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Peerless-Premier Appliance Company
Belleville, Illinois

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PREFACE

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Cheryl Fairfield Estill, M.S., P.E. and Stephen D. Hudock, Ph.D., of the Engineering Control Technology Branch, Division of Physical Sciences and Engineering (DPSE) and Daniel J. Hewett of the Clinical Investigations Branch, Division of Respiratory Disease Studies. Field assistance was provided by Daniel S. Watkins. Drawings were designed by Daniel S. Watkins. Desktop publishing was performed by Pat Lovell. Review and preparation for printing was performed by Penny Arthur.

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Health Hazard Evaluation Report 97-0231-2705
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Belleville, Illinois
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SUMMARY

On June 3, 1997, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Boilermakers Union to evaluate potential ergonomic hazards in the press, assembly, and subassembly departments at the Peerless-Premier Appliance Company in Belleville, Illinois. The ergonomic survey consisted of a NIOSH ergonomist viewing each worker and completing a risk factor checklist and a NIOSH researcher analyzing each workstation and completing a workstation profile. These two forms provided information about posture and force required to perform each job.

Ergonomic stressors were found among the press, assembly, and subassembly employees. In the press area, the main risk factors for musculoskeletal disorders are extreme shoulder abduction and flexion, neck flexion, and the use of foot pedals while standing. Many of these hazards can be reduced by the elimination of overhead press activation buttons, and elimination of foot pedals while standing. Waist-level, heat-activated buttons can be used to replace the overhead and foot activations.

In the assembly and subassembly areas, the main ergonomic stressors are extreme back flexion, neck flexion, and shoulder flexion. The back and neck flexion risk factors in the assembly area can be reduced by raising the conveyor line at some workstations. Shoulder flexion in both the assembly and subassembly areas can be reduced by redesigning workstations to reduce the amount of work performed over shoulder or head level, with special emphasis on the carts used to move parts in both areas.

The results of this investigation indicate that press, assembly, and subassembly employees at this facility are exposed to ergonomic hazards. Extreme back flexion, shoulder flexion and abduction, and neck flexion are common stressors found in these departments. These hazards can be reduced by a number of workstation changes presented in this report. A Plant Ergonomics Committee should be formed consisting of hourly and salary workers. This committee should be responsible for prioritizing and completing the recommendations in this report.

Keywords: SIC 3631 (household cooking equipment), ergonomics, work-related musculoskeletal disorders, household appliances, ranges, incentive pay, upper extremity musculoskeletal disorders.

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INTRODUCTION

On June 3, 1997, the National Institute for Occupational Safety and Health (NIOSH) received a union request for a health hazard evaluation (HHE) at Peerless-Premier Appliance Company in Belleville, Illinois. The request was from the International Brotherhood of Boilermakers, Iron Ship Builders, Blacksmiths, Forgers and Helpers, AFL-CIO, which represents two of the unions in the facility, Locals S4 and S60. The HHE request was initiated by reports of musculoskeletal injuries, especially sprains and strains in the upper extremities. The requesters also expressed concerns over silica exposures in the enameling department. In response, NIOSH personnel conducted site visits at the plant on September 30, 1997, and December 2-3, 1997, to evaluate these employee concerns. This report discusses the details of the site visits and presents the findings and recommendations.

BACKGROUND

Peerless-Premier Appliance Company manufacturers gas and electric household ranges, which are smaller or larger economy ranges than the standard 30-inch-wide range. The range production line starts in the fabrication department, where sheet metal is sheared, pressed, bent, clipped, or welded to make the primary structural components of the ranges. From there, the sheet metal is moved to the enameling area, where it is painted. A fire at the plant in September 1997 destroyed the enameling department. Therefore, silica exposures in the enameling department could not be assessed during this HHE. From enameling, the process moves into the assembly area, where the ranges are assembled. There are five assembly lines: three lines assemble gas ranges, and two lines assemble electric ranges. Other parts are assembled in a subassembly area and transferred to the assembly lines. From the assembly area, the ranges move to the crating department, where they are packaged for shipment.

As of December 1997, there were 305 employees at Peerless-Premier. Following are the approximate numbers of employees by department: 162 in the assembly area, 26 in subassembly, 62 laborers (transport materials, drive forklifts), 15 in enameling, 66 in fabrication, 4 in the machine shop, 15 maintenance, and 44 salary. Also, approximately 52 employees have been laid off from the enameling department because of the fire.

METHODS

An ergonomic survey was conducted at the facility on December 2 and 3, 1997. The ergonomic survey consisted of a risk factor checklist, a workstation profile (dimensions and weights of workstation and parts), and a videotape record of employee work tasks. The analysis focused on the press, assembly, and subassembly departments.

In the assembly department, Lines 1 (15 employees) and 3 (16 employees) were evaluated. Line 1 produced a gas range, and Line 3 produced an electric range. These lines also had the most employees per line, which caused employee tasks to be divided into shorter periods of time (shorter cycle times), which is a risk factor for repetitive motion injuries.

In the subassembly area, eight employees were evaluated. Evaluation of at least one type of subassembly job was attempted. In the press department, 12 employees were evaluated. One or more of each type of machine in the press area was evaluated.

Information collected on the risk factor checklist included the most extreme posture for the following body parts: back, neck, shoulder, forearm, wrist, hand, fingers, and lower extremities. The risk factor checklist also collected information about cycle time (the time to work on one range), recovery time (amount of rest between ranges), a hand repetition rating scale, a hand pauses rating scale, contact stress, segmental vibration, whole-body vibration, job rotation, tool configuration, employee height, and recommendations. The risk factor checklist was filled out by an ergonomist. A copy of the risk factor checklist is in Appendix A.

A workstation profile included information on hand tool characteristics, layout of workstation, push-pull force, power grip force, pinch grip force, lateral grip force, wiring, seating, floor matting, working height, lifting, and part weights. A workstation profile form is shown in Appendix B.

RESULTS

Press Area

The location of the activation mechanism on the presses appears to be a problem on most machines. The activation mechanisms consist either of buttons located above the head, or a foot pedal located near the floor. There are 29 machines (presses, brakes, clippers, not including welding machines) in the press area (Figure 1). Of those 29 machines, 13 have overhead buttons, 12 have foot pedals, 3 have waist level controls, and 1 was inoperable. For those employees using overhead buttons, the percentage of time that they spent with their hands overhead averaged 28% of their work cycle and the height of the overhead buttons averaged 70 inches (Table 1).

