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HENDERSON, KENTUCKY

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## I. SUMMARY

On May 31, 1988, the National Institute for Occupational Safety and Health (NIOSH) received a confidential request to conduct a health hazard evaluation at the Accuride Corporation in Henderson, Kentucky. The request stated that over the years employees working in or near Department 475 (Wheel Assembly) had undergone surgery for nerve and tendon deterioration of the hand, wrist and elbow, and treatment for low back sprains/strains. The requestors also asked NIOSH to evaluate potential exposure hazards for "ARC" and "MIG" welders assigned to Department 475.

The company fabricates wheels for trucks and buses. When NIOSH investigators conducted the initial site visit (August 10-11, 1988), 560 workers were employed at the plant. During this visit environmental air samples were collected to evaluate wheel assembly workers' exposures to welding fumes and metal grinding dusts. Additionally, Clean and Finish Operators and Touch-up Painters were also monitored for exposures to organic vapors released during wheel painting operations. Company-maintained OSHA 200 Logs and plant medical records were reviewed by the NIOSH medical officer. NIOSH investigators made a follow-up visit on January 30-31, 1989, to conduct an in-depth ergonomic analysis of certain job tasks which appeared to present ergonomic hazards for back injury.

The results from the NIOSH industrial hygiene survey revealed that production workers were not exposed to excessive concentrations of welding fumes, grinding dusts, or volatile organic compounds (VOCs) during the time the environmental samples were collected. Specific metals identified in the welding fume and grinding dust air samples were mostly iron oxide, with trace amounts of manganese, titanium, and zinc. Detectable exposures to iron oxide dust and fume ranged from 0.05 to 0.71 milligrams per cubic meter (mg/m$^3$). The highest exposures detected for manganese, titanium and zinc were, respectively, 0.04, 0.03, and 0.01 mg/m$^3$. The highest air concentrations detected for specific VOCs released from wheel painting operations were 0.1 parts per million (ppm) methyl isobutyl ketone (MIBK), 2.15 ppm toluene, 1.9 ppm xylene, 0.72 ppm ethylene glycol monobutyl ether (EGMBE), 5.77 ppm ethylhexanol, and 0.45 ppm ethylene glycol monohexyl ether (EGMHE). These concentrations were all well below applicable exposure criteria.

A review of occupational injuries was performed using data from OSHA Logs (January 1986 to December 1987) and plant medical dispensary logs for the year 1987. Comparison rates were obtained using the 1987 Bureau of Labor Statistics (BLS) injury incidence data. The company's overall musculoskeletal injury rate was 26.1 per 100 full-time workers per year, which exceeded the rate of 10.6 injuries per 100 workers per year based on 1987 BLS injury rates for motor vehicle parts manufacturers (SIC 3714). Back injuries comprised the largest group of musculoskeletal disorders within this workforce (57%), and the overall back injury rate of 11.3 per 100 workers per year was greater than five times the back injury rate for the industrial population. Wheel Assembly and Disc Departments had the highest back injury rates (24 and 20 per 100 workers per year, respectively).

At about the time that the request was submitted to NIOSH, the company had obtained the assistance of a private consultant in industrial ergonomics to address the company's concerns about musculoskeletal problems in the workforce. Rather than duplicate ergonomic efforts, the NIOSH investigators decided to await the completion of the consultant's report before proceeding further. The consultant evaluated the activities at the plant, and in late November 1988 submitted a comprehensive report that recommended wide ranging improvements in the material handling practices used at the factory. After receiving a copy of this report, the NIOSH investigators returned to the plant in order to study the back injury problem in more detail and to evaluate the recommendations that had been made by the company's ergonomist. Three tasks were evaluated in detail by the NIOSH ergonomist. The analysis revealed that the average weight lifted in all 3 tasks exceeded the action limit, and, in all but one instance, also exceeded the maximum permissible limit recommended by NIOSH's Work Practices Guide for Manual Lifting. The consultant's report was found to contain a comprehensive analysis of the many ergonomic hazards at the plant, and to present suitable recommendations to redesign those hazardous tasks.

Environmental air sampling results for welding fumes, metal grinding dusts, and volatile organic compounds from painting operations did not exceed NIOSH's environmental criteria. Results from the ergonomic evaluation performed by NIOSH revealed that the average weight of objects being handled during the performance of the three tasks examined exceeded the action limit and, in all but one instance, also exceeded the maximum permissible limit recommended by NIOSH's Work Practices Guide for Manual Lifting. Therefore, specific recommendations for task redesign are made in Section X.

