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HARVARD INDUSTRIES, INC.
TRIM TRENDS DIVISION
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I. SUMMARY

In January 1991, the National Institute for Occupational Safety and Health (NIOSH) received a joint request from management and the Allied Industrial Workers of America (AIW), Local 107, to evaluate health concerns related to repetitive motion, welding fumes, and grinding dust at Harvard Industries, Inc. in Bryan, Ohio. On August 13-14, 1991, NIOSH representatives conducted a site visit to the facility's Trim Trends Division.

Nine personal breathing zone (PBZ) samples and one area air sample were collected to determine metal exposures in the welding and grinding areas. Two filters were analyzed by phase contrast microscopy to determine the percentage of respirable size particles (<10 micrometers [µm] in diameter). Material safety data sheets (MSDSs) were reviewed, and work practices and engineering controls were evaluated. Air movement was evaluated using smoke tubes. Thirteen employees participated in voluntary private medical interviews. Occupational Safety and Health Administration (OSHA) 200 logs were reviewed for documentation of repetitive movement injuries.

Sample concentrations for iron, magnesium, manganese, and zinc (0.001 to 0.266 milligrams per cubic meter [mg/m^3]) were below existing guidelines and standards established by NIOSH, OSHA, and the American Conference of Governmental Industrial Hygienists (ACGIH). One PBZ sample collected from a welder (5-hr partial-shift) was reported at 0.17 mg/m^3). The NIOSH and OSHA criteria specify an average exposure limit of 0.10 mg/m^3. The phase contrast microscopy analyses found that approximately 95% of the particles in the sample collected in the assembly grinding area and 80% of the particles in the sample collected in the loading area of the assembly conveyor were of respirable size. Some health and safety hazards, such as worn chain hoists, unenforced hearing protection policy, and inappropriate protective clothing were identified.

Videotape of work activities was analyzed after the site visit. Many of the production jobs observed during the site visit exposed employees to risk factors commonly associated with upper extremity cumulative trauma disorders. These included repetitive hand/wrist movements and excessive manual force application. The grinding task was determined to represent the greatest risk, since this task also exposed workers to hand/arm vibration. Several tasks required workers to make lifts and long reaches in awkward positions. These tasks present an additional risk of back injury to the worker. Among the 13 employees interviewed, six reported wrist pain, four reported hand numbness, three reported a prior diagnosis of carpal tunnel syndrome (CTS), three reported elbow pain, and three reported back pain. Grinding and press-operation were the two jobs that were most commonly reported to be associated with upper extremity symptoms.

The ergonomic evaluation of the work activities at the facility indicated that a potential health hazard for upper extremity cumulative trauma disorders existed for employees in the welding and grinding areas of Harvard Industries. Grinders and press operators reported the most upper extremity symptoms. Recommendations to reduce ergonomic risk factors and improve safety conditions are offered.

KEYWORDS: SIC 3442 (Metal Doors, Sashes, Frames, Molding, and Trim), cumulative trauma disorders, welding, grinding.

II. INTRODUCTION

In January 1991, the National Institute for Occupational Safety and Health (NIOSH) received a joint request from the management of Harvard Industries and the Allied Industrial Workers of America (AIW), Local 107 to evaluate health concerns related to repetitive motion, welding fumes, and grinding dust at the facility located in Bryan, Ohio. On August 13-14, 1991, NIOSH representatives conducted a site visit to Harvard Industries Inc., Trim Trends Division, in Bryan, Ohio.

III. BACKGROUND AND DEPARTMENT DESCRIPTIONS

Harvard Industries Inc., Trim Trends Division manufactures automobile parts including window sashes, spinners (transmission parts), stampings, and door beams. At the time of the site visit, the company employed 230 hourly employees. The facility has an open floor plan, and the majority of the building is two stories in height. There is no central heating or air conditioning. The facility uses electric overhead space heaters. The majority of welding is preformed by robotic machines. At the time of the site visit, two of the four robotic welders were not operating. Spray welding was used for reworking parts. The repair welding uses a copper-based alloy. Exhaust fans are used in the roof over the robotic welders.

Hearing protection is required in the press, door frame, and roll departments of the plant. All grinders and welders are required to wear some form of eye protection (face shields, goggles, and/or approved safety glasses with side shields). Safety shoes are recommended but not required.

The Detroit Diesel Component (DDC) Department is an assembly area for automotive engine components. Raw materials are supplied by outside vendors. The department contains six separate work areas, each devoted to assembly of a different product (oil pump assembly, accessory drive assembly, water pump assembly, fan spindle assembly, air compressor assembly, fuel pump drive assembly). When active, each workstation is staffed by one or two operators, working separately or together, to assemble components into a final product. The department employs six workers on the first shift, three workers on the second shift, and one worker on the third shift. Monthly production is dependent on customer demand; however, monthly production for May through July 1991, varied between 7,000 - 10,000 units.

The Window Sash (or CT-20) Department is the main department in the plant and employs 126 workers on three shifts. The department can operate up to eight production lines at once. Maximum production rate is 3500 frames/shift.

In the Transmission Department, three types of clutch components are manufactured. Round blanks are automatically loaded into a stamp where the part is formed. Formed parts are deposited into bins which are taken to spinners. Operators process parts through the spinner and hang them on a moving overhead hook for washing. After parts are washed, an operator removes the parts from the conveyor and sorts them into different bins by style. Twelve workers on three shifts are employed making transmission parts.

In the Reinforcement Beam Department, two operators place reinforcement panels and end plates in an automated welding machine. After parts are loaded, the machine is activated by pressing two palm buttons. The operators wait for the machine to weld the end plates to the panels. After welding is finished, operators remove the reinforcement beams from the machine and pass them to the packer.

In the Straight Side Department, two types of presses are used: the Niagara Press and the Verson Press. When using the Niagara Press, operators load rods from carts or bins into the press and activate palm-button controls to start the press. Six workers are employed on the first and second shifts to operate the press. When using the Verson press, the operator loads rods from carts or bins into the press and activates palm-button controls to start the press. After the press operation is completed, the operator transfers the part from the press to another cart or bin.

