequent in welders (PR = 2.2, 95% CI 0.9 - 5.3).

Work-associated nausea and headaches were more frequent among welders than controls, and these differences were accounted for by non-smokers. Work-associated fever was only reported by 2 workers, both welders.

Overall, the prevalence ratio exceeded 1.0 for 10 of these 12 work-associated symptoms, although only two of these elevated prevalence ratios were statistically significant.

The frequencies of symptoms reported by welders in the fabrication, cab assembly, and ladder departments are shown in Table 9. For most symptoms, the lowest prevalences were reported by ladder shop employees. This group also had the lowest proportion of smokers. Thirty-one percent of fabrication department employees reported symptoms of chronic bronchitis and thirty-eight percent reported work-associated cough. None of the welders in the other two departments reported these symptoms.

Results for spirometry test residuals (observed minus predicted) for welders and controls are summarized in Table 10. As indicated by the negative values of the residuals, current and ex-smokers had lower pulmonary function than predicted for their age, height, race, and sex. Comparing ever-smoking welders to ever-smoking controls, the welders had lower residual spirometry results (greater negative deviation from predicted) than controls for FEV1, (FEV1/FVC)% and FEF 25-75. However, the differences were generally small and not statistically significant, controlling for current smoking and pack-years smoked. Among never-smokers, welders had lower spirometry residuals than controls for FEV1, FVC, FEV1/FVC% and FEF 25-75, and these differences were also not statistically significant.

Fewer welders than controls had abnormal spirometry according to the criteria described in Appendix A. Three welders and four controls had obstructive abnormalities, one welder and three controls had restrictive abnormalities, and one welder and one control had mixed (obstructive and restrictive) abnormalities. All subjects with abnormal results were current or ex-smokers. The differences in the proportions of welders and controls with various types of abnormal test results were not statistically significant by Fisher's exact test.

Table 11 summarizes the regression analysis of spirometry residuals (dependent variables) among welders in terms of the estimated regression coefficients (ß's) for years worked as a welder at Four Wheel Drive Corporation. These are estimated separately for ever-smokers and never-smokers. For ever-smokers, the coefficients are adjusted for current smoking status and pack-years smoked.

Among ever-smokers, there was a statistically significant, inverse relationship between years worked as a welder at FWD Corp. and the following residual spirometry results: 1) residual FEV1 (observed FEV1 minus predicted FEV1) (ß = -36cc per year, 95% CI -56 - -16cc/year); 2) residual (FEV1/FVC)% (ß = -0.35% per year, 95% CI -0.68 - -0.04% per year); and 3) residual FEF 25-75 (ß= -65cc/year, 95% CI -111 - -19cc/year). The regression coefficient for years welding at Four Wheel Drive was negative, but not significantly different from 0, when residual FVC was the dependant variable. Figure 1 shows FEV1 residuals plotted against years worked as a welder at Four Wheel Drive for ever-smoking welders, and the "best-fitting" line from the relationship between those two variables asjusted for smoking status and pack-years. Figure 2 shows a similar plot with (FEV1/FVC)% on the y axis. From this plot, it is apparent that the negative slope of the regression line for all observations is largely due to 1 observation with 41 years welding at FWD Corp. and (FEV1/FVC)% 34% less than predicted. The regression line shown excluding that "outlier" observation has a slope of -0.13% per year (95% of CI -0.44 - 0.18% per year).

Among welders who were never-smokers, there were no statistically significant associations between spirometry residuals and years worked as a welder at Four Wheel Drive, but all regression coefficients were positive.

VII. DISCUSSION

A. Environmental:

It should be noted that during the environmental survey of March 1987 conditions were not representative of everyday operations. Production rates were below normal, and the tack welder was not in use in the ladder shop during the day sampling was conducted in that area. The tack welding operation was not ventilated and could be a significant source of metal fumes in that shop when operating.

Two of the metals detected, nickel and chromium, have NIOSH RELs that are relatively stringent compared to other applicable environmental criteria. Nickel compounds are considered by NIOSH to be suspect carcinogens. Analyses of samples collected show the presence of nickel above the NIOSH REL. The results of analyses for total chromium are all below the applicable environmental criteria. However, the analyses performed do not distinguish between hexavalent chromium (chromium VI) and other forms of chromium. In each instance where welding was conducted on stainless steel the amounts of chromium were considerably higher than in areas where stainless steel was not used. This difference would most likely be due to the presence of chromium VI which is commonly found in stainless steel and is considered by NIOSH to be a suspect human carcinogen.

Despite the fact that the brake shoe machining process was equipped with local exhaust ventilation, the accumulation of visible particulate material machined from the brake shoes was noted throughout the area. This creates the potential for the spread of asbestos-containing materials to other areas of the plant. Also, the worker observed in this area was not wearing appropriate personal protective equipment.

B. Medical:

The medical survey was intended to assess any relationship between work as a welder at Four Wheel Drive and respiratory symptoms and pulmonary function.

A higher proportion of welders than controls reported most of the symptoms surveyed, controlling for the effect of smoking. The association between work as a welder and symptoms was especially consistent for work-associated symptoms. Although elevated prevalence ratios were statistically significant for only two work-associated symptoms, ten of the 12 work-associated symptoms had prevalence ratios greater than 1.0. If the "true" frequencies of work-associated symptoms among welders and control workers under the conditions at FWD Corp. were equal one would expect, on average, 6 of the 12 prevalence ratios to exceed 1.0 and 6 to be less than 1.0. The probability of 10 or more symptoms occurring more frequently in welders by chance is 0.019 (exact binomial probability). Most of these work-associated symptoms are suggestive of exposure to respiratory tract irritants. This finding is consistent with the known properties of some components of welding fume and with symptoms reported by other workers exposed to welding fume.[12]

Symptoms of chronic bronchitis were reported more often by welders than controls, though the difference was not statistically significant. Chronic bronchitis is a known consequence of cigarette smoking[17], and may be caused by repeated airway irritation by cigarette smoke. Chronic bronchitis symptoms have been associated with welding in other studies[13,14,15] and may be due to repeated exposure to respiratory irritants present in welding fume.