KEYWORDS: SIC 3714 (Motor Vehicle Parts and Accessories), welding-fume, metal-dusts, musculoskeletal injuries, ergonomics, manual-lifting

## II. INTRODUCTION

On May 31, 1988, the National Institute for Occupational Safety and Health (NIOSH) received a confidential request for a health hazard evaluation at the Accuride Corporation in Henderson, Kentucky. The request stated that over the years employees working in or near Department 475 (Wheel Assembly) had undergone surgery for nerve and tendon deterioration of the hand, wrist and elbow, and treatment for low back sprains/strains. The requestors asked NIOSH to evaluate potential exposure hazards for "ARC" and "MIG" welders assigned to Department 475. In addition to welding fume exposures, there was concern about the use of two chemical substances, one identified as "AS-12A" and the other called "Liquid Envelope." AS-12A, which is 72-75% trichlorotrifluoroethane, had been used to prevent weld splatter from sticking to the wheel surface. It was used in Department 475 from March 1983 to December 1987. Because of worker concerns about using a solvent-based material in a welding environment, the company replaced the product with a water-diluted surfactant containing no organic solvents.

NIOSH investigators conducted their initial site visit on August 10-11, 1988. The initial evaluation involved reviewing OSHA 200 Logs and other pertinent records, conducting medical interviews with employees, and collecting environmental samples to evaluate worker exposures. To conduct an in-depth ergonomic analysis of certain job tasks, NIOSH investigators conducted a follow-up survey on January 30-31, 1989. This ergonomic investigation involved an analysis of three job tasks; methods included reviewing videotapes and 35-mm photographs, and making various static measurements at the work sites. Interim reports were sent September 9, 1988 and March 27, 1989.

## III. BACKGROUND

### A. Work Force

The Accuride Corporation manufactures steel wheels for large trucks and buses. Formerly owned by Firestone, the plant was opened in 1974. At the time of the NIOSH survey, the plant operated three work shifts per day and employed about 560 production workers.

### B. Process Description

Major production processes were contained in the Rim, Disk, Assembly, and Painting Departments. Both coiled steel stock and pre-cut steel strips feed the Rim lines, where flat steel strips are shaped and circled into rims. Resistance welding machines then weld the ends of each rim together. In the Disk Department, huge punch press machines cut out disks (5 or 6 at a time) from coiled steel stock. The disks are then sent through a "spinner" machine to form the bowl-shaped center portion of the wheel. Before final assembly, the bowls are pierced to create hub, bolt and hand holes.

In the Assembly Department, rims and bowls are washed and manually off-loaded from a J-hook conveyer and then mounted in an assembly press to squeeze the rim and and bowl together to produce the assembled wheel. The wheel assembly is then spray-coated with the anti-splatter compound in an exhaust vented enclosure. This compound is sprayed on the wheels to prevent weld splatter from permanently sticking to the wheel. After spraying, each wheel assembly is welded together inside an exhaust-vented welder machine. After welding, each wheel is then sent through an exhaust-vented brushing machine to remove the weld splatter from the front surface of the wheel. Wheels coming from the brush machine then receive final inspection. Rejected wheels are diverted to a repair welder station, where defective welds are manually re-done. After inspection, the wheels are loaded on another J-hook conveyer and sent through the Painting Department, where they are cleaned and finish coated in an electro-deposition dip tank system. All wheels receive either a gray or white finish. After painting, workers off-load the J-hook conveyer and stack wheels in carts for shipment.

## IV. EVALUATION DESIGN AND METHODS

### A. Environmental

During the initial site visit, air samples were collected to evaluate exposures to welding fumes for assembly line welders, production welders working on rim lines, and repair welders working on the assembly lines and in Central Repair. Also monitored for metal fume and dust exposure were a worker operating a grinder in central repair and a quality assurance inspector working near a brush machine on assembly line 468. According to union and management representatives, the locations sampled had the greatest potential for welding fume or grinding dust exposure.

Clean and Finish operators and touch up painters were monitored for exposures to organic vapors released during wheel painting operations. Reports from past inspection surveys were reviewed. Copies of the more recent survey reports were given to the NIOSH investigators. Material Safety Data Sheets were obtained for the wheel paints and for the welding wire used on the assembly lines. Photographs were taken of various production operations.

#### 1. Welding Fume and Grinding Dust Exposure Samples

Air samples were collected on mixed cellulose ester filters housed in three piece plastic cassettes. To collect personal breathing zone samples on welders, the cassettes were kept inside the welding helmets. Each filter cassette was connected via plastic tubing to a battery-powered air sampling pump worn by the worker. All pumps used were pre-calibrated to pull air through the filter at a flow rate of 1 liter per minute (Lpm). Using an inductively coupled plasma atomic emission spectrometer (ICP/AES), the NIOSH contract laboratory identified and quantitated individual trace elements collected on the filter by NIOSH Method 7300.[1]

#### 2. Organic Vapor Samples

To monitor exposures to paint vapors, one area and five personal breathing zone air samples were collected on organic vapor-absorbing charcoal tubes. The charcoal tubes were mounted in plastic holders and clipped to the sampled worker's shirt collar. The area air sample was collected near the gray clean and finish line. This sample was analyzed by gas chromatography/mass spectrometry (GC/MS) to identify individual organic vapors released from wheel painting operations. Each sampling tube holder was connected via plastic tubing to a battery-powered air sampling pump, which pulled air through the tube at a flow rate of about 100 cubic centimeters of air per minute. After sampling, the charcoal tubes were capped and sent to the NIOSH laboratory for analysis. Specific VOCs selected for quantitation were the predominant compounds identified by GC/MS from the area air sample collected near the clean and finish line.