IV. EVALUATION CRITERIA AND TOXICOLOGY

A. Environmental Criteria

In order to assess the hazards posed by workplace exposures, industrial hygienists use a variety of environmental evaluation criteria. These criteria propose exposure levels to which most employees may be exposed for a normal working lifetime without adverse health effects. These levels do not take into consideration individual susceptibility such as pre-exiting medical conditions or possible interactions with other agents or environmental conditions. Evaluation criteria change over time with the availability of new toxicologic data.

There are three primary sources of environmental evaluation criteria for the workplace: 1) NIOSH Recommended Exposure Limits (RELs),[1] 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs®),[2] and 3) the U.S. Department of Labor Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[3] The OSHA PELs may include the feasibility of controlling exposure in various industries where the agents are used; whereas, the NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required to meet those levels specified by an OSHA standard.

Welding and grinding, in general, have been associated with two specific types of health hazards: 1) exposure to substances such as fumes, gases, and particles that are formed or released by the processes, and 2) the physical hazards such as ionizing and nonionizing radiation, noise, vibration, high temperatures, and electricity.[4]

B. Metals

The potential health effects associated with the metals which were detected in the environmental samples are shown in Table 1. These metals include copper, iron, magnesium, manganese, and zinc. The NIOSH REL, OSHA PEL, and ACGIH TLV® are presented for each metal.[1-5]

Epidemiologic studies have shown several adverse health effects associated with the different welding processes. Metal fume fever and pneumonitis are the most common acute respiratory diseases associated with short-term exposures to high concentrations of welding fumes and gases. Chronic respiratory diseases that have been observed among welders include cancer, pneumoconiosis, and bronchitis. Other health effects that have been associated with welding include cardiovascular and gastrointestinal diseases, cancers of the kidney and other urinary tract organs, cancer of the larynx, hearing loss, skin sensitization, eye injury, and musculoskeletal injury. There is limited evidence of a possible relationship between adverse reproductive outcomes and welding fume exposure. The majority of the epidemiologic studies do not contain sufficient information to associate a particular hazard with a specific health effect.[4]

C. Cumulative Trauma Disorders

Cumulative trauma disorders (CTDs) of the musculoskeletal system occur in workers whose jobs require repetitive movements and forceful exertions. These injuries frequently affect the tendons, tendon sheaths, muscles and nerves of the upper extremities. Common CTDs include tendinitis, synovitis, tenosynovitis, bursitis, ganglionic cysts, strains, DeQuervain's disease, and carpal tunnel syndrome (CTS). Studies have shown that CTDs can be precipitated or aggravated by activities that require repeated or stereotyped movements, large applications of force in awkward postures, or exposure to hand/arm vibration.[6-8] Postures often associated with upper extremity (UE) CTDs are extension, flexion, and ulnar and radial deviation of the wrist (Figure 1), open-hand pinching, twisting movements of the wrist and elbow, and reaching over shoulder height. Activities associated with UE CTDs are frequently observed in many manufacturing and assembly jobs in industry. Occupations associated with a high incidence of CTDs include electronic components assembly, garment manufacturing, small appliance manufacturing and assembly, and meat and poultry processing.[9-11]

In all cases, engineering controls are the preferred method of reducing UE CTD risk. The goal of engineering controls is to make the job fit the person, not the person fit the job. Administrative (personnel-based) controls should be used only as a temporary measure to control CTD risk until engineering changes can be implemented.

V. EVALUATION DESIGN AND METHODS

A. Industrial Hygiene

Nine personal breathing zone samples and one area air sample were collected on mixed-cellulose ester filters (37 millimeter (mm) diameter, 0.8 micrometer (µm) pore size) using a flowrate of 2.0 liters per minute (l/min). Samples were collected for periods as near as possible to entire workshifts (6 to 7 hours). The samples were analyzed for metals according to NIOSH Method 7300.[12] In the laboratory, the samples were wet-ashed with concentrated nitric and perchloric acids and the residues were dissolved in a dilute solution of the same acids. The resulting sample solutions were analyzed by inductively coupled plasma (ICP) atomic emission spectrometry.

Two samples were collected and analyzed by phase contrast microscopy to determine the percentage of respirable size particles (<10 micrometers [µm] in diameter) to determine if the grinding or finishing operations were generating particles in the respirable size range. The material data safety sheets (MSDSs) were reviewed. General work practices and engineering controls were evaluated. Air movement was evaluated using smoke tubes.

B. Medical

OSHA 200 logs were reviewed for 1989-1991. Before our visit to the facility, employees were informed of the NIOSH visit by management and union representatives. They were told that NIOSH representatives would be available to confidentially discuss any work-related health concerns. Union representatives aided us in identifying those individuals who were known to have some work-related health concern. During the NIOSH walk-through inspection, these employees, as well as other employees who we noted were performing tasks that had the potential for leading to cumulative trauma disorders, were encouraged to participate in an interview. Private medical interviews were conducted with 13 of the 230 employees.

C. Ergonomic

The first objective of the ergonomic evaluation was to identify biomechanical risk factors for UE CTDs in jobs performed at this facility. A second objective was to develop recommendations to eliminate or reduce the hazards identified in these jobs. Jobs performed in the facility on the day of the site visit were observed and videotaped. A total of 14 jobs/operations were included in the evaluation. Additional information, such as the number of workers employed in each job, the types of tools used and their characteristics, the workstation dimensions, and the force requirements of certain tasks, was also collected.

A job analysis was performed to assess the repetitiveness of each task and to document instances of awkward hand, wrist, arm and trunk postures. Manual force requirements were estimated. Exposures to hand/arm vibration were also noted; however, no direct measurements of hand-transmitted vibration were made.

VI. RESULTS

A. Industrial Hygiene

Employee exposures to metals were monitored throughout the door sash assembly part and the welding areas. Table 2 presents the results for metals detected. The one area sample and all nine of the PBZ air concentrations for iron, magnesium, manganese, and zinc ranged from 0.001 to 0.266 milligrams per cubic meter [mg/m^3] and were below existing guidelines and standards established by NIOSH, OSHA, and ACGIH. One partial shift, PBZ air sample from a welder measured a copper concentration of 0.167 mg/m^3. The NIOSH REL and OSHA PEL are both 0.1 mg/m^3 for copper fume.