Cough and chronic bronchitis appeared to be associated with work in the fabricating area. This may be related to the finding of the highest levels of total welding fume exposure in this department during the survey.

Among ever-smoking welders there was an association between longer tenure as a welder at FWD Corp. and poorer performance on spirometric measures of airflow (FEV1 and FE25-75). In this group, negative, but non-significant, regression coefficients were also estimated for years welding at FWD corp. when FVC and (FEV1/FVC)% were the dependent variables (excluding 1 outlier from the (FEV1/FVC)% regression analysis). Because of the limited battery of pulmonary function tests we could reasonably carry out in a field setting we were unable to determine whether reduced lung volumes, reduced airflow, or both, accounted for the association observed between years of welding at Four Wheel Drive Corporation and lower spirometry results (see Appendix A). We did not find a similar association between welding and pulmonary function among never-smokers.

These findings suggest that past exposure of welding fume at Four Wheel Drive Corp. and cigarette smoke may have "interacted" to cause a combined adverse effect on pulmonary function which is greater than expected from their individual effects. This does not mean that smoking is the "cause" of the lower pulmonary function seen among ever-smoking welders with longer duration of welding. The association between pulmonary function and years welding at FWD Corp. was present after controlling for the effects of smoking in the group of ever smokers. The apparent interaction between cigarette smoke and welding observed in this study is consistent with some other studies.[16,18]

More controls than welders had abnormal spirometry results, but the numbers of abnormal results were small, and this observation is consistent with a chance finding. Our study was not designed to attribute a cause to any individual test result and focused only on group comparisons.

Several limitations of our survey need to be mentioned. This was a cross-sectional study of currently employed welders. Since workers who develop adverse health effects from welding may be more likely to change jobs, observations limited to current workers may underestimate the adverse effects of welding. Such a study cannot directly measure changes in health due to an exposure, because individuals are only studied once. No ever-smoking welders with between 9 and 18 years of tenure at FWD Corp. were available for testing, nor were historical data on welding fume exposure available. Therefore, the relative effect of past versus more recent welding fume exposure on lung function cannot be assessed.

VIII. CONCLUSIONS

1. Employees working in the fabrication area (department #02) were exposed to concentrations of total welding fume in excess of the ACGIH TLV and the OSHA PEL and to concentrations of nickel and silver in excess of the NIOSH REL and OSHA PEL, respectively.

2. Welders at Four Wheel Drive currently report more work-associated symptoms of irritation of the mucous membranes of the eye, nose, throat and lower respiratory tract and have a higher prevalence of chronic bronchitis symptoms than do non-welding workers, and these symptoms are likely to be caused by excessive exposure to welding fume.

3. Duration of work as a welder at Four Wheel Drive Corporation was associated with lower values of FEV1 and FEF 25-75 among ever-smokers. This finding suggests that the cumulative effect of past exposure to welding fumes, under conditions at this facility, have interacted with cigarette smoking to cause a decrease in those lung function tests.

4. Environmental measurements suggested a potential for significant exposures to chromium VI during stainless

steel welding. Observations suggested a potential for significant exposures to asbestos in the brake shoe assembly area.

IX. RECOMMENDATIONS

The following recommendations were discussed with representatives of the management and the union during the closing conference on March 12, 1987. These recommendations should be implemented if they have not already been completed.

1. General and local exhaust ventilation (LEV) systems should be installed in all welding departments to reduce the levels of metal fume.

2. Since welding and other fume-producing operations are routinely performed in the cab assembly area (dept. #03), the fabrication area (dept. #02), and the ladder shop (dept. #04), exhaust ventilation should be used to remove metal fumes. Ideally, freely moveable fume hoods with flexible ducting should be used which would allow the welder to position the hood as close as practicable to the piece being welded.

3. An LEV system should be installed in the ladder shop at the tack welding operation. This type system could be easily installed and would significantly reduce airborne concentrations of metal fumes when this operation is running.

4. Local exhaust ventilation (LEV) systems of the type discussed above were available at the welding booths in the fabrication area (dept. #02) however, these systems were old and were not being used during the time of our survey. These systems should be repaired or replaced as necessary, and employees should be instructed in the correct usage of these systems and encouraged to use the systems.

5. Portable LEV systems should be used when welding or cutting in confined areas, such as inside cabs. In non-confined areas LEV systems should be used, particularly when working with stainless steel, a primary source of carcinogenic hexavalent chromium (Cr VI), nickel, and other toxic metals. When using LEV systems, the hood should be placed as close as practical to the arc site. Provisions should be made to ensure that welding fumes of the toxic metals are not exhausted into an area where other workers are present. Additionally, make-up air for confined spaces where LEV systems are used should be clean.

6. In situations where the use of LEV systems is impractical, workers should be provided with appropriate respiratory protection. Supplied air respirators are required in confined spaces in the absence of sufficient contaminant removal and/or make-up air. This type of respirator should also be used when welding on stainless steel in non-confined work spaces where use of an LEV system is impractical.