B. Medical

During the initial site visit our review of the OSHA Form 200 (Log and Summary of Occupational Injuries and Illnesses) for 1986 and 1987 revealed that many musculoskeletal disorders had occurred among Accuride workers. These disorders included numerous cases of lumbosacral strain, in addition to carpal tunnel syndrome, and tendinitis, which are musculoskeletal conditions associated with cumulative trauma. To determine if employment in certain departments presented an elevated risk for musculoskeletal injury, department injury incidence rates were calculated on the basis of reports in the company-maintained OSHA 200 logs. An assessment of the accuracy of OSHA Log reporting at the company was done by comparing these data with medical dispensary visit logs for 1987.

Musculoskeletal injuries in this evaluation referred to all soft tissue disorders which were a direct result of a work-related injury. The group of disorders consisted primarily of back strains, as well as strains and sprains of the upper extremities, carpal tunnel syndrome (both probable and definite), and tendinitis. Back injuries included strains and sprains of the back, degenerative disc disease, as well as ill-defined pain. Back conditions other than strain accounted for less than 6% of all back injuries.

The term cumulative trauma disorder (CTD) refers to a category of musculoskeletal injuries that are caused, precipitated or aggravated by repeated exertions or movements of the body. A main distinction between CTDs and strain and sprain injuries is that the latter usually appear to result from a single act, including injury while falling or slipping, i.e. acute trauma. Unlike the causes of strains and sprains, there are few if any distinctive features surrounding the onset of CTDs, which are thought to result from excessive musculoskeletal system use over time, rather than a specific "accident" or event.

C. Ergonomic

During the follow-up visit the company's safety engineer accompanied the NIOSH survey team on a tour of the plant. After this tour, tasks in Departments 454 (Disk) and 475 (Wheel Assembly) that appeared to present the greatest risk for musculoskeletal injuries were observed. The potentially hazardous tasks in Department 475 included wash line loading, wheel press, coin press, welding, inspection, repair, as well as white paint line, disc cell trim, and wash line loading operations. Three of these tasks (which appeared to present significant ergonomic hazards for back injury: white paint line unloading, disc cell trim, and wash line loading operations) were chosen for indepth ergonomic evaluation and analysis by the NIOSH investigators.
The NIOSH survey team's study method was similar in design to that of the ergonomics consultant

hired by Accuride to evaluate work tasks in the plant during September and October of 1988. The NIOSH ergonomics evaluation consisted of the following tasks:

1. Analysis of the injury records.
2. Videotaping of the selected jobs.
3. Task analysis for the selected jobs.
4. Biomechanical analysis of the stresses imposed on the workers for selected jobs.
5. Evaluation of the risk of injury to the workers and grouping of jobs into risk factor categories.
6. Job re-design recommendations related to workplace layout, material handling procedures, and equipment needed for mechanization of the critical and/or important jobs.

The unload white paint line, disc cell trim, and wash line load jobs were analyzed using videotape, 35-mm photographs, static measurements, and interviews with the workers at risk for injury in these three jobs. Analysis of other jobs was not done because a comprehensive task analysis had previously been completed by Accuride's consultant.

# V. EVALUATION CRITERIA

## A. Environmental Criteria

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff use environmental evaluation criteria for assessment of many 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. However, 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, 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 level 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 which could potentially increase the total exposure. Lastly, evaluation criteria may change over the years as new information on the toxic effects of an agent becomes available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH criteria documents and recommendations, (2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs),[2] and (3) the U.S. Department of Labor (OSHA) occupational safety and health standards.[3] Often, the NIOSH recommendations and ACGIH TLVs are lower than the corresponding OSHA standards. Both NIOSH recommendations 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-recommended exposure limits (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, employers should note that they are legally required 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.

Because the composition of welding fume varies for different welding processes, NIOSH no longer uses the total welding fume exposure criteria of 5 mg/m$^3$ recommended by the American Conference of Governmental Industrial Hygienists (ACGIH). Because of possible interaction of the individual chemical or physical agents present in welding emissions, NIOSH recommends reducing exposures to the lowest concentrations technically feasible using engineering controls and good work practices. The current exposure limits for the individual components in the welding fume are considered the "upper boundaries of exposure."[4] The established limits of exposure for the toxic substances monitored during the environmental survey, as specified by either NIOSH, OSHA, or the ACGIH, are presented in Table 1.

For the purposes of this evaluation, NIOSH has selected the most stringent exposure limits as the evaluation criteria. The major health effects anticipated for workers exposed above these evaluation criteria are summarized in Table 1. Currently there are no established criteria for 2-ethyl-1-hexanol (ETHEX) and ethylene glycol n-hexyl ether (EGMHE).