The phase contrast microscopy analyses found that approximately 95% of the particles in the sample collected in the assembly grinding area and 80% of the particles in the sample collected in the loading area of the assembly conveyor were respirable sized particles (< 10 µm in diameter).

The tool room had local exhaust ventilation connections for each machine, but not all of them were functioning. It was possible to see the welding arc from the tool room area, thus exposing individuals in the area to electromagnetic radiation. Air flow patterns showed little air movement in the vicinity of the welding station located near the center of the tool room. A visual haze was created in the vicinity of some of the employees when oil, to prevent rusting, was added to parts immediately after welding.

Air flow patterns were highly variable due to the operation of man-cooling fans throughout the different departments. Hearing protection was required in the press, door frame, and roll departments of the plant, but not everyone wore hearing protection in those areas. Some of the fire extinguishers were not located where indicated according to post markings. Three chains used for lifting were noticeably worn, and one had a repaired link. Employees were observed smoking in the general work area. Individuals were working with hot metal while wearing tennis shoes and shorts.

B. Medical

Review of the OSHA 200 logs for the years 1989-91, revealed one back strain, one back sprain, five shoulder strains, two neck strains, one wrist tendinitis, one elbow tendinitis, and one wrist pain. Among the 13 employees interviewed, six reported wrist pain, six reported respiratory irritation, four reported hand numbness, three reported a prior diagnosis of carpal tunnel syndrome (CTS), three reported elbow pain, and three reported back pain. Workers who were press operators and/or grinders reported the most upper extremity symptoms, and grinders reported the most respiratory irritation.

C. Ergonomic Evaluation

At the time of the site visit fourteen different jobs/operations were observed. The evaluations are presented according to job title within department.

1. DDC DEPARTMENT

Repetitiveness does not appear to be a concern in the DDC Department, since operators perform a variety of different tasks during the day to complete assemblies. Workers also tend to work on different parts from day-to-day. Factors presenting the greatest risk for musculoskeletal injuries are awkward postures and excessive force exertion during tool use and frequent lifts.

Awkward postures appear to be the result of a workbench that is too high. An overhead reach is required to grasp and pull the drill press handle. During this operation, force is exerted with the elbow extended and the wrist deviated. Similarly, an overshoulder reach is required to grasp and turn the torque wrench handle. Elbow abduction (away from the midline) and wrist deviation were observed during a manual nut driving operation. At the time of the site visit, most parts were assembled without the use of powered tools. Workers stated that although powered tools were available, many times they were not used.

Workers were frequently observed lifting steel housings from large shipment crates or containers, or bending forward to place finished assemblies on pallets. In several cases, lifts were executed while leaning over the side of a box and grasping the assembly with one hand. According to workers in the area, housings and finished assemblies can weigh as much as 37-42 pounds (lbs). These practices increase the risk of back strain or injury to workers in this area.

2. WINDOW SASH DEPARTMENT

a. Job Title: Roll Press Operator

Window sash fabrication begins at the roll press. Large coils of sheet metal are loaded on one end of the roll press, and the flat metal is fed through a series of rollers which bend the sheet into a bar. The operator monitors the machine's operation and performs hourly quality control checks. The rolled steel is cut into 4-6 foot pieces, and the operator stacks the bars on carts for transport to the bender.

Because the majority of the operator's time is spent either setting up the roll press or monitoring the machine's operation, there are few ergonomic concerns associated with this job. The operator is required, however, to unload bars from the machine and stack bars onto carts while the machine is in operation. Because the cart is not height adjustable, the operator may be forced to bend forward or twist at the waist, or reach across the cart to position the bar on the stack. Awkward postures of this type can result in back or shoulder fatigue.

Another concern, not unique to the roll press operator but applicable to all workers required to move loaded carts, is the amount of push-pull force required to initiate movement of a fully-loaded cart. Although the magnitude of the force varies with the orientation of the cart wheels and the condition of the floor, up to 90 lbs of force can be required to initiate cart movement for this job. The recommended upper limit of horizontal force to start the cart motion is 50 lbs.[13] The risk of arm, shoulder and back strain is significantly increased when force requirements exceed this level.

b. Job Title: Bender/Saw

Bar stock from the roll press is lanced and delivered to the bender on carts. The operator removes bars from the cart and places them inside the bender. After activating two palm buttons to begin operation of the bender, the operator waits for the machine to complete its cycle. The operator then removes the bar from the fixture, places it inside the saw and activates two palm buttons to trim the ends from the bar. After the machine cycle is complete, the operator removes the bar from the machine and passes it to the next operator to be lanced and/or notched. Cycle time is about 25 seconds (sec)/part (no delays); approximately 100 parts can be processed through this operation in an hour.

The ergonomic risk factors identified during the analysis of the bender operation are described as follows.

Bars are retrieved individually (one at a time) from the cart for processing. This method requires the operator to make numerous trips to and from the cart. Retrieving bars from the cart can require the operator to bend at the waist and make an extended reach, especially as the stack of bars gets smaller. Frequent bending and reaching can become fatiguing and increases the risk of back injury.

Loading bar stock into the machine fixture requires the operator to lean forward and reach inside the machine (reach distance = 26 inches). The length of this reach is 6 inches greater than the maximum recommended.[13] Repetitive bending and reaching places unnecessary strain on the operator and increases the risk of back and shoulder injury.

The operator is required to activate the press three times each cycle. Activating spring-loaded palm buttons requires wrist flexion and puts stress on soft tissues in the hand. Wrist flexion and manual force are risk factors for hand/wrist CTDs such as carpal tunnel syndrome. In addition, the operator is required to hold down both palm buttons while the bender is operating or resetting. This process imposes additional stress due to sustained muscle contraction.