Of the 12 machines that were activated by foot pedals, only 2 allow the employee to be seated. One machine (power brake 17, see figure 1) had a foot pedal that was 15 inches from the floor.

There were six types of carts in use in the press department during the survey: long truck from enamel, long truck from press department, steel carts, yellow steel with wood tops, wooden carts, and orange racks. Using a force gage, three of each type of cart were pushed while empty to determine the initial push force required to move the cart (Table 2).

Twelve employees using different presses and other equipment were included in the risk factor checklist and workstation profile analysis. The following machines were included in this analysis: presses 1, 2, 5, 6, 8, 9, 10, L23P, shear S63S, brake return table, spot welder 2, and old clipper. All employees were male; their average height was 71.5 inches, with a range of 65 inches to 75 inches. The most extreme motion in each direction during the cycle was marked. Results are shown in Table 3. The average cycle time for the 12 employees was 12.1 seconds (s) and the average recovery time in between cycles was 0.8 s; resulting in an average rate of completion of approximately 4.5 parts per minute. Nine employees performed a forceful lateral pinch grip (thumb opposes side of forefinger) of 2 pounds or more (measured by asking worker if the pinch grip was more or less than squeezing a small binder clip). The average weight of the parts that were monitored for this evaluation was 4.4 pounds and they were handled an average of two times per cycle (maximum of three times per cycle). Only 2 of the 12 employees had floor matting, the other 10 stood directly on the cement floor.

Assembly Area

Fifteen employees on a gas range assembly line (Line 1) and 16 employees from an electric range assembly line (Line 3) were included in the risk factor checklist and workstation profile analysis. Twenty employees were male and 11 were female. The average height of the assembly employees was 68 inches (range: 60 inches to 74 inches). As with the press operators, the most extreme motions in each direction during the cycle were recorded. Results are in Table 4.

Twenty-nine (of 31) employees used gloves on the assembly line, primarily to protect their palms from cuts by sharp metal edges. Seven employees used a foot control to activate a tool or equipment. One employee was seen to kneel or squat to complete the job task. Two employees had to stand on their toes to complete their assigned job tasks. Four employees used their knee as a hammer to force some part into place.

The average cycle time for the 31 assembly line employees was 78.6 s, and the average recovery time between cycles was 5.8 s. The actual number of units produced on December 2 were 257 for Line 1 and 193 for Line 3.

The assembly line employees used an average of 1.4 powered hand tools per workstation. The majority of tools were screw guns (32), followed by rivet guns (4), and nut runners (3). The average weight of the tool was 2.7 pounds. In 17 cases (of 42, 40%), the tool was suspended or supported by a tool balancer system. In 25 cases (of 42, 60%), the tool was not supported or suspended. Twenty-three tools had straight, in-line grip configurations. Nineteen tools had pistol-grip configurations. Thirteen employees (42%) were observed using powered hand tools where the grip configuration was not appropriate for the task (for example, using a pistol grip tool vertically, when an in-line tool would be more appropriate). The tools were activated in the following ways: 18 had single digit triggers; 18 had multiple digit triggers; 5 had thumb triggers; and 1 was activated by applying force on the bit.

Four employees (all on line 3) attached wire terminals to connectors (average of 3 wires per cycle, maximum of 14). Those same four employees wore finger wrap. Twenty-seven employees (87%) had floor matting at their workstation. Assembly line employees handled an average of 3.25 parts per cycle. Each part averaged 4.6 pounds. This resulted in employees handling an average of 15 pounds per cycle.

Subassembly Area

Eight employees performed the following subassembly tasks at the following numbered workstations which were included in the risk factor checklist and workstation profile analysis: wiring-1 and 2, drawers-6, door liners-9, back guards-13 and 14, manifold pipe-18, and burner-22 (see Figure 2 for workstation locations). The average height of the subassembly employees was 68 inches. As with the assembly employees and press operators, the most extreme motions in each direction during the cycle were recorded and are shown in Table 5. Five employees used gloves with the fingers cut out to enhance manual dexterity. One employee wore a finger wrap.

The average cycle time for the eight subassembly employees was 64.2 s, and the average recovery time in between cycles was 0.9 s.

The subassembly employees used an average of 1.1 powered hand tools per workstation. The majority of tools were nut runners (5), followed by screw guns (4). In seven cases, the tool was suspended or supported by a tool balancer system. In two cases, the tool was not supported or suspended. Eight tools had straight, in-line grip configuration; one tool had a pistol-grip configuration. Two employees were observed using powered hand tools where the grip configuration was not appropriate for the task (for example, using a pistol grip tool vertically, when an in-line tool would be more appropriate).

Seven employees were observed using forceful pinch grips. These pinch grips performed an average of 10.4 times per cycle. Five employees attached wire terminals to connectors, averaging 8.7 wires per cycle. All eight subassembly employees had floor matting at their workstation. Subassembly employees handled an average of 3.0 parts per cycle. Each part averaged 2.9 pounds. This resulted in employees handling an average of 10.8 pounds per cycle.

DISCUSSION

Press Area

The average height of the press employees that were monitored was 72 inches, the average height for the U.S. civilian male population is 68.2 inches; median male shoulder height is 56 inches. This information can be used when designing new equipment or re-designing existing equipment. Appendix C shows other dimensions that can be used to help in designing workstations.

The press area employees spent 28% of working time with their hands overhead at a height of approximately 70 inches. To activate the presses more than half of the men at those jobs reached over their head, and all reached over shoulder height during each cycle. The average 150-pound man will have an arm weighing approximately 7 pounds. Therefore, when lengthening the arm to reach buttons, the whole 7-pound weight becomes amplified by the distance from the body. Even with no load in the hand, holding the arm overhead in a static position for 2 seconds presents a large demand on one muscle group in the shoulder. Reaching above shoulder height frequently or for lengthy periods is of particular concern because it has been shown to cause degenerative tendinitis in the biceps and supraspinatus muscles (Chaffin, 1991). Studies which tested pain and fatigue from holding the arm in elevated positions have concluded that sustained elevated arm work should be minimized to avoid shoulder muscle fatigue and tendinitis problems (Hagberg, 1981). Even without a hand load, any elevation of the arm above 90 degrees greatly increases the stress on various tendon-ligament-capsular tissues (Engin, 1980). There are some possible anatomical anomalies that may increase a person's risk of developing thoracic outlet compression. The presence of a horizontal cervical rib between the clavicle and the first rib causes additional costoclavicular compression (Moseley et al., 1991). These anomalous cervical ribs occur in about 1% of the population (Leffert, 1980).