7. Those workers welding for prolonged periods of time in one location should use a fan or LEV system to prevent fumes from entering his/her breathing zone.

8. Welding curtains should be purchased and used as much as possible to minimize ultraviolet (UV) radiation exposure of other workers in the area.

9. All welding and cutting operations should comply with the requirements outlined in the General Industry Occupational Safety and Health Standards, OSHA (29 CFR 1910.252).

10. The asbestos brake shoe area should be isolated from other areas of the facility to prevent the spread of asbestos fibers.

11. All accumulated asbestos fibers in the brake shoe areas should be cleaned up using appropriate procedures and a regular housekeeping schedule should be implemented to prevent future accumulation of asbestos containing materials.

12. The removal of accumulated asbestos fibers in the brake shoe area should be accomplished by the use of a vacuum system, dry sweeping techniques should not be used. Ideally, a central vacuum system equipped with a high efficiency particulate air (HEPA) filter should be installed. A portable vacuum system equipped with a HEPA filter could be used as an alternative to the installation of a central vacuum system. Vacuum "collectors" should be emptied and their contents disposed of using appropriate procedures.

13. Appropriate protective coveralls should be provided and worn by employees working on the brake shoe machining operation or clean-up of that area. These should be laundered or disposed of properly, depending on the type used.

14. Until effective engineering controls are installed, the use of an appropriate respirator should be required and enforced.

15. When the installation of engineering controls is completed, the areas should be monitored for airborne concentrations of total welding fume, chromium VI, nickel and other metal fumes in all welding areas and for asbestos at the brake shoe operation to determine the effectiveness of these controls.

16. The present respirator program should be thoroughly reviewed and updated to ensure that the respirator program is in compliance with all requirements of 29 CFR 1910.134.

17. The present program for blood lead monitoring should be reviewed to ensure that it is in compliance with all requirements of 29 CFR 1910.1025,[19] including the use of an OSHA-approved laboratory to perform the blood lead measurements.

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XII. DISTRIBUTION AND AVAILABILITY OF DETERMINATION REPORT

Copies of this Determination Report are currently available upon request from NIOSH, Division of Standards Development and Technology Transfer, Resources and Dissemination Section, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days the report will be available through the National Technical Information Services (NTIS), Port Royal Road, 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 the following:

A. Four Wheel Drive Corporation
B. Allied Industrial Workers Union, Milwaukee, Wisconsin

C. Allied Industrial Workers, Local 816

D. U.S. Department of Labor, OSHA - Region V

E. NIOSH, Cincinnati

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

Table 1

Elements Analyzed by ICP-AES and Their Corresponding
Analytical Limits of Detection

Four Wheel Drive Corporation
Clintonville, Wisconsin
HETA 86-524

Element	Analytical Limit of Detection (micrograms per sample)
Aluminum	10
Antimony	10
Arsenic	5.0
Boron	10
Barium	1.0
Beryllium	1.0
Calcium	5.0
Cadmium	1.0
Cobalt	1.0
Chromium	1.0
Copper	1.0
Iron	1.0
Lanthanum	5.0
Magnesium	1.0
Manganese	1.0
Molybdenum	1.0
Nickel	1.0
Lead	2.5
Selenium	10
Silver	2.5
Tin	10
Tellurium	10
Thallium	10
Titanium	10
Vanadium	10
Yttrium	1.0
Zinc	1.0
Zirconium	10

Note: 1000 micrograms = 1 milligram

Table 2
Metals detected on personal breathing zone air samples
Four Wheel Drive Corporation
Clintonville, Wisconsin
HETA 86-524
March 9 - 12, 1987

Substance (Metal)	Range (mg/M^3)	Number of samples detected on	NIOSH REL (mg/M^3)	ACGIH TLV (mg/M^3)	OSHA PEL (mg/M^3)
Total welding fume	0.7 - 6.2	33/33	---	5	5
Aluminum	0.017 - 0.16	9/33	---	5	---
Barium	0.001 - 0.005	9/33	---	0.5	0.5
Calcium	0.011 - 0.22	32/33	---	2	5
Chromium	0.002 - 0.051	21/33	*	0.5	1
Copper	0.003 - 0.022	32/33	---	0.2	0.1
Iron	0.17 - 2.6	33/33	---	5	10
Magnesium	0.003 - 0.063	32/33	---	10	15
Manganese	0.014 - 0.44	33/33	---	1	5-C
Molybdenum	0.002 - 0.010	16/33	---	5	5
Nickel	0.001 - 0.022	17/33	0.015	1	1
Silver	0.015	1/33	---	0.1	0.01
Titanium	0.091	1/33	---	10	15
Zinc	0.003 - 1.2	33/33	5	5	5

C - an employee's exposure shall at no time exceed the ceiling value
*The NIOSH RELs for chromium compounds distinguishes chromium (VI) compounds which are carcinogenic (REL 0.001 mg/m^3) and chromium (VI) compounds which are non-carcinogenic (REL 0.025 mg/m^3). These RELs are not applicable for total chromium, which was measured in this study.