The saw is located across the aisle from the bender. The arrangement requires the operator to lift the bar from the fixture, pivot 180 degrees and replace the bar in a new fixture. This process doubles the number of lifts and reaches required.

Finally, because of the height of the machine, the operator is required to stand on a metal grating while performing this job. Prolonged standing on hard surfaces can lead to low back, leg, knee and foot pain.

c. Job Title: Notcher

The notcher may perform up to four different operations after receiving the part from the bender. Most operations require the worker to place the bar in a fixture and activate two palm buttons. After the machine cycle is completed, the part is removed and placed in the next press. The final operation requires the worker to hold the part in a punch press, which is activated with a foot pedal. Parts are stacked in bins or on carts for transport to other work areas. Cycle time for the notcher is 19 sec/part; however, idle time (delay) is introduced because the notcher is dependent on the bender for parts.

Ergonomic concerns relevant to the notching operation are described below. First, the arrangement of the machines requires the operator to repeatedly lift, move and position bars in the various fixtures. Four lift-and-position movements are executed every cycle. This process requires continuous movement and shoulder/arm activity, and can result in fatigue over time.

The operator activates three sets of palm buttons every cycle. Activating spring-loaded palm buttons results in repeated wrist deviation and puts stress on soft tissues in the hand. Both factors increase the risk of hand/wrist CTD development.

Bars are loaded into metal bins or carts after notching is completed. Torso flexion and an extended reach are required, especially if the bin or cart is nearly empty. These movements place stress on the back and shoulders.

Finally, prolonged periods of standing and walking on a hard surface can result in foot, leg and back pain. In many areas floor mats were not provided; in other areas, mats were in poor condition and need replacement.

d. Job Title: Drill Finisher/Grinder/Twister

This job is performed by three operators working in sequence. The drill finisher removes bars from a cart and places them in a fixture. After activating two palm buttons (causing holes to be drilled in the ends of the pillar), the operator waits for the machine cycle to complete. The operator then removes the bar from the fixture, places it inside another machine (which saws the bar in half), and activates two palm buttons. After the machine cycle is complete, the operator removes both halves from the machine, punches the ends, and passes the bars to the grinder. The grinder deburrs the edges using a wheel-driven belt grinder, and punches a hole in the middle of each piece. Parts are then passed to the twister, who uses a small handheld grinder to deburr the hole. The operator places each part in a fixture and presses two buttons to activate the machine (which applies a slight twist to the bar). After the machine cycle is complete, the operator stacks the parts in a bin for transport to the welder. Sixty to eighty parts are processed through this sequence each hour.

A number of ergonomic hazards were identified in the analysis of the finisher/grinder/twister operation. The drill finisher retrieves bars individually (one at a time) from the cart for processing. This method requires the operator to make numerous trips to and from the cart. Retrieving bars from the cart can require the operator to bend and make an extended reach, especially as the stack of bars gets smaller. Frequent bending and reaching can become fatiguing.

The saw is located across the aisle from the drill. The arrangement requires the operator to lift the bar from the drill, pivot 180 degrees and place the bar in a new fixture. This process increases the number of lifts and reaches required of the operator, and requires travel between machines.

Repeated activation of spring-loaded palm buttons puts stress on the soft tissues and nerves in the hand. Application of force with the palm of the hand is a risk factor for hand/wrist CTDs such as carpal tunnel syndrome.

The grinder and twister operators are both exposed to hand/arm vibration every cycle. Because this exposure tends to be very brief (3-5 secs/cycle for the grinder, 2 secs/cycle for the twister), it probably does not present a great risk to either worker.

Finally, operators currently stand while performing this job. Prolonged standing on hard surfaces can lead to low back, leg and foot pain. Mats were either not provided, or in need of replacement/repair.

e. Job Title: Welder

Welding is performed throughout the plant at various stages of the door frame assembly process. Robotic welding stations join larger components to form the door frame. Less sophisticated spotwelding machines are also used for lighter applications (e.g., attaching mirror brackets to frame components, closing seams, etc.). Operators load individual frame components into fixtures and activate palm-button controls to start the welding process. Robotic welders require operators to flip the frame mid-way through the process. Twenty-three operators are employed on the first and second shifts.

Ergonomic hazards identified in the welding operation are described below. First, loading components into robotic welding machines requires torso flexion and a 27 inch reach. This reach is 7 inches greater than the maximum recommended.[13] Repetitive bending and reaching places unnecessary strain on the operator and increases the risk of back injury or fatigue.

A number of problems associated with the machine controls were identified. Buttons that control gripping mechanisms in the robotic welders are located to the side of the machine, above shoulder height. An extended overshoulder reach is required to activate these controls. Palm buttons on at least one of the spot welders in the press area were located above shoulder height. Activation of this spot welder also required an overshoulder reach. Further, repeated activation of spring-loaded palm buttons puts stress on the soft tissues and nerves in the hand. Although operating the robotic welders is not a highly repetitive task (the operator can rest while the robot works), application of force with the palm of the hand is a risk factor for hand/wrist CTDs such as CTS.

A problem specific to the spot-welder who joins mirror bracket components involves the heavy plastic sheet (cut into strips) used to protect the operator from sparks during the welding process. While the sheet does provide protection from sparks, the sheet also obstructs vision and interferes with movement when the operator is loading and unloading the machine. Notably, other welding machines in the facility have no mechanisms to protect operators (or adjacent workers) from sparks or direct exposure to the welding beam. Directly viewing the welding beam, especially at close distances, can cause eye damage. Welders wear safety glasses, but not those designed to protect the eye from exposure to high-intensity light sources.

Finally, welding requires continuous standing and walking. Prolonged standing can lead to low back, leg, knee and foot pain.

f. Job Title: Grinder

After welding is completed, belt-driven grinding wheels and hand-held grinders and buffers are used to remove rough edges from the frame joints and apply a shine to the metal. Thirty-eight grinders are employed on the first and second shifts.

Awkward static postures, manual force exertion, and vibration from the grinding and buffing tools are the main hazards presented by the grinding task.