Foot pedals are not recommended for standing work, except for very infrequent use (Eastman Kodak Company, 1986). Pedals that result in over-stretching of the ankle joint (more than 25 degrees around the resting position of the foot) are not recommended (Eastman Kodak Company, 1986). Pedals should be low enough to the ground that the employee does not have to lift the leg to reach the foot pedal. For those jobs that have moderate or low force requirements and are performed primarily from a stationary position with little or no reaching, a sit/stand stool should be provided. In the past five years, numerous stool design options have become commercially available. Supplier agreements for trial use of different style stools should be considered.

An alternative to overhead buttons or foot pedals are waist level buttons. These buttons are typically activated by the heat of the hand so they cannot be easily by-passed. NIOSH data have shown that after depressing shoulder-level buttons (mean 1.45 m/s), employees can move their hands faster than after depressing waist level buttons (mean 1.23 m/s) (Pizatella and Moll, 1987). Therefore, when the buttons are the same distance from the point of operation, hands moving from the shoulder height would reach the point of operation before hands moving from waist height. Hence, waist height buttons are safer in terms of preventing the operator from moving the hands into the area of operation after machine actuation as long as the distance is the same.

As seen in the results sections, the carts vary quite a bit in push force required to move them. The two older types of carts, the yellow steel cart with wooden top and the wooden cart, had the highest standard deviation of required force when comparing different carts. Of the smaller carts, the employees seemed to prefer the wooden carts that tilted because of a fifth wheel in the middle. New carts could be made in-house (like the steel carts) except with a fifth wheel in the middle that is the same size as the other four wheels. The fifth wheel makes it easier to move large weights over the uneven and cracked surfaces that are in the plant floor. Also, increasing wheel diameter generally decreases push forces; currently the steel cart has 6-inch-diameter wheels. These carts should also have handles that are located between 36 and 44 inches from the floor so that employees do not have to stoop when handling the carts (Eastman Kodak Company, 1986).

The risk factor checklist and workstation profile analysis showed that the machine operators require a great deal of shoulder flexion and abduction, to use overhead buttons. Neck flexion also appears to be a problem. Employees must flex their neck to see into the machine to make sure that the part is properly in place. Continued or repeated neck flexion has been associated with neck musculoskeletal disorders (Bernard, 1997). Additionally, several of the same muscles are used in the shoulder girdle and the upper spine. One way to eliminate some neck flexion is to improve lighting inside the press and give the employee a sit/stand stool to lower his body. The improved lighting will enable the employee to see detailed part positions from further away. Providing a sit/stand stool will enable the employee to lean against the stool or actually sit on it, which will lower the employee's upper body so he can see directly into the press.

As mentioned in the Results Section, on average a 4.4 pound lateral pinch grip was performed every 6.6 s or 9 times per minute. Repetitive use of a pinch grip creates friction on the two tendons that control the thumb. The two tendons share a common sheath, which elevates the tension needed to maintain a pinch grip (Putz-Anderson, 1988, p. 55).

The press area has the fewest employees who stand on floor matting; only 2 of the 12 press employees had floor matting; the other 10 stood on the cement floor. Only 4 of 31 assembly employees were not provided with floor matting in the assembly area, and all employees we observed in the subassembly area had floor matting. One study (Kim, Stuart-Buttle, and Marras, 1994) found that the erector spinae muscle of the back benefitted (based on EMG recordings) from having employees stand on mats. Another study (Rys and Konz, 1990) found that the comfort level of subjects was increased as a result of standing on floor mats. The floor mats also accounted for higher foot and leg temperatures and lower heart rates, which the authors suggested correspond to higher productivity. The authors also found that the less compressible the floor mat, the greater the comfort when comparing mats which were 6% and 18% compressible. Conversely, Redfern and Chaffin (1995) found that softer and thicker flooring materials correlated with less perceived tiredness. Redfern and Chaffin also found that tiredness and discomfort ratings were as low for shoe inserts as for similar floor matting material; however, those participants wearing the shoe inserts also reported increased heat in their shoes. These reports show that floor matting is important to relieve tiredness and discomfort in employee's feet and legs, and in reducing back muscle use. All of these studies found that tiredness or discomfort were greater when participants stood on cement floors. It is important to provide anti-fatigue mats for jobs that will be performed in a standing posture (which is almost every job in this plant). It is best to evaluate several types of matting during a trial period before making a purchase. Supplier agreements for the trial use of matting may be less common than is found in seating. Talk with different floor matting suppliers about possible matting available for the fabrication area. Some mats slope on the edges so that carts can roll onto them. In addition to providing some fatigue relief benefits, mats also reduce the ambient noise in the workplace. If the proper floor matting cannot be found for some workstations, then the company should resort to providing anti-fatigue shoe inserts for the employees in that location.

Assembly

In the assembly area, 31 employees were observed on either the gas or electric range lines. The results of the risk factor checklists and the workstation profiles show that many employees have very extreme postures (back flexion > 45º, neck flexion > 45º, shoulder abduction [upper arm lifted out to the side] > 60º). Eighteen of 31 employees had back flexion of greater than 45º, possibly because of the low level of the conveyor (Line 1 ranges from 14 to 31 inches, with an average of 22 inches; Line 3 ranges from 10 to 19 inches with an average of 15 inches). For tasks that require the bottom or the lower part of the range to be worked on, the assembly line should be raised to reduce the extreme back flexion required of many employees. Many employees also had neck flexion attributable to the low level of the assembly line. Increased task lighting for fine attachments would help reduce the amount of neck flexion needed to complete those tasks. Extreme shoulder abduction was also seen among many of the assembly line employees because of the number of tasks that require work above the employee's shoulder height. Only about 5 of the 31 jobs on the two conveyor lines required a work height above 50 inches (which would be about shoulder height). However, many of the supply racks and other workstation areas away from the conveyor required a working height above shoulder height.

Four employees who were connecting wires wore finger wrap. The best way to alleviate the high pinch forces required in wiring is by using low-insertion force terminals. If a change in terminals is not possible, an alternative is a manual hand tool which would take the force away from the small muscles of the fingers and allow use of the larger muscles of the hand (NIOSH, 1997a).

Four assembly line employees used their knee as a hammer (tasks include hitting the side panel and the fume columns in place) and eight used their hand (tasks include opening the hinges, attaching the gas supply to the range, punching out painted-over holes, forcing on bottom plate, etc.). High forces applied to the hand in the palm area can cause injury to the median nerve, which travels through the hand at the base of the palm. High forces to the knee can cause bursitis of the knee or fluid buildup.