Table 3
Personal air sampling results for Welding Fumes in Department #03
Four Wheel Drive Corporation
Clintonville, Wisconsin
HETA 86-524
March 9 - 12, 1987

Date	Job (type steel)	Sample Time (minutes)	Sample Volume (liters)	Environmental Concentration (mg/M^3) Total Welding Fume	Total Chromium	Iron Oxide	Nickel	Silver
3/09/87	Cab assembly (stainless)	436	654	3.8*	0.029	0.83	0.010*	ND
3/09/87	Cab assembly (mild, galvaneal)	431	646	2.2	0.006	0.70	0.002	ND
3/09/87	Roof assembly (mild, galvaneal)	428	642	2.4	0.005	0.83	0.002	ND
3/09/87	Cab assembly (mild, galvaneal)	425	638	1.4	ND	0.33	ND	ND
3/09/87	Cab assembly, side panel (mild, galvaneal)	430	645	1.4	0.002	0.43	ND	ND
3/09/87	Cab assembly (mild, galvaneal)	424	636	2.6*	0.004	0.85	ND	ND
3/09/87	Misc.	415	622	3.2*	0.005	1.5	0.002	ND
3/09/87	Misc.	414	621	3.0*	0.004	0.76	ND	ND
ENVIRONMENTAL CRITERIA			NIOSH REL	---		---	0.015	---
			ACGIH TLV	5		5	0.1	0.1
			OSHA PEL	5		10	1	0.01

* - greater than 50% of the most stringent occupational criteria for this substance
ND - not detected

Table 4
Personal air sampling results for Welding Fumes in Department #02
Four Wheel Drive Corporation
Clintonville, Wisconsin
HETA 86-524
March 9 - 12, 1987

Date	Job (type steel)	Sample Time (minutes)	Sample Volume (liters)	Environmental Concentration (mg/M^3) Total Welding Fume	Total Chromium	Iron Oxide	Nickel	Silver
3/10/87	Frame line (mild)	475	712	3.9*	0.004	1.1	0.002	ND
3/10/87	Frame line (mild)	300	450	3.4*	0.008	1.1	0.008*	ND
3/10/87	Frame line (mild)	470	705	5.6**	0.007	2.6*	0.003	ND
3/10/87	Booth 15 (galvaneal)	463	694	6.2**	0.004	0.79	0.002	ND
3/10/87	Booth 9 (galvaneal)	453	680	2.2	0.004	0.60	0.002	ND
3/10/87	Booth 8 (aluminum)	455	682	1.8	0.005	0.29	0.002	ND
3/10/87	Booth 11 (aluminum, brass)	450	675	1.9	0.003	0.25	0.001	0.015**
3/10/87	Frame line (galvaneal, stainless)	446	669	2.2	0.051	0.79	0.022**	ND
3/10/87	Frame line (mild)	448	672	3.3*	0.010	1.4	0.003	ND
3/10/87	Booth 2, stick welding	155	232	1.7	ND	0.69	ND	ND
3/10/87	" (mild, galvaneal, stainless)	285	428	4.5*	0.023	1.5	0.008*	ND
3/10/87	Booth 12, stick welding (mild)	441	662	2.1	0.004	0.60	0.005	ND
3/10/87	Next to Booth 12 (galvaneal)	437	656	3.1*	0.008	0.90	0.005	ND
ENVIRONMENTAL CRITERIA			NIOSH REL	---		---	0.015	---
			ACGIH TLV	5		5 the most **		
			OSHA PEL	5		10	1	

* - greater than 50% of the most stringent occupational criteria for this substance
- exceeds stringent occupational criteria for this substance
ND - not detected

Table 5
Personal air sampling results for Welding Fumes in Department #04
Four Wheel Drive Corporation
Clintonville, Wisconsin
HETA 86-524
March 9 - 12, 1987

				Environmental Concentration (mg/M^3)				
Date	Job (type steel)	Sample Time (minutes)	Sample Volume (liters)	Total Welding Fume	Total Chromium	Iron Oxide	Nickel	Silver
3/11/87	Ladder shop (mild)	481	722	0.7	ND	0.21	ND	ND
3/11/87	Ladder shop (mild)	478	717	1.0	ND	0.31	ND	ND
3/11/87	Ladder shop (mild)	475	712	1.7	ND	0.55	ND	ND
3/11/87	Ladder shop (mild)	470	705	1.0	ND	0.28	ND	ND
3/11/87	Ladder shop (mild)	466	699	1.3	ND	0.49	ND	ND
3/11/87	Ladder shop (mild)	433	650	1.5	ND	0.48	ND	ND
3/11/87	Ladder shop (mild)	463	694	1.8	ND	0.46	ND	ND
3/11/87	Ladder shop (mild)	457	686	1.5	ND	0.48	ND	ND
3/11/87	Ladder shop (mild)	455	682	1.1	ND	0.31	ND	ND
ENVIRONMENTAL CRITERIA			NIOSH REL	---		---	0.015	---
			ACGIH TLV	5		5	0.1	0.1
			OSHA PEL	5		10	1	0.01

ND - not detected

Table 6

Personal air sampling results for Welding Fumes in Departments #23, #22, and #16

Four Wheel Drive Corporation
Clintonville, Wisconsin
HETA 86-524

March 9 - 12, 1987

Date	Job (type steel)	Sample Time (minutes)	Sample Volume (liters)	Environmental Concentration (mg/M^3)				
				Total Welding Fume	Total Chromium	Iron Oxide	Nickel	Silver
3/12/87	Final assembly, dept. #23, (misc. welding)	460	690	0.8	0.003	0.17	0.002	ND
3/12/87	Final assembly, dept. #22, (misc. welding)	459	688	0.9	ND	0.19	ND	ND
3/12/87	Final assembly, dept. #16, (misc. welding)	455	682	1.0	0.003	0.31	ND	ND
ENVIRONMENTAL CRITERIA			NIOSH REL	---		---	0.015	---
			ACGIH TLV	5		5	0.1	0.1
			OSHA PEL	5		10	1	0.01