## B. Low Back Pain

In most cases of low back pain, a specific cause (e.g., herniated disk) for the pain cannot be determined. Such cases without a specific cause are usually diagnosed as back strain or sprain. Low back symptoms typically begin during young adulthood, with a rising prevalence until the fourth and fifth decades, with an apparent leveling off after about age 45.[5] The usefulness of preplacement low back x-rays has been addressed by several investigators, with the majority concluding that such x-rays are poorly predictive of future back pain.

Although there is some variation with respect to gender differences from one study to another, men and women generally appear equally likely to be affected with low back pain. However, Magora has reported that women had a higher incidence of low back pain in occupations demanding strenuous physical efforts.[6]

It is postulated that good general physical fitness may protect individuals from incurring back pain. A prospective study done by Cady, et al. demonstrated that the least fit group of firefighters was ten times more likely to experience low back pain than the the most fit group of these workers.[7]

An attempt has been made by investigators to correlate job type with low back pain incidence. According to recent Bureau of Labor Statistics data, the highest incidence of back injuries occurs among the construction and mining industries, followed closely by the trucking industry. Data are inconsistent to support the postulation that the worker in heavy industry is more susceptible to back injury. However, it appears likely that certain job tasks (primarily lifting) may play a role in the development of low back pain. Snook found that handling tasks were associated with 70% of low back injuries.[8] In lifting injuries, the weight of the object has been implicated; in a recent study, more than half of the injured workers had lifted objects weighing at least 60 pounds.[9]

C. Ergonomic

The NIOSH Work Practices Guide for Manual Lifting[10] and the University of Michigan, 2-D Static Strength Biomechanical Analysis Program[11] were used to evaluate the unloading of wheels from the white paint line, disc cell trimming, and wash line loading operations. The NIOSH Work Practices Guide provides guidelines for the limits for low back compression forces and strength required to perform manual material handling tasks. The 2D Static Strength Prediction Program™ is a microcomputer sofware program used to predict human static strength requirements to perform various manual materials handling tasks, such as pushes, lifts, and pulls. It also estimates low back spinal compression forces experienced during these exertions.

## VI. RESULTS

A. Environmental

The results obtained from the welding fume and grinding dust samples are shown in Table 2. The metals found in the welding fume at Accuride were mostly iron oxide, plus trace amounts of manganese, titanium, and zinc. All compounds detected were well below their established exposure limits. All iron oxide exposures were below 1 mg/m$^3$.

The chromatogram obtained from the GC/MS analysis of the area sample, collected near the clean and finish line, is shown in Figure 1, with identified peaks labelled. Major compounds found were 2-ethyl-1-hexanol (ETHEX), xylene, 1-methoxy-2-propanol, methyl isobutyl ketone (MIBK), butyl cellosolve (2-butoxyethanol), ethylene glycol n-hexyl ether (EGMHE), and 1,1,1-trichloroethane.

Based on the GC/MS analytical results, the remaining five personal air samples were quantitated for MIBK, toluene, xylene, ethylene glycol monobutyl ether (2-butoxyethanol), ETHEX, and EGMHE. These analyses detected no exposures that exceeded OSHA permissible exposure limits or the NIOSH recommended exposure limits. The highest exposure detected was to ETHEX, 5.77 ppm, for the gray line Clean and Finish Operator. Because there is no established exposure limit for ETHEX, NIOSH investigators were unable to determine if this exposure was excessively high. Apparently, large quantities of ETHEX have been used for many years in industry without reports of adverse health effects.[12] Exposures detected are shown and compared with established exposure limits in Table 3. Considering the strong, and sometimes irritating, paint odors experienced by the NIOSH industrial hygienist when collecting air samples near the Clean and Finish dip tanks, the air sampling results were lower than expected. These strong odors were the result of paint vapors escaping from the dip tank enclosure room, which was over-pressured from a recently installed paint line "blow-off" system. Apparently, the workers monitored avoided these areas during the time they wore sampling pumps.

## B. Medical

For the 2-year study period there were 588 OSHA Log entries for injuries. Two hundred ninety-seven of these were excluded from our analysis because they involved eye injuries, burns, fume inhalations, contusions, lacerations, or fractures. Table 4 shows that, of the remaining 291 musculoskeletal injuries, 219 were strains and sprains, 34 were CTDs and 38 were others (primarily bursitis, inguinal hernias, ligament tears, etc.) Our comparison of plant dispensary log visits with OSHA Log entries indicated that, for the year 1987, injuries were being accurately reported in the OSHA Log.

The total number of cases of strains, carpal tunnel syndrome, tendinitis, and miscellaneous musculoskeletal injuries, and the number of workers in each department (calculated assuming each employee works 2,000 hours per year) were used to compute the departmental musculoskeletal injury incidence rate. The total musculoskeletal injury rate for the plant was 26.1 per 100 workers per year; this number exceeded the expected rate of 10.6 injuries per 100 workers/year based on the 1986 Bureau of Labor Statistics for motor vehicle parts manufacturers.