The design of the belt-driven grinder permits most workers to keep their hands at waist level while handling the frame. However, the neck must be bent forward to see the piece. Prolonged static forward neck flexion can result in "tension neck" syndrome or other cervicobrachial disorders. Awkward upper extremity postures were observed during operation of the hand-held grinders. These postures appear to result from the fixed workstation height. The working height of the hands is currently set at 42 inches, which is too high for tasks requiring large downward forces. Shoulder and elbow abduction and wrist deviation were frequently observed.

Both grinding tasks expose workers to hand/arm vibration for prolonged periods of time. Unlike other jobs in the plant, there are few natural breaks in the grinding task which give workers an opportunity to rest. Hand/arm vibration transmission is exacerbated by application of manual force. Although the hand-held grinders are fairly light (2.7 - 4.0 lbs) and the force requirements do not appear to be excessive, continuous gripping and application of manual force can result in fatigue.

g. Job Title: Quality Check (Gage)

After grinding is completed, a final 100% quality check is performed to ensure sashes conform to specifications. The worker measures various dimensions of the sash with a template before releasing the part for packing.

Gaging presents some mild ergonomic risks to the worker due to the repetitiveness of the task. Frequent overshoulder reaches (2-4/minute) are required to place the frame in the various templates and make adjustments in its position. Some bending and reaching (requiring mild shoulder and trunk flexion) is required to place frames in templates near the back of the table. Moderate force exertion is sometimes required to make small corrections in the bend of the frame.

h. Job Title: Packer

After the sashes have passed inspection, packers apply a small amount of lubricating oil to the frame surface. Sashes are then packed into boxes for shipment to the customer.

Bending and reaching forward to place frames inside shipment boxes are the primary hazards associated with this job. Cardboard boxes, 52 inches long, 46 inches wide, and 43 inches tall (with pallet), are the most difficult to pack. Operators lean forward and reach over the side of the box to position frames inside. Wire mesh containers, 52 inches long, 48 inches wide, and 35 inches tall, are easier to pack because of the reduced height; however, some bending and reaching is still required. According to management, the type of package used is determined by the customer's preference.

3. TRANSMISSION DEPARTMENT

a. Job Title: Spinner

The operator removes clutch parts from gravity feed bins and places them in a fixture inside the spinner. After activating two spring-loaded palm buttons, the operator waits for the spinner to finish its cycle, and removes the piece from the fixture. The operator may put the part in another press, which he/she activates. The final task in the process is to hang the part on a moving conveyor belt. Average production rates vary between 165-170 pieces per hour per spinner.

Although the task is somewhat repetitive, minimal force is required to operate the spinner, and the workpace is largely determined by the operator. Therefore, this job appears to present little risk to the operator. Repeated activation of palm buttons can; however, result in trauma to soft tissues in the hand. Also, there is no mechanism for adjusting the height of the worksurface; therefore, shorter operators are required to make overshoulder reaches to access parts in the machine. Finally, operators are required to stand throughout the work shift, putting stress on the legs, knees and feet.

4. REINFORCEMENT BEAM DEPARTMENT

a. Job Title: Welder

Two operators place reinforcement panels and end plates in an automated welding machine. After parts are loaded, the machine is activated by pressing two palm buttons. The operators wait for the machine to weld the end plates to the panels. After welding is finished, operators remove the reinforcement beams from the machine and pass them to the packer.

Few ergonomic hazards were identified in the analysis of the welding task. The task is not highly repetitive (operators load the machine once every 45 seconds), and there is time for operators to rest while the machine is operating. The height of the loading platform is, however, slightly too low. Taller operators are forced to bend at the waist to load and unload the machine. As in most other areas of the plant, spring-loaded palm buttons are used to activate the machine. As previously-mentioned, repeated activation of palm buttons can result in soft tissue trauma.

b. Job Title: Packer

After reinforcement beams are removed from the welding machine, the packer loads beams into a crib (46 inches by 108 inches, 32 inches high) for storage. The packer loads three beams into the crib at a time. After a new layer of beams is laid in the crib, the packer sprays the welds with a water-based solvent.

The size of the crib is a source of stress to the packer. The packer must lean and reach over the side of the crib to position beams inside. The task is most difficult when the crib is nearly empty, and when beams must be placed in the middle of the crib. Bending and reaching while carrying and positioning heavy objects puts the packer at risk for back injury or shoulder strain.

5. STRAIGHT SIDE DEPARTMENT

a. Job Title: Niagara Press

Operators load rods from carts or bins into the press and activate palm-button controls to start the press. Six operators are employed on the first and second shifts.

Biomechanical hazards identified in the Niagara Press area are described below.

Operators were frequently observed bending and reaching into metal bins to retrieve parts. The bottom of the bin is 4.5 inches above the floor; the side of the bin extends 28 inches above the floor. Therefore, retrieving parts near the bottom of the bin requires a particularly low reach. Repeated bending and reaching is inefficient and puts stress on the arms, shoulders and lower back.

There is no mechanism for adjusting the height of the worksurface relative to the operator. On many presses, palm buttons are located 40 inches above the floor. Fixtures inside the press are located 49-51 inches above the floor. Presses are currently activated by spring-loaded palm buttons. Repeated activation of palm buttons can result in trauma to soft tissues in the hand.

Finally, the current press configuration does not allow operators to work while seated. Operators are required to stand throughout the work shift, putting stress on the legs and feet.

b. Job Title: Verson Press

An operator loads rods from carts or bins into the press and activates palm-button controls to start the press. After the press operation is completed, the operator removes the part from the press to another cart or bin.

There appeared to be little standardization in the location of controls, and in many cases, the die was located at or near shoulder height. To load parts in and out of the press, shorter female operators had to lift the arms and abduct the shoulders. The press was activated by spring-loaded palm buttons which were also located just below the shoulder. Activation of spring-loaded palm buttons requires repeated wrist deviation and puts stress on soft tissues in the hand. Both factors increase the risk of hand/wrist CTD development.