ND - not detected

TABLE 7
Comparison of Demographic Variables, Smoking, and Occupational History in Welders and Controls

	Welders (N = 47)	Controls (n = 37)
Age		
% 35 years or less	28.8%	16.2%
% 36 to 46 years	27.7%	21.6%
% 46 to 55 years	14.9%	32.4%
% 55 years and older	27.7%	29.7%
Education		
% less than 12 years	25.5%	27.0%
% 12 years	66.0%	70.3%
% more than 12 years	8.5%	2.7%
Smoking		
% current smokers	25.5%	40.5%
% ex-smokers	42.6%	32.4%
% never smokers	31.9%	27.0%
Pack-years (among ever smokers)		
mean	23.7	18.1
S.D.	24.6	15.0
Years worked at FWD		
mean	19.0	21.2
S.D.	11.3	9.6
Years worked as welder		
mean	20.1	-0-
S.D.	11.1	---
Years worked as Welder at FWD		
mean	17.7	-0-
S.D.	11.3	---
Years worked as Machinist at FWD		
mean	0.7(1)	19.9
S.D.	3.0	10.2

(1) Three current welders worked as machinists in the past.

TABLE 8

Comparison of Symptom Frequencies in Welders and Controls

	CURRENT SMOKERS		CURRENT NON-SMOKERS		Smoking-Adjusted	
	Welders	Controls	Welders	Controls	PR (1)	95% CI (2)
Number of participants	12	15	35	22		
Lower Respiratory Tract Symptoms:						
usual cough	58%	73%	29%	41%	0.7	(0.5 - 1.2)
usual phlegm	33%	60%	37%	36%	0.8	(0.5 - 1.4)
episode of cough and phelgm	33%	13%	29%	18%	1.8	(0.8 - 4.1)
coughed up blood	17%	13%	6%	5%	1.3	(0.1 - 13.1)
wheezing	25%	27%	23%	18%	1.1	(0.6 - 2.2)
chest illness	17%	7%	20%	5%	3.6	(0.9 - 14.5)
dyspnea	25%	40%	31%	23%	1.0	(0.5 - 2.1)
Chronic Bronchitis	25%	20%	14%	0%	2.7	(0.7 - 9.9)
Work-associated (3) Lower Respiratory Symptoms:						
cough	42%	13%	14%	9%	2.3	(0.8 - 6.2)
phlegm	17%	42%	31%	13%	1.2	(0.5 - 2.5)
dyspnea	8%	7%	9%	0%	3.9	(0.4 - 36.4)
wheezing	17%	13%	14%	5%	2.0	(0.5 - 7.6)
Work-associated Mucous Membrane Irritation:						
nasal congestion	33%	13%	29%	14%	2.2	(0.9 - 5.3)
eye irritation	33%	13%	26%	0%	6.4	(1.7 - 23.9)
nosebleeds	0%	0%	3%	5%	0.6	(0.0 - 9.6)
throat irritation	25%	7%	17%	5%	3.8	(1.0 - 14.7)
Other Work-associated Symptoms:						
nausea	8%	7%	11%	0%	4.7	(0.5 - 40.7)
headache	25%	27%	29%	9%	1.8	(0.7 - 4.5)
lightheadedness	17%	20%	11%	9%	1.0	(0.3 - 3.2)
fever	8%	0%	3%	0%	(4)	

(1) prevalence ratio
(2) 95% confidence interval
(3) "better on days away from work"
(4) zero in denominator

TABLE 9

Comparison of Symptom Frequencies for Welders in Fabrication, Cab Assembly, and Ladder Departments

	Fabrication	Cab Assembly	Ladder Shop
Number of participants	26	8	7
Current Smokers	31%	25%	14%
Lower Respiratory Tract Symptoms			
usual cough	62%	0%	14%
usual phlegm	46%	38%	29%
period of increased cough and phelgm	31%	38%	29%
coughed up blood	31%	0%	29%
wheezing	27%	38%	0%
chest illness	23%	25%	0%
dyspnea	35%	50%	29%
Chronic Bronchitis	31%	0%	0%
Work-associated (1) Lower Respiratory Symptoms:			
cough	38%	0%	0%
phlegm	35%	25%	29%
dyspnea	12%	13%	0%
wheezing	19%	25%	0%
Work-associated Mucous Membrane Irritation:			
nasal congestion	38%	38%	14%
eye irritation	31%	50%	14%
nosebleeds	4%	0%	0%
throat irritation	23%	25%	0%
Other work-associated Symptoms:			
nausea	15%	38%	14%
headache	4%	13%	0%
lightheadedness	4%	13%	0%
fever	8%	0%	0%

(1) "better on days away from work"

TABLE 10

Comparison of Spirometry Test Residuals (1) in Welders & Controls

	Smoking Status	Welders	Controls
Number Tested	Current	11	15
	Ex	20	11
	Never	15	10

	Smoking Status	Mean	(S.E.M)(2)	Mean	(S.E.M.)	p Value
FEV1 Residual (cc's)	Current	- 97	(211)	- 91	(176)	0.88(3)
	Ex	-182	(116)	- 69	(200)	
	Never	137	(131)	241	(111)	0.58(4)
FVC Residual (cc's)	Current	100	(228)	- 72	(202)	0.71(3)
	Ex	- 17	(116)	6	(211)	
	Never	115	(140)	192	(212)	0.70(4)
(FEV1/FVC) Residual (%)	Current	- 6.5	(2.4)	- 3.2	(2.6)	0.52(3)
	Ex	- 5.3	(2.0)	- 4.5	(2.5)	
	Never	- 0.7	(1.4)	0.2	(0.7)	0.61(4)
FEF(25-75) Residual (cc/second)	Current	-1284	(446)	-845	(356)	0.47(3)
	Ex	-1418	(249)	-1186	(460)	
	Never	- 447	(389)	- 300	(273)	0.78(4)

(1) [observed result - predicted result] - based on sex, height, age, and race

(2) Standard error of mean

(3) p value for partial F test of difference in means between welders and controls among current and ex-smokers, controlling for current smoking status and pack-years smoked.