Back injury (primarily low back strain) comprised the largest proportion of injuries in the strain/sprain group. One hundred twenty-five out of 219 (57%) of all strain injuries involved the back. The overall plant incidence rate for back injury was 11.3 per 100 workers per year. Since the expected annual incidence of back injuries in the industrial workforce is only 2/100 workers/year, this constitutes an approximate 5-fold excess (Table 5).

Based on the calculations of back injury rates by gender (Table 6), the plant's rates for back injury appear to be similar for men and women. Females, however, had a higher incidence of musculoskeletal injuries overall (37.8 injuries per 100 full-time workers per year) than males (24.5 injuries per 100 full-time workers per year).

The Disc Department had the highest injury rate for carpal tunnel syndrome, 7.0 cases per 100 workers per year, followed by the Wheel Assembly with 2.5 cases per 100 workers per year, and the Rim Department with 1.7 cases per 100 workers per year. Among these three departments, the only cases of tendinitis were recorded in the Disc Department, with an injury rate for this disorder of 3 per 100 workers per year. The remaining cases of tendinitis were dispersed throughout other departments in the plant. In the Disc, Wheel, and Rim departments, carpal tunnel syndrome resulted in a mean of 87 missed work days, over 3 times as many as back injuries (Table 7).

## C. Ergonomic

At about the time that the health hazard evaluation request was submitted, the company had obtained the assistance of a private consultant in industrial ergonomics to address the company's concerns about musculoskeletal problems in the workforce. Rather than duplicate ergonomic efforts, NIOSH investigators decided to await the completion of the consultant's report before proceeding further. The consultant evaluated the jobs at the plant, and in late November 1988 submitted a comprehensive report that recommended wide-ranging improvements in the material handling practices at the factory. After receiving a copy of this report, the NIOSH investigators returned to the plant in order to study the back injury problem in more detail and to evaluate the recommendations that had been made by the ergonomist retained by the company. During the return investigation conducted on January 30-31, 1989, three job tasks which appeared to present significant ergonomic hazards for back injury were evaluated. These jobs were analyzed using videotape, 35-mm still pictures, and static measurements. Additionally, randomly selected workers were interviewed to ascertain the nature and severity of their injuries. These workers associated their injuries with straining to lift heavy objects and noted differences in severity ranging from mild low back pain of brief duration to incapacitating back pain lasting for weeks. The three tasks evaluated were:

1. Unload Paint Line

   The average weight of the wheels that were handled on the line was 78 pounds. This weight exceeded the action level (AL) and maximum permissible limit (MPL) as calculated using the NIOSH Work Practices Guide for Manual Lifting.

   (Engineering controls based on the company consultant's recommendations have been applied to this task, and it has been redesigned. The workers now use a manually-operated over-head mechanical lift assist device to unload the wheels from the paint line conveyor onto the shipping pallets. The original ergonomic problem identified in this task has been addressed.)

2. Disc Cell Trim

   The average weight of the disc that was handled in this operation was 36 pounds. This weight exceeded the AL in all cases, and the MPL in all but one height configuration, Disc Cell Trim/High. This job was being redesigned and also was being considered for full mechanization in the future. The use of a mechanical tilt/lift device was being evaluated for this task).

3. Load Wash Line

   The average weight of the wheels that were handled on this line was 54 pounds. This weight exceeds the AL and MPL. (Management had scheduled this job for evaluation and redesign.)

   For the 3 tasks discussed above, the L5/S1 back compressive forces calculated in the company consultant's study using Biomechanics Corporation of America BackSoft Program were compared with the L5/S1 forces calculated using the University of Michigan, 2-D Static Strength Biomechanical Analysis Program. The findings of these two analyses yielded very similar results.

## VII. DISCUSSION

### A. Environmental

Some assembly line welders expressed concern about the company's previous practice of welding wheel assemblies coated with chlorofluorocarbon containing solvent such as AS-12A. They speculated that this was a possible source of airborne fluorides, released by thermal degradation as hydrofluoric acid. There was concern that this fluoride exposure could produce flourosis (osteosclerosis due to deposition of fluoride from repeated exposures to high fluoride concentrations over a period of years). Since AS-12A was no longer used, this potential hazard could not be evaluated by the NIOSH investigators. However, it seems an unlikely source, because most of the AS-12A was applied under a local exhaust hood. By the time wheels were transported to the welding bench, most of the trichlorotrifluoroethane would have evaporated. Even more important, welding fumes and other emissions from the assembly line welding machines were captured by local exhaust systems, which at the time of the NIOSH survey appeared to be working effectively.