VII. DISCUSSION/CONCLUSIONS

The one area and all nine of the PBZ air sample concentrations for iron, magnesium, manganese, and zinc were below existing guidelines and standards established by NIOSH, OSHA, and ACGIH, although the respirable size of the particles indicated that there was a potential inhalation hazard. One PBZ air sample from a welder measured a copper fume exposure of 0.167 mg/m^3 (Table 2). Although this sample was collected for only a partial shift (5 hr), it indicates a potential over-exposure condition. During the walkthrough survey, some potential health and safety hazards were identified, such as worn chain hoists, unenforced hearing protection policy, and inappropriate protective clothing.

Many of the production jobs observed on the day of the site visit exposed employees to risk factors commonly associated with upper extremity cumulative trauma disorders such as repetitive hand/wrist movements and excessive manual force application. The grinding task was determined to represent the greatest risk, since this task also exposed workers to hand/arm vibration. In addition, interviewed workers who were most likely to report upper extremity symptoms were either press operators or grinders. Several tasks required workers to make lifts and long reaches in awkward positions adding additional risk of back injury to the worker.

VIII. RECOMMENDATIONS

A. Industrial Hygiene/Medical

1. The rest of the machines in the tool room should be connected to the local exhaust ventilation system already in place. This area had little air movement. The flow rates should be measured and compared to the recommended flow rates in the ACGIH publication Industrial Ventilation.[15]

2. Smoking should not be allowed in the work environment. NIOSH considers environmental tobacco smoke (ETS) to be a potential occupational carcinogen and recommends exposure be reduced to the lowest feasible concentration, either by eliminating smoking or restricting it to dedicated rooms ventilated directly to the outside. Recent epidemiologic studies have found that ETS can cause lung cancer and suggest a possible association between ETS and an increased risk of heart disease in non-smokers. Suggestions to eliminate or restrict smoking in the workplace are found in the NIOSH "Current Intelligence Bulletin 54: Environmental Tobacco Smoke in the Workplace: Lung Cancer and Other Health Effects."[16]

3. Exposure to welding fumes should be controlled so that workers are exposed to the lowest concentrations technically feasible since compliance with specific exposure criteria does not ensure complete protection against adverse health effects.[4] Engineering controls and personal protective equipment such as respirators would be appropriate.

4. The use of hearing protectors in the designated areas should be enforced.

5. Safety shoes and other appropriate clothing (no shorts in welding area) should be worn to prevent injury.

6. Welding areas should be shielded from the rest of the work area using devices such as welding curtains.

B. Ergonomic

1. DDC DEPARTMENT

Excessive reaches can be eliminated by lowering the workbench, or providing some mechanism to permit adjustment of the work height. The height and location of components and fixtures used for assembly tasks should be considered in selecting an appropriate workbench height. For light assembly and packing tasks, the optimal working height of the hands is 42 inches.[13] Frequently-used controls, such as buttons and levers on drill presses, should be located between elbow and shoulder height, and within 20 inches of the front of the workbench. Although absolute force requirements are not reduced, less effort is required to operate controls located in this range. Component parts (e.g., nuts and bolts) should also be stored in this range for easy access.

Adaptations or adjustments should be made to permit wider use of powered or semiautomatic tools. Power hand tools not only perform work faster than manual tools, but also cause less operator fatigue. Greater uniformity of product can be expected when power tools are used.[17] Precautions must be taken; however, to minimize exposure to vibration produced by these tools.

Bends and lifts should be eliminated by placing pallets on pneumatically-driven, adjustable lift tables. Cardboard crates and boxes should be opened before they are delivered to the DDC area. Workers should not have to lean over the side of a box to retrieve components.

2. WINDOW SASH DEPARTMENT

a. Roll Press Operator

1. Awkward postures associated with unloading bars to the cart can be eliminated by using an automatic unloading mechanism to place bars in the cart. A mechanism of this type might use a robotic pick-and-place arm to move bars from the press to a cart positioned next to the machine. An alternative suggestion is to replace the current carts with transportable scissor lifts or carts that are height-adjustable. These would allow the operator to reposition the height of the stack as the number of bars on the cart increases.

2. The force required to move and maneuver carts is affected greatly by the floor characteristics. Floors that are heavily etched or cracked increase the effort required to move or maneuver carts. To reduce this force, flawed or cracked surfaces should be repaired. Installing larger wheels on carts would also reduce force requirements. An alternative to using hand carts is to use powered forktrucks to transport bar stock to areas where it is needed. This solution is less desirable, since it would increase forklift traffic on the production floor.

b. Job Title: Bender/Saw

1. The number of long reaches and bends required to retrieve parts from the cart can be reduced by storing bar stock on transportable scissor lifts or spring-loaded carts. These devices allow the height of the stack to be adjusted according to worker stature. As stock is depleted, the cart height can be readjusted to prevent bends and reaches.

2. The length of the reach into the machine should be reduced to 20 inches or less. It may be possible to reduce this reach by moving the palm buttons away from the front of the machine.

3. The possibility of combining bending and trimming tasks in one machine should be examined. Using the same machine to bend and trim bars would not only improve efficiency, but would also reduce the number of lifts and reaches required by 50%.

4. Stress imposed by repeated activation of the palm buttons can be reduced by replacing the current buttons with "LiteTouch" or "Break-a-Beam" controls. These controls are activated by breaking an infrared beam with the hand. No force exertion or wrist deviation is required.

5. Cushioned floor mats (or antifatigue mats) are recommended to reduce stress on the operators' legs, knees and feet during prolonged periods of standing.

c. <u>Job Title: Notcher</u>

1. This task could be performed with fewer lifts, reaches, and twists if the multiple machines and presses were replaced with a single machine which could perform several (or all) notching operations at once. Combination tools which perform several operations simultaneously result in the greatest efficiency. The time required for the operation and the potential for operator fatigue would be reduced.

2. Stress imposed by repeated activation of the palm buttons can be reduced by replacing the current buttons with "LiteTouch" or "Break-a-Beam" controls. These controls are activated by breaking an infrared beam with the hand. No force exertion or wrist deviation is required.

3. Transportable scissor lifts and cartons with fold-down sides would reduce the number of bends and reaches needed to place bars in storage bins. The transportable lift table would allow operators to position the bin next to the press, at a height which could be accessed without a bend or reach. Fold-down sides would allow operators to access the inside of the carton without reaching over the side.