(4) p value for t-test comparing mean in welders and controls among never smokers.

TABLE 11

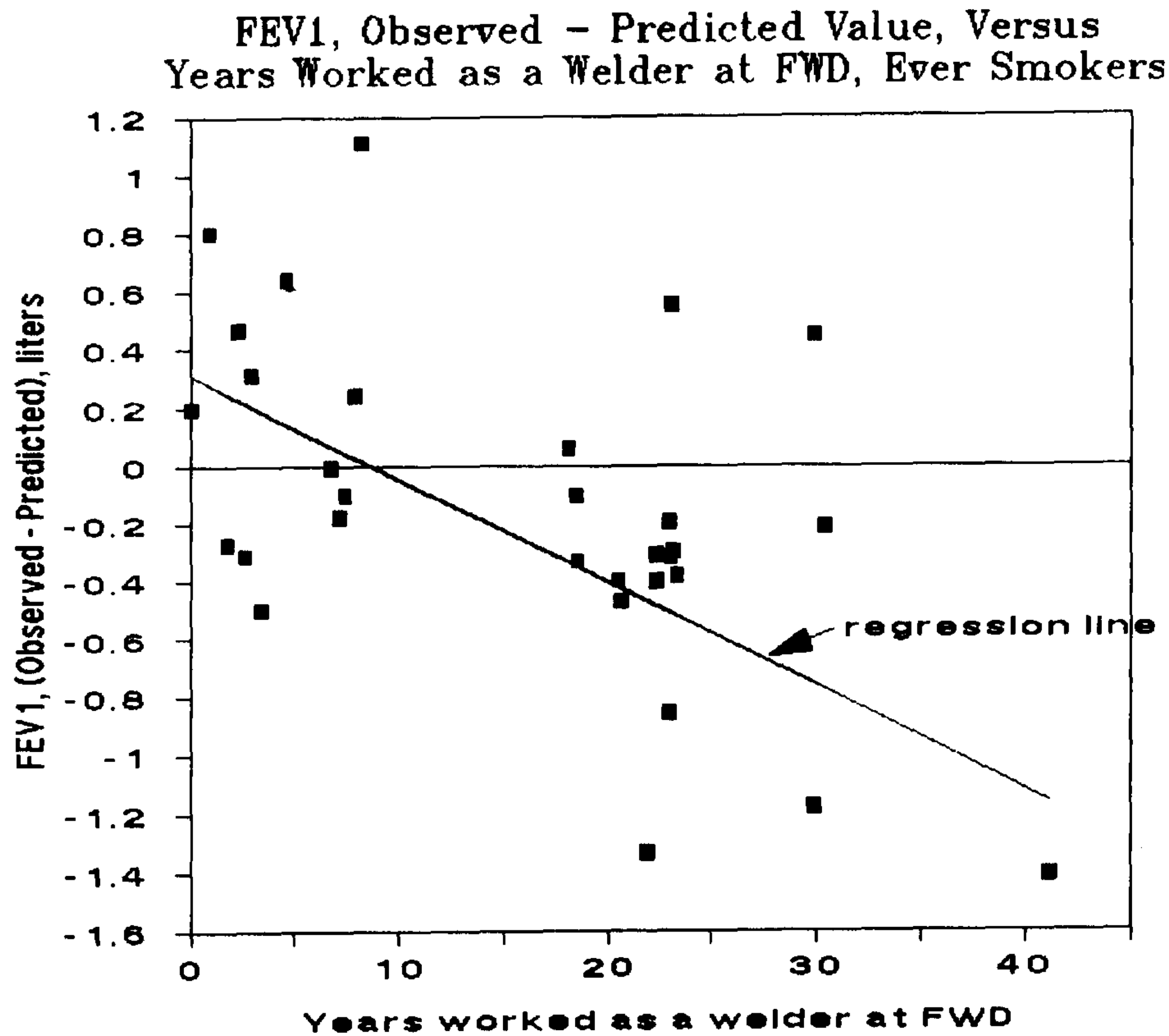
Regression Coefficients for Spirometry Test Residuals (1) versus
Years Worked as a Welder at FWD Corporation

Dependent Variable	Units of Coefficient	Current & Ex-Smokers (2)		R^2	Never Smokers		R^2
		Coefficient	95% CI		Coefficient	95% CI	
FEV1 Residual	cc/year	-36	(-56 - -16)	0.34	19	(-4 - 42)	0.19
FVC Residual	cc/year	-20	(-44 - 4)	0.11	17	(-9 - 34)	0.14
(FEV1/FVC) % Residual	%/year	-0.35	(-0.68 - -0.04)	0.17	0.12	(-0.15 - 0.39)	0.06
FEF 25-75 Residual	cc/year	-65	(-111 - -19)	0.24	26	(-50 - 102)	0.04