Although another source of fluorides was found (welding wire Fabco RXR, used on assembly lines 477, 468, 478, and 469, contains fluorspar, and the MSDS for this wire lists fluorides as a "reasonably expected constituent of the welding fume") the results from personal air samples taken from assembly line welders show very low exposures to welding fume. For example, the total welding fume concentration detected for the assembly line welders ranged from 0.06 to 0.1 $mg/m^3$. The NIOSH REL and OSHA PEL for inorganic fluorides are 2.5 $mg/m^3$; this limit was established to prevent complaints of eye and respiratory irritation.[13]

Previously, the company spray-painted some wheels with a top coat paint in various colors. To keep paint from building up on the inside walls of the top coat spray booth, a protective coating of "Liquid Envelope," manufactured by the Red Spot Paint and Varnish Company, was sprayed inside the top coat spray booth. When paint over-spray built up on the booth, the coating was pealed away to remove the paint. Vapors released when applying a new coat of Liquid Envelope to the spray booth was a source of complaint for some assembly line welders. At the time of the site visit, the company only produced wheels painted white or gray in an electro-plating dip tank. Because the wheels were no longer spray painted, except for minor touchup, these painting booths were no longer needed and Liquid Envelope was no longer used. Thus, potential exposure hazards from applying this product could not be evaluated by the NIOSH investigators. According to the MSDS, solvents contained in Liquid Envelope included toluene (35%), acetone (30%), isophorone (less than 5%), and methyl ethyl ketone (less than 5%).

B. Medical and Ergonomic

Back pain continues to be identified as a major health problem among industrial workers. Among the ten leading work-related diseases and injuries suggested by NIOSH, musculoskeletal disorders rank second, preceded only by respiratory diseases.[4] Back injuries are the most costly of the musculoskeletal disorders. The largest single category of back injuries is the strain/sprain group, which accounts for 85% of the claims for compensation. At an estimated cost of approximately 14 billion dollars per year, the economic cost to our society is profound. The evaluation of work practices and injury records at this company showed that workers faced an elevated risk of back and other musculoskeletal injury. Fortunately, the company has recognized the problem and has undertaken a comprehensive program to modify hazardous tasks. An ergonomic committee has been formed, and considerable funds have been committed to provide ergonomic improvements in the plant.

## VIII. CONCLUSIONS

1. Results from the industrial hygiene survey showed production workers were not exposed to excessive concentrations of welding fumes, grinding dusts, or volatile organic compounds (VOCs) during the time environmental samples were collected. Specific metals identified in the welding fume and grinding dust air samples were mostly iron oxide, with trace amounts of manganese, titanium, and zinc.

2. The overall musculoskeletal injury rate at this company was much higher than the expected rate for motor vehicle parts manufacturers. Since lacerations, contusions, fractures, and other injuries were not included in the calculation of this rate, this injury rate represents a conservative (low) estimate.

3. Almost 60% of the musculoskeletal injuries were back injuries, and about one-fourth of the total workforce incurred disabling back injuries each year.

4. In order to identify the cause for these elevated injury rates, ergonomic evaluations were performed by a consultant. Many tasks were identified that required modification and recommendations regarding job task redesign were made.

## IX. GENERAL RECOMMENDATIONS

1. Eliminate pulling and pushing tasks.

2. Eliminate below-waist-level lifting tasks.

3. Eliminate manual material handling tasks above shoulder height.

4. Install tilt/lift tables at selected jobs to reduce or eliminate lifting, bending, and reaching tasks.
5. Redesign, automate, or mechanize production lines to reduce the need for manual material loading and unloading activities.

6. Encourage worker participation in job redesign.

7. Encourage workers to interrupt sustained flexion postures during their work shift by performing trunk extension and upper extremity range-of-motion exercises.

8. Conduct in-service training sessions to educate workers on the benefits of cardiopulmonary fitness and proper body mechanics.

## X. SPECIFIC RECOMMENDATIONS

### A. Unload Paint Line

Critical Factors: Bending, twisting, heavy loads, high frequency of lifts, pinching.

Potential for Injury: Back sprains/strains, overexertion, cumulative trauma disorders of the upper extremities.

Recommendations:

1. Use mechanical lifting devices. (Implemented 1988)
2. Install rotating/hi-lo tables. (Implemented 1988)
3. Rotate workers.
4. Encourage workers to perform trunk extension and upper extremity range-of-motion exercises to off-set sustained flexion postures.

### B. Disc Cell Trim

Critical Factors: Bending, twisting, moderate loads, moderate frequency of lifts, pinching, and wrist deviation.

Potential for Injury: Back sprain/strain and cumulative trauma disorders.

Recommendations:

1. Eliminate the manual materials handling task through engineering redesign.
2. Install a tilt/lift table.
3. Encourage workers to perform trunk extension and upper extremity range-of-motion exercises to off-set sustained flexion postures.

### C. Load Wash Line

Critical Factors: Bending, twisting, lifting from above shoulder height.

Potential for injury: Back sprain/strain, upper extremity sprain/strain, cumulative trauma disorders to the upper extremities.

Recommendations:

1. Use a mechanical lifting device.
2. Install rotating tables.
3. Eliminate manual material handling task through engineering redesign.
4. Encourage workers to perform trunk extension and upper extremity range of motion exercises to off-set sustained flexion postures.