Almost one-fourth of the assembly line employees used foot controls, but none of these employees were seated. Foot controls should only be used on a routine basis by employees who are seated.

Almost half of the assembly line employees used powered hand tools where the grip configuration was not appropriate for the task. Less than half of the tools were suspended. Using the wrong grip configuration causes the employee to hold an awkward wrist posture in a static position. The combination of the vibration from the power tool and the awkward posture could put the employee at risk of a nerve disorder.

One of the most ergonomically stressful jobs appears to be installing a bottom panel and gas line on the gas range, then picking up and manually flipping the range over on to its back. Initially, the employee places a label onto the back panel and dabs connectors with a paint brush containing sealant or grease. The employee then laterally bends to his left and picks up a bottom panel from the stockpile on the floor. The employee swings the six-pound panel up onto the back of the range, lifting both hands above eye level so that the panel does not hit the range. The employee then grabs a gas tubing assembly from a rack above eye level and attaches it to the bottom panel. This panel is then screwed to the range. The employee then picks up the 36-pound range, one hand low and one hand high on the range, and manually flips it 180 degrees. This task may put the employee at an increased risk of developing a work-related injury from lifting. (Approximate lifting index of 1.9; a lifting index greater than 1.0 poses an increased risk for lifting-related low back pain for some fraction of the workforce). During production delays, this employee opened oven door hinges by holding them in his hand and slamming the hinge against the work table. This action would transmit impact vibrations to the hand, wrist and elbow of the employee. The greatest ergonomic risk factors on this job are lifting with little recovery time (2 lifts during a 76 s cycle time) and impact vibrations to the hand.

Another ergonomically stressful job on both the gas and electric range line, is installing bottom brackets and feet onto the range. The employee pushes the range over on to its back on a platform above and behind the conveyor belt. The employee then attaches two bottom brackets and four leveling legs onto the range using two different pistol-grip drivers. When finished, the employee pulls the range upright and sends it to the next station. The employee spends one-half of the cycle time bent over to work on the rear leveling feet and brackets on the bottom of the range. The ergonomic risk factor associated with this job is extreme and lengthy forward bending. The height of the bottom two legs is too low (15 inches from the floor). Work tasks should be designed so that most tasks are at a height between the waist and the shoulder (40 to 54 inches, average for men and women, respectively). A tilting work table with an adjustable height should remove the major stressors from this position.

Subassembly

Much of the discussion of the assembly area applies to the subassembly area because the jobs had similar cycle times and tasks. In general, the subassembly areas had received recent attention and various ergonomic improvements had been made to several of the workstations. Power tools used in the gas manifold area had articulating arms to allow the tool to hang near the work area and to support the tool while in use by the employee. Jigs were provided to hold the splash guards, gas manifolds, and burner hangers in place while using. All of the observed subassembly workstations were equipped with floor matting.

The assembly of the back splash guard panels utilized pinch grips to hold wires while inserting them onto connectors. The thumb was often used to push wires onto connectors or to push control knobs onto stems. Manual tools may be used in lieu of the fingers and thumbs. Jigs hold the splash guards prone, parallel to the floor and perpendicular to the median plane of the employee. This position results in a large amount of wrist flexion to attach wires into the splash guard. Tilting the jig or piece toward the employee will reduce the wrist flexion while wiring. However, tilting the jig will increase the amount of radial deviation while using an in-line driver vertically. An overall solution to reduce flexion and radial deviation would be the development of a two-position jig that may help to minimize awkward postures.

In another of the electric range back guard assembly areas, the employee must join two sets of wires using wire nuts. This results in wrist rotation, radial to ulnar. Other types of connectors could eliminate this motion. The employee joins the wires also using the hand repeatedly as a hammer or pressing with the fingers to force pieces to join properly. A rubber mallet could substitute for the hand and fingers when forcing parts into place. Tighter tolerances from part suppliers would minimize the likelihood of parts not fitting together properly.

In both the subassembly and assembly areas, small parts are often stored in cardboard shipping boxes at the workstation. The employee must reach over the front edge of the box and down into the box to retrieve a part. Small parts bins with lower front walls, called hopper fronts (Figure 4), or boxes with the front wall cut out, would eliminate the majority of the wrist flexion associated with parts retrieval.

The bottom-drawer subassembly area was crowded with incoming parts or outgoing product. The finished product cart was stacked over five feet high with product, forcing the employee to lift the 8.5 pound finished drawer over shoulder height to position it on top of the stack.

Employees at the bottom-drawer workstations used an in-line tool to attach a nut in a horizontal position. A pistol grip tool would result in less stressful wrist postures when used horizontally. While driving bolts through nuts, the employee would use fingers to hold the nut to allow the fastener to tighten without slippage. Use of a small box or open end wrench to hold the nut would eliminate contact stresses to the fingers.

In the door liner subassembly task, the employee sandwiches a piece of glass and insulation between two halves of an oven door. The employee stages pieces of the oven door on the floor by the workstation to eliminate the need to constantly walk to the supply cart. Unfortunately, as currently designed, the workstation is too low, causing the employee to flex his back and neck when installing the screws into the doors. The employee also reaches across the oven door to drive the screws on the far edge of the door.

In the burner hanger subassembly, the jig is set to hold seven pieces horizontally, which results in the employee flexing and twisting the back and stretching the arms when inserting flexible tubing through holes in each end of the hangers.

CONCLUSIONS

Ergonomic stressors have been found among the press, assembly, and subassembly operations at this facility. In the press area, the main stressors are extreme shoulder abduction and flexion, neck flexion, and the use of foot pedals while standing. Many of these hazards can be reduced in the press area by the elimination of overhead press activation buttons and the elimination of foot pedals while standing. Waist-level, heat-activated buttons can be used to replace the overhead and foot activations. In the assembly and subassembly areas, the main ergonomic hazards are extreme back flexion, neck flexion, and shoulder flexion. The back and neck flexion risk factors in the assembly area can be reduced by raising the conveyor line at some workstations. Shoulder flexion in both the assembly and subassembly areas can be reduced by redesigning workstations to reduce the amount of work performed over shoulder or head level, with special emphasis on the carts used to move parts in both areas. These activities should be carried out by a Plant Ergonomics Committee composed of hourly and salaried workers.

RECOMMENDATIONS

Press Area

1. Replace all overhead button activations to waist-level positions to eliminate the need for employees to reach overhead. Secure waist-level activation mechanisms the same distance from the press point of operation as the overhead buttons.