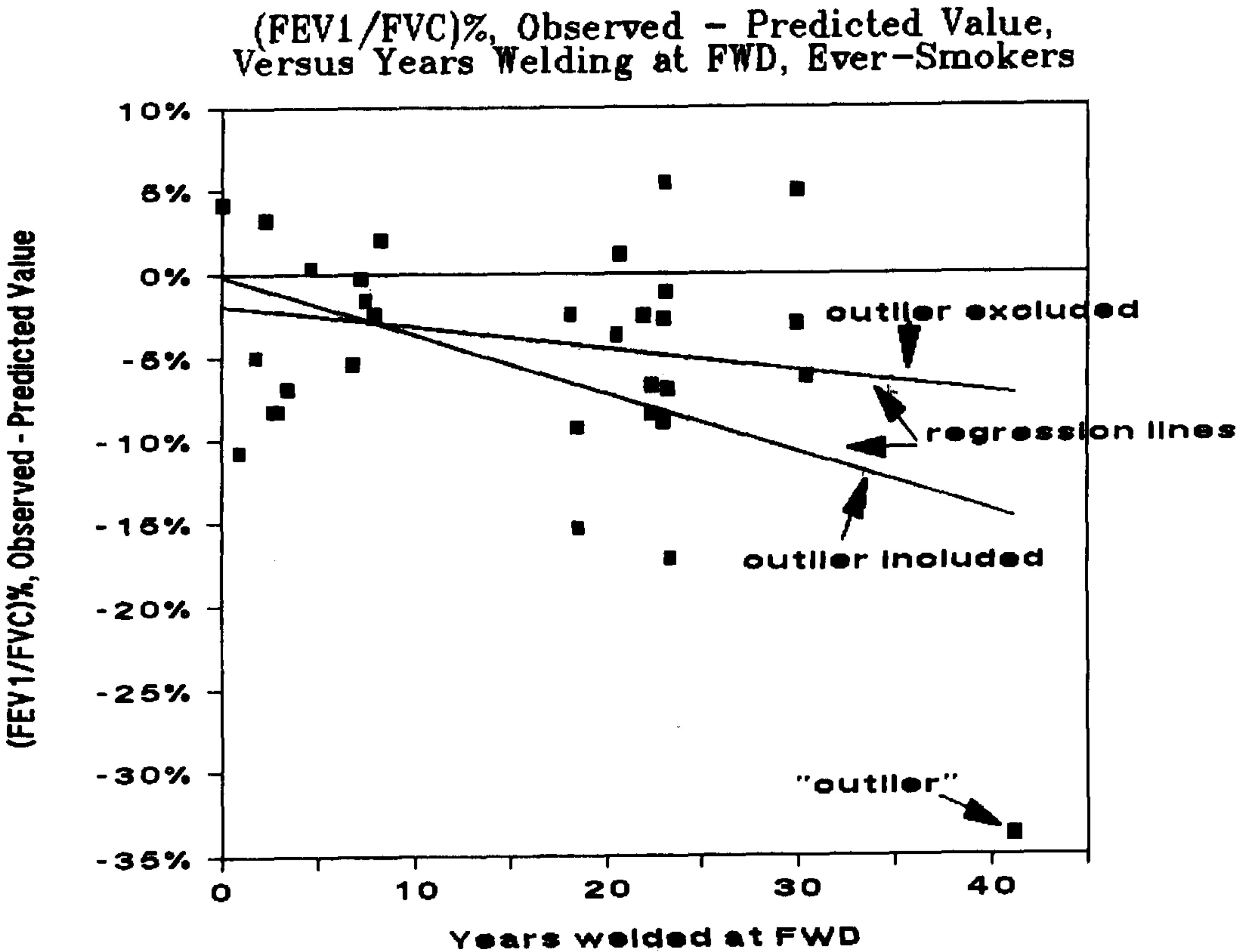
(1) [observed test result - predicted test result (based on sex, age, race, and height[20])]

(2) Adjusted for current smoking status and pack-years of smoking

Graph 1


FEV1, Observed - Predicted Value, Versus
Years Worked as a Welder at FWD, Ever Smokers
FEV1, (Observed - Predicted), liters
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6
0
10
20
30
40
Years worked as a welder at FWD
regression line

Graph 2


(FEV1/FVC)%, Observed - Predicted Value,
Versus Years Welding at FWD, Ever-Smokers
10%
5%
0%
-5%
-10%
-15%
-20%
-25%
-30%
-35%
(FEV1/FVC)%, Observed - Predicted Value
outlier excluded
regression lines
outlier included
"outlier"
0
10
20
30
40
Years welded at FWD

Appendix A

Interpretation of Individual Spirometry Tests

The purpose of the pulmonary function tests was to determine if long-term employees, as a group, had evidence of reduced lung function that could be attributed to exposures, including welding fume, at Four Wheel Drive. The following spirometric measures were used to determine whether an individual had pulmonary function results outside the conventional range of normal: forced vital capacity (FVC), 1-second forced expiratory volume (FEV1) and calculation of the ratio (FEV1/FVC)%. FVC is the total amount of air that can be forcibly exhaled after a full inspiration; FEV1 is the amount of air exhaled during the first second of a forced expiration. Any condition that impairs FVC also impairs FEV1 (but not necessarily (FEV1/FVC)%), but the reverse is not true. Conditions that impair FEV1 do not necessarily impair FVC. FEV1 and FVC are evaluated by comparing them to "predicted" values that take into account age, height, sex, and race. Pulmonary function is considered "normal" if the FVC and FEV1 are 80% or more of their predicted values and (FEV1/FVC)% is 70% or more. Generally speaking, a low (FEV1/FEV)% (less than 70%) indicates an "obstructive" impairment to exhaling rapidly, and a low FVC (less than 80% of predicted) indicates a "restrictive" impairment of lung capacity. If both FVC and (FEV1/FVC)% are low a "mixed" impairment (both obstructive and restrictive) is said to be present. Some individuals with moderate or severe obstructive impairment are not able to empty their lungs fully during the time forced vital capacity is usually measured (6 seconds). In such cases, the FVC may be below normal, indicating a restrictive or mixed impairment, when, in fact, only an obstructive impairment exists. Additional pulmonary function tests, not suitable for "field" administration, are needed to characterize accurately the type of abnormality in such persons.