4. Finally, floor mats are recommended to reduce stress on the operators' legs, knees and feet during prolonged periods of standing.

d. <u>Job Title: Drill Finisher/Grinder/Twister</u>

1. Transportable scissor lifts and storage bins with fold-down sides would reduce the number of bends and reaches required by this task. Bars could be positioned next to the work area at a height which could be accessed without a bend or reach.

2. The possibility of combining tasks in one machine (e.g., drill and saw) should be examined. Using the one machine instead of two would not only improve efficiency, but would also reduce the number of lifts and reaches required by 50%.

3. Stress imposed by repeated activation of the palm buttons can be reduced by replacing the spring-loaded mechanical buttons with electromechanical relays controlled by photoelectric sensors. Controls of this type are activated without force exertion or wrist deviation.

4. Hand/arm vibration transmission can be reduced by providing operators with vibration-absorbing gloves. Thicker gloves, lined

with sorbothane or some other vibration-absorbing material, will provide better protection than the cotton gloves currently used. The belt-driven grinder should also be mounted on an adjustable pedestal, to allow the operator to position the grinder at a comfortable working height.

5. Finally, floor mats are recommended to reduce stress on the operators' legs, knees and feet during prolonged periods of standing.

e. <u>Job Title: Welder</u>

1. The reach distance required to load components into the robotic welding machines could be reduced by removing the green metal railing that currently surrounds the machine. Operators lean over this railing to reach the fixture. Because the railing may be in place due to an OSHA requirement; however, this matter requires further investigation before it can be implemented. It may be possible to replace the railing with a laser light guard or a series of proximity sensors to prevent accidents while the operator is loading the machine.

2. Repeated overshoulder reaches can result in arm and shoulder fatigue. Therefore, it is recommended that all controls be relocated below shoulder level. In particular, the palm buttons on the spot welding machine should be moved to waist level since these controls are activated more frequently.

3. Stress imposed by repeated activation of the palm buttons can be reduced by replacing the current buttons with infrared light beam sensors. The machine would be activated by breaking an infrared light beam with the hand. No force exertion or wrist deviation is required.

4. The heavy plastic curtain on the bracket welding machine should be replaced. A guard is needed only when the machine is in operation. An alternative (which could be installed on all welding machines) is a shield made of a coated plexiglass (or similar material), which descends and covers the front of the machine during operation. After welding is completed, the shield would rise and allow the operator to freely access the interior of the machine.

5. While expensive, a material ("Speedglas") has been developed that automatically darkens with exposure to welding light. The material becomes clear again after the exposure is ended. Welding glasses made of this material would provide additional eye protection to welding operators.

6. Finally, cushioned floor mats or "anti-fatigue" mats are recommended to reduce stress on the operators' legs, knees and feet during prolonged periods of standing.

f. Job Title: Grinder

1. Improved lighting is recommended to enhance visibility in the grinding area. Better lighting may improve the operator's ability to visually inspect the workpiece. Applying a slight forward tilt to the grinding fixture may also reduce forward neck flexion.

2. Awkward postures can be corrected by lowering the height of the grinding fixtures, or providing a mechanism for adjusting the fixture height. The working height of the hands should not be greater than 36 inches. Additional lighting may enable operators to view the workpiece at the lower work height.

3. The manual force requirements of the task may be reduced somewhat by using tool balancers to support the weight of the grinder. The tool balancer will allow the operator to release his/her grip on the tool when it is not in use. A period of adjustment may be necessary following introduction of the tool balancers to determine the line tension needed to correctly counterbalance the tool weight.

4. The following recommendations are offered to mitigate hazards resulting from hand/arm vibration exposure. Notably, many of these recommendations are applicable to other areas of the plant where vibrating tools are used.

   a. The vibration associated with hand-held grinders is related to the unbalanced rotating mass of the grinder and to the interaction between the grinder wheel, cup or pad, and the workpiece. If the grinder is well maintained, the vibration associated with the rotating mass of the grinder is usually not a problem.[18] Therefore, regular maintenance and inspection of hand-held grinders and grinding wheels is encouraged. Grinders should be replaced when vibration can no longer be controlled through maintenance.

   b. The vibration energy produced by vibrating tools must be transmitted to the operator's hands to produce a harmful effect.[18] Research indicates that cotton or leather gloves provide little or no protection against vibration and may even increase the transmission of vibration. Vibration absorbing materials (e.g., Sorbothane), in the form of a glove or handle wrap, may be useful for minimizing hand/arm vibration transmission.

   c. Vibration isolation handles should be considered as an additional method of minimizing hand/arm vibration transmission. Isolation handles are designed to act as a low-pass mechanical filter between the vibrating tool and the human hand.[19] Lightweight vibration isolation handles which can be attached to portable tools are commercially available.

d. Because the pathophysiological effects of vibrating tool use are related to use time, limiting daily and weekly exposure may reduce the potential for injury. Recommendations include allowing grinders more frequent rest breaks, rotating grinders to other tasks with no vibration exposure (e.g., welding or packing) and limiting vibrating tool use to one or two days a week.

g. Job Title: Quality Check (Gage)

1. Postural problems associated with placing frames in the template can be corrected by reducing the tilt of the gaging table and rearranging some of the templates. Templates near the back of the table should not require a reach above shoulder height; the maximum reach should be no more than 50 inches above ground level.[13] Templates which require the frame to be positioned vertically should be placed near the front of the table. Also, templates at the front of the table should not obstruct access to other templates.

2. It may be worthwhile to investigate sources of error in the bend of the frame. A final press operation could be introduced to make small corrections in the shape of the frame prior to gaging if small errors appear frequently and consistently.

h. Job Title: Packer

1. A recommendation to reduce bending and reaching during packing is to place boxes on a crate positioning platform. A crate positioner would allow operators to tilt the box so that the interior can be accessed without a reach over the side.

2. Another recommendation is to obtain wire mesh containers with fold-down gates on the ends or sides. Again, these would provide better access to the interior of the container.