## XI. REFERENCES

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## XIII. DISTRIBUTION AND AVAILABILITY OF REPORT

Copies of this report are temporarily available upon request from NIOSH, Hazard Evaluations and Technical Assistance Branch, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through the National Technical Information Service (NTIS), 5285 Port Royal, Springfield, Virginia 22161. Information regarding its availability through NTIS can be obtained from the NIOSH Publications Office at the Cincinnati, Ohio address. Copies of this report have been sent to:

1. The Accuride Corporation, Henderson, Kentucky
2. United Auto Workers, Local 2036
3. United Auto Workers National Headquarters
4. NIOSH Atlanta Regional Office
5. OSHA Region IV

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

TABLE 1 - EVALUATION CRITERIA / HETA 88-277 / ACCURIDE CORPORATION, HENDERSON, KENTUCKY

**Recommended Exposure Limits Airborne Dusts and Fumes From Welding or Grinding Steel Wheels**

| SUBSTANCE | NIOSH | ACGIH | OSHA | HEALTH EFFECTS |
|---|---|---|---|---|
| | | (as $mg/m^3$) | | |
| Iron Oxide | -- | 5 | 10 | Benign pneumoconiosis |
| Manganese Fume | -- | 1 | 1 | Metal fume fever, central |
| (STEL) | -- | 3 | 3 | nervous system effects, pneumonia |
| Titanium Dioxide | -- | 10 | 10 | Slight lung fibrosis |
| Zinc Oxide Fume | 5 | 5 | 5 | Metal fume fever |
| (STEL) | 15 | 10 | 10 | |

**Volatile Organic Compounds From Paint and Finish Lines**

| SUBSTANCE | NIOSH | ACGIH | OSHA | HEALTH EFFECTS |
|---|---|---|---|---|
| | | (as ppm) | | |
| MIBK | 50 | 50 | 50 | Irritation, liver, kidney, and |
| (STEL) | -- | 75 | 75 | nervous system effects |
| Toluene | 100 | 100 | 100 | Central nervous system |
| (STEL) | 200 | 150 | 150 | depressant |
| Xylene | 100 | 100 | 100 | Central nervous system |
| (STEL) | 200 | 150 | 150 | depressant, irritation |
| EGMBE | -- | 25 | 25 | Eye nose and throat irritation, hemolysis, hemoglobinuria |
| ETHEX | -- | -- | -- | Eye irritation, reproductive effects |
| EGMHE | -- | -- | -- | Severe eye irritant by direct contact, central nervous depressant, skin absorbtion |

Note: All values above are for 8-hour Time Weighted Average (TWA) exposures unless otherwise noted. The TWAs are believed to be 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. STEL = Short Term Exposure Limit (15-minutes)

TABLE 2
WELDING FUME EXPOSURES
HETA 88-277
ACCURIDE CORPORATION
HENDERSON, KENTUCKY
August 9-10, 1988

| SAMPLE NUMBER | SAMPLE DESCRIPTION | TIME START | TIME STOP | TIME HR:MN | IRON $mg/m^3$ | MANGANESE $mg/m^3$ | TITANIUM $mg/m^3$ | ZINC $mg/m^3$ |
|---|---|---|---|---|---|---|---|---|
| **RIM LINE** | | | | | | | | |
| AA-1 | Butt welding, line 436 | 07:35 | 15:07 | 07:32 | 0.10 | ND | ND | ND |
| AA-2 | Butt welding, line 427 | 07:39 | 15:05 | 07:26 | 0.15 | ND | ND | ND |
| **CENTRAL REPAIR** | | | | | | | | |
| AA-3 | Station 2 welder | 07:46 | 14:21 | 06:35 | 0.08 | ND | ND | 0.01 |
| AA-4 | Station 3 welder | 07:50 | 14:19 | 06:29 | 0.48 | ND | ND | ND |
| AA-5 | Station 2 grinder | 07:54 | 14:22 | 06:28 | 0.11 | 0.01 | ND | ND |
| **ASSEMBLY** | | | | | | | | |
| AA-7 | Repair welder, line 476 | 08:07 | 14:57 | 06:50 | 0.22 | 0.02 | ND | ND |
| AA-8 | QA, brush mach line 468 | 08:16 | 15:11 | 06:55 | 0.71 | 0.04 0.03 | ND | |
| AA-9 | Rep. weld., lines 468/477 | 08:20 | 14:23 | 06:03 | 0.16 | 0.01 | ND | ND |
| AA-10 | Welder operator, line 477 | 08:26 | 14:18 | 05:52 | 0.05 | 0.01 | ND | 0.01 |
| AA-11 | Welder operator, line 469 | 11:00 | 15:27 | 04:27 | 0.09 | 0.01 | ND | ND |
| Evaluation Criteria: ACGIH TLV (8-hour TWA) | | | | | 5 | 1 | 10 | 5 |
| ACGIH STEL (15-minute) | | | | | -- | 3 | -- | 10 |
| NIOSH REL (8-hour TWA) | | | | | -- | -- | -- | 5 |
| OSHA PEL (8-hour TWA) | | | | | 10 | 5 (c) | 10 | 5 |

(c) designates a ceiling limit

ND = None Detected
PEL = Permissible Exposure Limit
STEL = Short-Term Exposure Limit
REL = Recommended Exposure Limit
TLV = Threshold Limit Value
$mg/m^3$ = Milligrams per cubic meter