2. Foot pedals should not be used for routine work; waist-level activation mechanisms should be used instead. If foot pedals continue to be used, the employee should be seated and the pedal should be moved low enough to the ground so that the employee does not have to lift his leg to reach the foot pedal. For purchasing stools, check with local distributors about a trial use before purchasing all that are required.

3. New carts, like the steel carts except with a fifth wheel that is the same size as the other four wheels, should be made in-house. The current carts with five wheels could easily topple a load. The wheel diameter should be increased from 6 inches to 8 or more inches. Handles should be provided on the carts to prevent stooped postures while transporting.

4. Institute a cart maintenance program so cart wheels always move smoothly.

5. To decrease awkward neck postures, add task lighting to the point of operation in the press and provide sit/stand stools.

6. For parts that are handled three times per cycle, change carts or workstation layout to eliminate one lift per cycle (the parts that were observed being handled three times per cycles were the control panel on press 9 and the 30 inch back guard on press 10).

7. Provide anti-fatigue matting for all workstations that require standing. Work with suppliers to find matting that is appropriate for the fabrication area. As a last resort, provide shoe inserts for employees who work at workstations that do not have floor matting.

Assembly and Subassembly Areas

The general recommendations can be divided into four distinct areas: workstation design, hand tools, manual materials handling, and quality control.

Workstation design recommendations

1. To reduce back and neck flexion, raise the height of the conveyor line at some workstations, especially for jobs requiring tasks on the lower front or bottom of the range.

2. To reduce extreme shoulder abduction, lower the top positions on racks to average shoulder height (54 inches).

3. Change terminal connectors to low-insertion force terminals or provide manual hand tools for wiring tasks (NIOSH, 1997a).

4. Foot controls should be used only by seated employees. Change the control activation mechanism or provide seating for these employees.

5. Provide turntables at workstations that require work on surfaces both near the front and back of the table (e.g., door subassembly). This turntable would reduce back and shoulder flexion due to stretching to complete the task.

6. Use self-leveling carts or self-elevating tables for the storage and movement of materials. In this way, manual material handling will be kept at waist height, a less stressful position. A less expensive alternative is to alter the carts so that all material is located between knee and shoulder heights (averages of 20 to 54 inches).

7. Access to parts and supplies is a key component to both productivity increases and minimizing postural stresses. Place all parts needed for the task within the forward functional reach area of the employee (average of 30 inches from the shoulder). Store all necessary parts and components no lower than waist height. Eliminate storage and stockpiling of material on the floor by using racks and tables.

8. Store small parts such as fasteners in hopper front bins instead of cardboard shipping boxes to reduce the amount of wrist flexion required to retrieve the parts (Figure 4).
9. Provide jigs to hold the components or work pieces while the task is being performed. Jigs should be designed together with the assistance of employees who better understand the job. Tiltable or adjustable jigs may be needed (for example, in splash guard subassembly).

Hand Tool Recommendations

1. To reduce awkward wrist postures, match the grip configuration to the task being performed. In-line drivers should be used primarily for vertical applications; pistol grip drivers should be used for horizontal applications. If necessary, additional tools should be added to the workstation to provide the correct configuration, or jigs that allow use of tools in strictly horizontal or vertical motions should be installed. Force-on-the-bit activation should be used to eliminate the need for the employees to provide one or more finger digits for activation while supporting the tool with the rest of their hand.

2. Tool handle diameter should be a consideration in accommodating both smaller and larger employees. Correct tool handle size (2.0 to 2.4 inches in diameter) will eliminate some of the static muscle effort within the hand that result from the use of an incorrectly sized tool.

3. Less than half of the powered tools on the assembly line were suspended. To reduce the amount of weight that employees must hold in a static position, tools should be suspended near shoulder height (average of 52 inches for women and 56 inches for men), rather than overhead. Tension on the tool should be adjusted to minimize effort to bring the tool to the work task so that upon release it still returns to the proper suspended position.

Manual Materials Handling Recommendations

1. Minimize the manual unsupported movement or repositioning of heavy parts. Lift tables and self-leveling bins can be used to support products on or off the workstation at approximately waist height. The use of lifting aids or devices in the transfer or reorientation of any parts over 25 pounds that occurs each cycle should be considered.

2. The flow of material in and out of each workstation as currently designed is in need of consideration. Parts are brought in on carts that

are placed near the workstations. Employees then stage the parts to a location nearer to their work, such as on the floor against the workstation. This staging of material results in excessive back flexion and twisting. Staging should be eliminated by providing room for the carts in close proximity to the work area.

Quality Control Recommendations

1. Take into account employee ergonomic risk factors when accepting out-of-specification or problem products from suppliers. Many range panels currently come to the workstations with fastener holes enameled over. These holes must be punched out by the employee using an awl or screwdriver requiring high forces and awkward postures. This problem was thought to be due to the use of a supplier in the enameling process who did not properly address the issue. When these types of problems are found, the ergonomic risk associated with repairing the problem should be taken into account. Because these problems are seen as temporary, the proper tools and jigs are often not supplied to the employees.

Specific Workstations

1. For the assembly line job requiring the 180º lift and turn of the 36-pound range, provide an alternate way to flip the range, such as a mechanized material handling device or simply added room on the conveyor line to manually push it onto its side and then onto its bottom. To reduce impact vibrations from opening the hinges, put together a small team to redesign the existing jig so that it is used.

2. For the assembly line job that requires installation of the bottom bracket and leveling legs, reduce the extreme static forward bending by increasing the assembly line height at that location and providing a tilting work table.

Overall

1. A Plant Ergonomics Committee should be developed. The team should consist of mostly production line employees from each department, at least one employee in the maintenance department, at least one engineer, and the manager who is in charge of health and safety. The employee performing the evaluated job task should be temporarily included in the team. The permanent members of the team should be provided with a minimum of a one-day ergonomic training course. The team could brainstorm solutions to some of the risk factors or carry out some of the recommendations presented in this report. NIOSH has recently published a book entitled, "Elements of Ergonomics Programs." (NIOSH, 1997b)

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Table 1. Percent of time employee spent with hands depressing overhead buttons

Machine	Cycle Time (s)	Time hands overhead (s)	Percent	Height of buttons from floor (inches)
Brake L34P2	7	2	29	
Press 1	10	3	30	69
Press 2	7	2	29	63.5
Press 4	12	3	25	
Press 5	7	2	29	75
Press 6	7	2	29	72
Press 7	8	2	25	
Press 9	14	2	14	72
Press 12	8	3	38	
Press 19	7	2	29	
	Average		28	70.3

Presses 8 and 3 were not in use when this information was collected. Press 8 had a button height of 70.5 inches. Button height was not determined for all machines. Note: One additional press had overhead buttons but appeared to be inoperable.