3. TRANSMISSION DEPARTMENT

a. Job Title: Spinner

1. If the reach distances can be reduced, this task could be performed by a seated operator. Allowing the operator the option of sitting or standing would reduce stress on the back, legs, knees and feet. Reach distances could be reduced by moving the spinner closer to the conveyor line. If sitting is permitted, an adjustable chair with an adjustable footrest, or a sit/stand stool is recommended.

It may be necessary; however, to remove a panel on the front of the spinner to create adequate space for the operator's legs.

2. Stress imposed by repeated activation of the palm buttons can be reduced by replacing the current buttons with "LiteTouch" or "Break-a-Beam" controls. These infrared controls can be activated without force exertion or wrist deviation.

4. <u>REINFORCEMENT BEAM DEPARTMENT</u>

a. <u>Job Title: Welder</u>

1. Only minor changes to the welding station are recommended. The loading platform should be raised slightly to allow operators to work without torso flexion. Spring-loaded buttons should be replaced with "LiteTouch" or "Break-a-Beam" controls, which can be activated without force exertion or wrist deviation.

b. <u>Job Title: Packer</u>

1. Bending and reaching requirements can be mitigated through redesign of the storage crib. Ideally, the crib should be smaller (to reduce the reach distance to the middle), and have a spring-loaded bottom. The operator would load parts into the top of the bin, and as the weight on top of the springs increased, the bottom would gradually sink. Reaches to the bottom of the crib would be eliminated. A smaller crib could be maneuvered more easily by fork truck.

5. <u>STRAIGHT SIDE DEPARTMENT</u>

a. <u>Job Title: Niagara Press</u>

Recommendations to reduce potential hazards associated with the Niagara Press include the following:

1. Bending and reaching can be minimized by providing parts to the operator between waist and elbow height. One solution is to provide combination lift and tilt tables next to presses, to raise and tilt bins toward the operator. Bins with spring-loaded bottoms, to push parts to the top of the bin as parts are removed, could also be used for storage. An alternative solution is to raise the bins above the floor and use gravity to feed parts to the operator at the desired height.

2. Stress imposed by repeated palm button activation can be reduced by replacing the current buttons with infrared sensor controls. These controls would eliminate wrist deviation and force application associated with the current palm buttons.

3. Leg and foot stress could be reduced by providing operators with height-adjustable chairs, equipped with adjustable footrings, or sit/stand stools. Alternative suggestions include providing cushioned floor mats to reduce

stress on the operators' legs, knees and feet during prolonged periods of standing, and providing a railing along the bottom of the press to be used as a footrest.

b. Job Title: Verson Press

1. The operator can perform this job while seated if changes are made in part storage and the location of the controls. Allowing the operator to sit or stand will reduce overall physiologic load and the potential for static loading of any particular body part.

2. Stress imposed by mechanical buttons can be reduced by replacing them with "LiteTouch" or "Break-a-Beam" buttons. These buttons have been described previously.

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Table 1

Possible Health Effects and Evaluation Criteria for Detected Metals

Harvard Industries
Bryan, Ohio

HETA 91-086

Metal	Health Effects	NIOSH REL (mg/m³)*	OSHA PEL (mg/m³)	ACGIH TLV® (mg/m³)
Copper (Fume)	irritation of upper respiratory tract; metallic taste; nausea; metal fume fever from fresh fume	0.1	0.1	1
Iron	siderosis (pneumoconiosis); scarring of the lung with increased quartz content	5	10	5
Magnesium	Eye and nasal irritation; metal fume fever from fresh fume	None	10	10
Manganese (Fume)	Chemical pneumonitis; central nervous system effects	1 3(STEL)**	1 3(STEL)	5
Zinc	Metal fume fever from fresh fume	5 10(STEL)	5 10(STEL)	10

* - mg/m^3 - milligram per cubic meter as time-weighted average (NIOSH-10 hour TWA; OSHA and ACGIH-8 hour TWA).

** - STEL - short term exposure limit - 15 minute TWA

Table 2
Results of Personal Breathing Zone and Area Samples for Metals
Using Inductively Coupled Plasma Emission Spectroscopy (ICP)

Harvard Industries
Bryan, Ohio
HETA 91-086

August 14, 1991

Job Title	Sampling Time	Sample Volume (l)*	Metal Concentrations (TWA-mg/m^3)** Cu	Fe	Mg	Mn	Zn
Personal:							
B-Welder	7:49 - 3:19	900	0.007	0.111	ND***	0.018	0.003
Welding (Separate Booth)	7:40 - 3:24	930	0.025	0.194	0.003	0.004	0.002
Stationary Grinding/ Forklift & Operator	7:42 - 3:32	940	0.009	ND	0.003	0.001	ND
Welding/Brazing Process	7:36 -12:36	600	0.167	0.158	0.008	0.008	0.002
Welding/Assembly	7:22 - 3:25	940	0.023	0.266	0.003	0.021	0.002
Welding/Assembly	7:25 - 3:22	954	0.020	0.147	0.003	0.006	ND
Grinding/Finishing	7:34 - 3:25	942	0.021	0.234	0.003	0.003	ND
Grinding/Finishing	7:48 - 3:19	902	0.006	0.122	0.002	0.018	0.002
Welding/Assembly	7:30 -10:32	364	0.019	0.110	ND	0.006	ND
Area:							
Large Robotic Welding Area	7:54 - 3:23	892	0.027	0.191	0.003	0.007	0.001
Limit of Detection (µg/filter)		1	1	2	1	1	
OSHA Permissible Exposure Limits (PELS)			0.1	10	10	1	5
NIOSH Recommended Exposure Limits (RELs)		0.1	5	None	1	5	
ACGIH Threshold Limit Values (TLVs®)			1	10	10	5	10

Metals: Cu - Copper; Fe - Iron; Mg - Magnesium; Mn - Manganese; and Zn - Zinc
* - l - liters
** - TWA-mg/m^3 - Time-weighted average - milligrams per cubic meter
*** - ND - None Detected, below the LOD