The forced expiratory flow rate during the middle half of expiration (FEF25-75) is usually also reduced when an obstructive impairment is present. However, since it can vary widely in between normal individuals and between different tests in the same individual, it is not generally used to diagnose an impairment on an individual basis. In this survey, the FEF25-75 was used only for group comparisons.

Various occupational and non-occupational conditions can affect the results of pulmonary function tests. Cigarette-related bronchitis and emphysema are probably the most common causes of a low FEV1/FVC among the general working population, although certain occupational chemical and dust exposures can also cause or contribute to it. A low FVC is more suggestive of the effects of occupational exposures such as crystalline silica, asbestos, and hard metal dust. Abnormal test results, by themselves, should be interpreted only as an indicator of impaired lung function, not as diagnoses of specific diseases. Furthermore, they should not necessarily be interpreted in any individual case as being due to either occupational exposures in general or specific exposures at Four Wheel Drive. That determination can only be made after a more complete medical evaluation than NIOSH provides.

APPENDIX B

Explanation of Prevalence Ratios and Smoking-Adjusted Prevalence Ratios

A prevalence ratio was calculated by dividing the prevalence of a symptom (proportion of persons reporting that symptom) among welders by the prevalence of a symptom in controls. A prevalence ratio of 1.0 means that the same proportion of welders and controls reported the symptom; a prevalence ratio of greater than 1.0 means that higher proportion of welders reported the symptom; a prevalence ratio of less than 1.0 means that fewer welders than controls reported a symptom.

To estimate a single prevalence ratio comparing all welders to all controls while accounting for the influence of current smoking, we computed a "smoking-adjusted prevalence ratio." This is a weighted average of the prevalence ratios for smokers and non-smokers, but has the same interpretation as the prevalence ratio for each smoking category (i.e., prevalence ratio greater than 1.0 means a symptom is more prevalent in welders). The smoking-adjusted prevalence ratio was computed using the "Mantel Hanzel estimate"[13], which refers to a specific method of statistical adjustment. For each smoking-adjusted prevalence ratio, we computed a 95% confidence interval which reflects the lower and upper limits of possible values of the "true" prevalence ratio (the prevalence ratio that would be obtained from averaging the results of a large number of studies of welders and controls under the same conditions as in this study) that the data we collected would be consistent with. We used a statistical technique called the "test-based" method to compute these confidence intervals. A property of these confidence intervals is that if the value 1.0 falls within a given confidence interval, the corresponding prevalence ratio estimate is not "statistically significantly" different from 1.0. For example, if the prevalence ratio estimate for a symptom is 1.8 and the 95% confidence interval is (0.8 - 4.1), welders in the study population were more likely (1.8 times more likely) to report that symptom. However, the difference between welders and controls could have occurred by chance 5% or more of the time even if, on the average, welders and controls have the same prevalence of symptoms. If, on the other hand, the 95% confidence interval for a prevalence ratio does not include 1.0, the corresponding estimate of the prevalence ratio is "statistically significantly" different from 1.0. For example, if the prevalence ratio estimate for a given symptom is 6.4 and the 95% confidence interval is (1.7 - 23.9), welders were 6.4 time more likely to report that symptom than controls. Such a large prevalence ratio would be expected, by chance, less than 5% of the time, if the "true" prevalence ratio were 1.0.

APPENDIX C

Computation of Spirometry Test Residuals[5]
(Observed minus Predicted)

Spirometry results were adjusted for height and age as follows: Using an equation derived from a study of healthy, non-smoking individuals [20] (see below), the value of each lung function parameter measured which would be expected, based on a subject's height and age was computed. This "predicted" value was subtracted from the value of the parameter "observed" (i.e. actually measured) in that individual. The result was the "residual" value for that lung function parameter. For example, if a given subject's FEV1 was 2.36 liters and the FEV1 expected based on his height and age was 3.08 liters, then his residual FEV1 would be -0.72 liters. In this case the subject's FEV1 is less then the average expected. A positive residual FEV1 indicates the FEV1 is greater than expected. The residual values for FEV1, FVC, FEF 25-75 and (FEV1/FVC)% were used in subsequent analysis.

Equations used to compute predicted values for spirometry:

Males, greater than or equal to 25 years of age:

Predicted: FEV1 (liters) = -4.203 + 0.052 * height (cm) - 0.027 * age (yrs)

FVC (liters) = -5.459 + 0.065 * height - 0.029 * age

FEF 25-75 (liters per second) = -1.864 + 0.045 * height - 0.031 * age

(FEV1/FVC)% = 103.64 - 0.087 * height - 0.140 * age

Males, less than 25 years of age:

Predicited: FEV1 (liters) = -4.808 + 0.046 * height + 0.045 * age

FVC (liters) = -5.508 + 0.050 * Height + 0.078 * age20

FEF 25-75 (liters) = -5.334 + 0.059 * height

(FEV1/FVC)% = 103.64 - 0.087 * height - 0.140 * age