Table 2. Initial push force required to push each type of cart.			
Type of Cart	Initial push force while empty (lb)	Average (lb)*	Standard Deviation
Long trucks from enamel department	6.1, 6.8, 8.0	7.0	1.0
Long trucks from press department	13.3, 8.2, 6.7	9.4	3.5
Steel carts	8.0, 12.1, 12.3	10.8	2.4
Yellow steel carts with wood top	10.5, 11.7, 21.6	14.6	6.1
Wooden carts	10.0, 12.0, 19.1	13.7	4.8
Orange racks	10.6, 12.5, 14.8	12.6	2.1

* Average of three different carts.

Table 3. Press Area Employees Observed Postures (12 employees)		
Posture	Number	Percent
Neck Flexion > 45°	3	25.0
Neck Flexion 20°-45°	8	66.7
Neck Flexion <20º	1	8.3
Shoulder Flexion > 90°	3	25.0
Shoulder Flexion 45°-90°	9	75.0
Shoulder Abduction > 60°	2	16.7
Shoulder Abduction 30°-60°	10	83.3
Lateral Pinch Grip of 2 lbs or more	9	75.0

Table 4 – Assembly Department Employees Observed Postures (31 employees)			
Posture	Number	Total Employees Evaluated*	Percent
Back Flexion > 45°	18	31	58.1
Back Flexion 20°-45°	8	31	25.8
Back Flexion < 20°	4	31	12.9
Neck Flexion > 45°	13	30	43.3
Neck Flexion 20°-45°	14	30	46.7
Shoulder Flexion > 90°	12	30	40.0
Shoulder Flexion 45°-90°	18	30	60.0
Shoulder Abduction > 60°	18	29	62.1
Shoulder Abduction 30°-60°	10	29	34.5
Wrist Flexion > 45°	2	28	7.1
Wrist Flexion 20°-45°	14	28	50.0
Wrist Extension > 30°	11	29	37.9
Wrist Ulnar Deviation (towards little finger)	14	29	48.3
Wrist Radial Deviation (towards thumb)	14	28	50.0
Forearm Supination (palms up)	19	28	67.9
Pinch Grip	29	30	96.7
Hand as Hammer	8	30	26.7

* For some variables, data were missing.

Table 5 – Subassembly Department Employee Observed Postures (8 employees)		
Posture	Number	Percent
Back Flexion > 45°	2	25
Back Flexion 20°-45°	2	25
Back Flexion < 20°	4	50
Trunk Twist > 20°	3	38
Neck Flexion > 45°	5	63
Neck Flexion 20°-45°	3	38
Shoulder Flexion > 90°	2	25
Shoulder Flexion 45°-90°	6	75
Shoulder Abduction > 60°	2	25
Shoulder Abduction 30°-60°	5	63
Shoulder Extension > 20º	1	13
Wrist Flexion 20°-45°	6	75
Wrist Extension > 30°	2	25
Wrist Ulnar Deviation (towards little finger)	4	50
Wrist Radial Deviation (towards thumb)	2	25
Forearm Supination (palms up)	5	63
Pinch Grip	8	100
Hand as Hammer	1	13

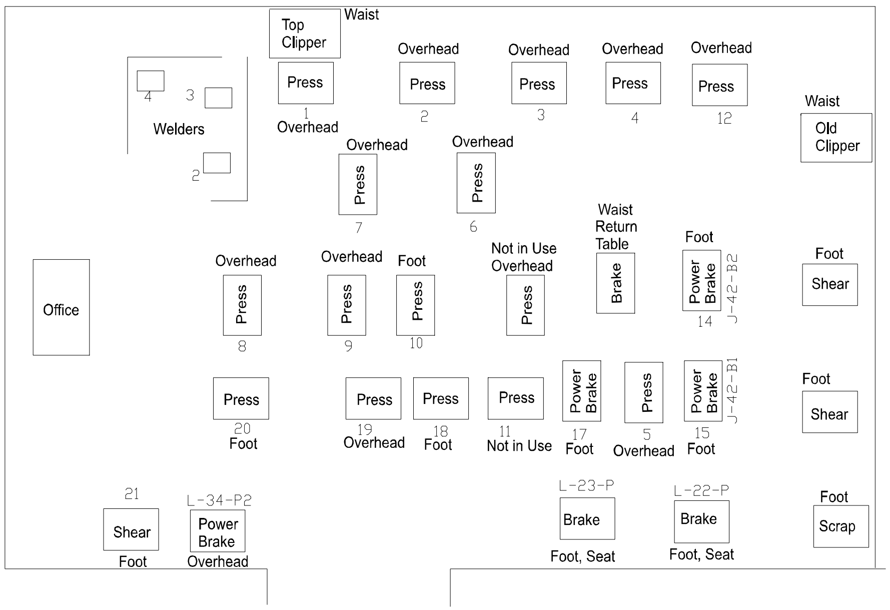

Figure 1 Diagram of Fabrication Area. Machines are marked for the location of activation mechanisms: FOOT-foot pedal, OVERHEAD-overhead push buttons, WAIST-waist level controls. Also, some machines are marked SEAT if they are seated workstations.

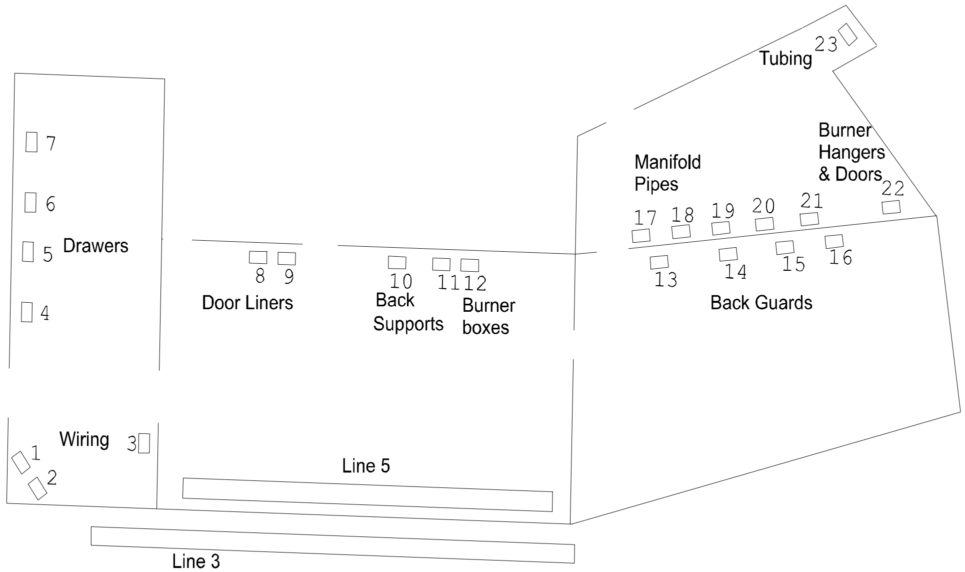

Figure 2 Diagram of the subassembly area.