TABLE 3
PAINT VAPOR EXPOSURES
HETA 88-277
ACCURIDE CORPORATION
HENDERSON, KENTUCKY
August 9-10, 1988

| SAMPLE NUMBER | SAMPLE DESCRIPTION | TIME START | TIME STOP | TIME HR:MN | MIBK ppm | TOLUENE ppm | XYLENE ppm | EGMBE ppm | ETHEX ppm | EGMHE ppm* |
|---|---|---|---|---|---|---|---|---|---|---|
| CT-1 | Touch up, white | 08:31 | 15:17 | 06:46 | ND | 2.15 | 1.92 | ND | ND | ND |
| CT-2 | Touch up, gray | 08:38 | 14:30 | 05:52 | (0.01) | ND | ND | (0.05) | (0.22) | ND |
| CT-3 | Clean & Finish, gray | 08:56 | 14:53 | 05:57 | 0.10 | ND | ND | 0.72 | 5.77 | 0.45 |
| CT-4 | Clean & Finish, White | 09:01 | 10:55 | 01:54 | (0.04) | ND | ND | (0.33) | 0.94 | 0.16 |
| CT-6 | Clean & Finish, White | 10:55 | 15:10 | 04:15 | (0.02) | ND | (0.24) | 0.22 | 0.60 | 0.10 |
| Evaluation Criteria: ACGIH TLV (8-hour TWA) | | | | | 50 | 100 | 100 | 25 | -- | -- |
| ACGIH STEL (15-minute) | | | | | 75 | 150 | 150 | -- | -- | -- |
| NIOSH REL (8-hour TWA) | | | | | 50 | 100 | 100 | -- | -- | -- |
| OSHA PEL (8-hour TWA) | | | | | 50 | 200 | 100 | 50 | -- | -- |

(c) designates a ceiling limit
* These results were quantitated using EGMBE as a standard and should therefore be considered approximations.

| | MIBK | TOLUENE | XYLENE | EGMBE | ETHEX | EGMHE |
|---|---|---|---|---|---|---|
| Limit of Detection (as micrograms per sample) | 1 | 17 | 13 | 9 | 15 | 9 |
| Limit of Quantitation (micrograms per sample) | 3 | 52 | 38 | 28 | 48 | 28 |

Note: Values in parentheses were below the limit of quantitation
Values identified as ND were below the limit of detection
PEL = Permissible Exposure Limitm g/m$^3$ = Milligrams per cubic meter
EGMBE = ethylene glycol monobutyl ether (2-butoxyethanol) REL = Recommended Exposure Limit
MIBK = methyl isobutyl ketone EGMHE = ethylene glycol monohexyl ether ND = None Detected
TLV = Threshold Limit Value ETHEX = 2-ethyl-1-hexanol STEL = Short-Term Exposure Limit

TABLE 4
MUSCULOSKELETAL INJURIES BY DIAGNOSIS, 1987-1988

HETA 88-277
ACCURIDE CORPORATION
HENDERSON, KENTUCKY

| DIAGNOSIS | OSHA LOG CASES | IR* |
|---|---|---|
| strains/sprains | 219 (75%) | 19.7 |
| carpal tunnel syndrome | 17 (6%) | 1.5 |
| tendinitis | 17 (6%) | 1.5 |
| others | 38 (13%) | 3.4 |
| TOTAL | 291 (100%) | 26.1 |

* IR (incidence rate) = number of injuries/100 full-time workers/year

TABLE 5
BACK INJURIES (Annual Incidence Rates), 1987-1988
HETA 88-277
ACCURIDE CORPORATION
HENDERSON, KENTUCKY

| DEPARTMENT | EMPLOYEES* | BACK CASES** | IR*** |
|---|---|---|---|
| Assembly | 59 | 14 | 23.7 |
| Disc | 50 | 10 | 20.0 |
| Rim | 118 | 14 | 11.9 |
| All Others | 330 | 25 | 7.4 |
| TOTAL | 557 | 63 | 11.3 |

* average number of full time employees/year based on each full time employee working 2080 hours per year

** average number of back injuries/year

*** IR (incidence rate) = number of injuries/100 full-time workers/year

TABLE 6
INJURY RATES* BY GENDER

HETA 88-277
ACCURIDE CORPORATION
HENDERSON, KENTUCKY

| | All Musculoskeletal Injuries | Back Injuries |
|---|---|---|
| Females | 37.8 | 11.6 |
| Males | 24.5 | 11.3 |

* Injury rate = number of injuries/100 full-time worker/year

TABLE 7
DAYS MISSED DUE TO INJURIES, Disc, Wheel, and Rim Departments 1987-1988
(mean number)

HETA 88-277
ACCURIDE CORPORATION
HENDERSON, KENTUCKY

| | |
|---|---|
| All Musculoskeletal Injuries Combined | 27 |
| Back Injuries | 25 |
| Carpal Tunnel Syndrome | 87 |
| Tendinitis | 9 |
| Others | 24 |