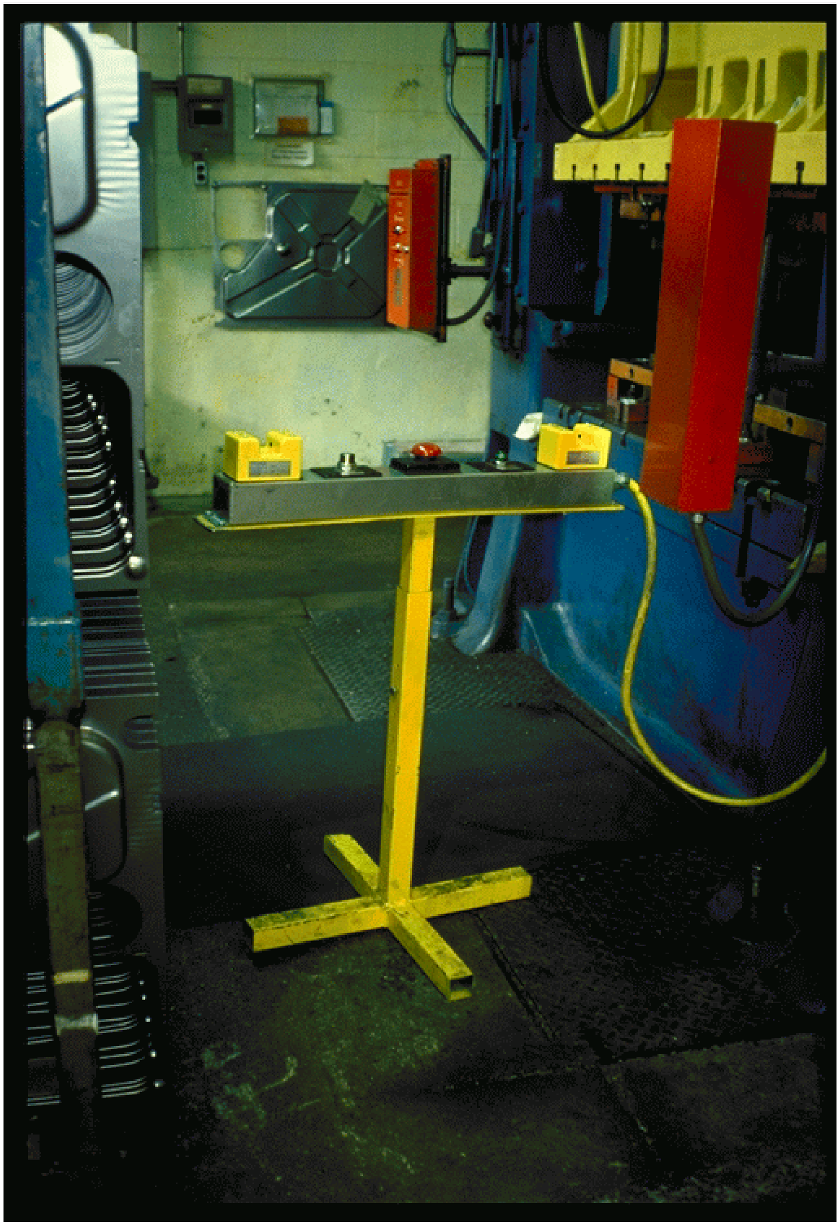

Figure 3 Heat-Activated waist level buttons to activate a press.

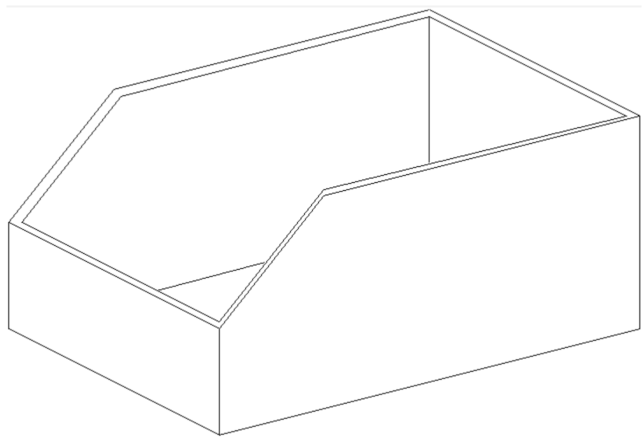

Figure 4 Diagram of preferred low-front bin.

Appendix A. Risk Factor Checklist

Date	_____________	Worker # (Y / N)	____________	Dept - Shift	______
1st SWC #	_____________	Team #	_____________	Station #	______
2nd SWC#	_____________	Team #	_____________	Station #	______
3rd SWC#	_____________	Team #	_____________	Station #	______
Analyst	_____________	Video Counter	_____________	Video Tape #	______
		Time of Day	______ am/pm		

BODY LOCATION	DURATION OF EXPOSURE *(JOB ROTATION)*	POSTURE	EXTREME CATEGORY *(circle condition)*	ADDITIONAL FACTORS *(use empty space for notes)*
Back		Flexion	20°-45° / >45° / N	Y / N Prolonged sitting without adequate back support Y / N Feet not firmly supported while seated
		Extension	>20° / N	
		Twist	>20° / N	
		Lateral	>20° / N	
Neck		Flexion	20°-45° / >45° / N	
		Extension	>5° / N	
		Twist	≥20° / N	
		Lateral	≥20° / N	
Shoulder		Flexion	45°-90° / >90° / N	Y / N Unsupported arm (e.g., no arm rest when doing precision finger work)
		Extension	>15° / N	
		Abduction	30°-60° / >60° / N	
Forearm		Pronation	Y / N	Y / N Rapid rotation of the forearm Y / N Resisting arm rotation from a tool ✓✓ Y / N Extremely flexed elbow
		Supination	Y / N	
Wrist		Flexion	20°-45° / >45° / N	
		Extension	>30° / N	
		Ulnar	Y / N	
		Radial	Y / N	
Hand		Pinch	Y / N	Y / N Using hand as a hammer Y / N Gloves worn (____ fingers cut out?)
		Lateral pinch	Y / N	
		Hook	Y / N	
Fingers		Finger press	Y / N	Y / N Forceful finger gripping, e.g., click and drag a mouse Y / N Finger wrap worn
Lower extremity		Ankle	Y / N Rapid flexion or extension Y / N Use of foot control	Y / N Kneeling or squatting Y / N Stand on toes Y / N Use knee as a hammer or kicker

Cycle time *(production work only)* ________ seconds *(do not count rest time between cycles)*

Recovery time between cycles ________ seconds

Part of recovery time used to prepare for next cycle(s)? Y / N

Repetition Ratings: (HANDS and ARMS only)

0	2	4	6	8	10
Hands & arms idle most of the time	Hands & arms idle often	Slow motion of hands & arms	"Normal" motion of hands & arms	Rapid motion of hands & arms	Frenzied motion of hands & arms

0	2	4	6	8	10
Nearly continuous pause	Prolonged pause with occasional exertions	Frequent pauses ≥5 seconds between exertions	Consistent or regular short pauses between exertions	No regular pauses between exertions	Never a pause

EXPOSURE	DURATI0N OF EXPOSURE *(job rotation)*	CLARIFICATION	RESPONSE	ADDITIONAL FACTS
Repetition		Identical or similar upper extremity motions ≤ 5 seconds apart	Y / N	
Control over work pace			Y / N	Y / N Active station box ✓✓ Y / N On main line Y / N Banks parts
Intensive keying		Similar to steady, paced data entry	Y / N	
Intermittent keying		Limited to <50% of work time	Y / N	
Contact stress		Hard, sharp objects pressing against skin	Y / N	Y / N Palm Y / N Elbow Y / N Fingers Y / N Armpit Y / N Wrist Y / N Leg Y / N Other___________________
Segmental vibration		Affects a body part such as hand, arm	Y / N Tool	____ Other ___________________
Whole-body vibration		Affects whole body	Y / N	Source________________________
Job rotation		Worker assigned to >one job	Y / N	Rotation Schedule: ______ times / day ______ times / week
Exposure to ergonomic hazards		Exposure to hazards on the job *(one job in the case of job rotation)*	Y / N	Duration Per Day: Y / N 7 hours 20 minutes _____ hours

✓✓ **Note exposure variations *(per model, etc.)* below:**

____

____

____

✓✓ **RECOMMENDATIONS: (incorporate worker's insights into recommendations)**

____

____

____

APPENDIX B. WORKSTATION PROFILE FORM

(✓✓ ask worker)

Date ____________________ Shift ____________________ ✓✓ Worker # ____________________

Dept: Assembly Line 1 2 3 4 5 Workstation #: ______________ Gender: M F

Subassembly Simple Workstation Desc:_____

Press ___________________________

Analyst: ____________________ Time of Day: _______________

Workstation Layout: *(sketch and list all dimensions in inches)*

List the following:

- ☞ height of major work surfaces
- ☞ working (arm) height *(if different)*
- ☞ reach distances *(parts, tooling)*
- ☞ manual and visual access points

Hand Tool Characteristics:

TOOL #	TOOL NAME	WT.	TOOL TYPE	TRIGGER TYPE	FASTENER HEAD	TOOL ACTIVATION S / CYCLE	FASTENERS INSTALLED / CYCLE
1	❒ screw gun ❒ rivet gun ❒ nut runner ❒ glue gun ❒ other *(specify)* ______________	______ Tool wt supported Y / N	❒ in line ❒ pistol grip ❒ angle head ❒ other *(specify)* _____________	❒ thumb ❒ single digit ❒ multiple digits ❒ force on bit	❒ phillips ❒ slot ❒ hex ❒ box ❒ other *(specify)* _____________	__________	____________
2	❒ screw gun ❒ rivet gun ❒ nut runner ❒ glue gun ❒ other *(specify)* ______________	______ Tool wt supported Y / N	❒ in line ❒ pistol grip ❒ angle head ❒ other *(specify)* _____________	❒ thumb ❒ single digit ❒ multiple digits ❒ force on bit	❒ phillips ❒ slot ❒ hex ❒ box ❒ other *(specify)* _____________	__________	____________
3	❒ screw gun ❒ rivet gun ❒ nut runner ❒ glue gun ❒ other *(specify)* ______________	______ Tool wt supported Y / N	❒ in line ❒ pistol grip ❒ angle head ❒ other *(specify)* _____________	❒ thumb ❒ single digit ❒ multiple digits ❒ force on bit	❒ phillips ❒ slot ❒ hex ❒ box ❒ other *(specify)* _____________	__________	____________

EXPOSURE	DURATION OF EXPOSURE *(JOB ROTATION)*	CLARIFICATION	RESPONSE	ADDITIONAL FACTS
Push-Pull		None[0] Lightload < 20# initial force[1] Moderate load 20-49# initial force[2] Heavy load ≥50# initial force[3]	________	DURATION _____ times / cycle / day
✓✓ Forceful Power Grip		None[0] Squeezing very hard[1] Squeezing hard[2] Squeezing moderate[3] Squeezing farily light[4] Squeezing very light[5]	________	DURATION _____ times / cycle
✓✓ Forceful Pinch Grip		More than 2 pounds force *(force of opening a small binder clip)*	Y / N	DURATION _____ times / cycle
✓✓ Forceful Lateral Grip		More than 2 pounds force *(force of opening a small binder clip)*	Y / N	DURATION _____ times / cycle
Wiring		Attaching wire terminals to connectors	Y / N	DURATION ______ wires / cycle ✓✓ ___ maximum number any unit
Seating Available			Y / N	Y / N adjustable height Y / N lumbar support Y / N foot stool or ring
Floor Matting			Y / N *(either answer)* ☞	BASE SURFACE MATERIAL Y / N cement Y / N wood Y / N metal grating
Ground Level Working Height			Y / N	OTHER WORKING HEIGHT Y / N platform Y / N pit
✓✓ Lifting		≥ 10 pounds lifted ≥10 times per day	Y / N	

Object Weights ***(parts and cartons; NOT individual fasteners):***

Part Name	Size (l x w x h)	Weight	Notes (times handled / cycles / day)
________________	________________	_________	__________________________
________________	________________	_________	__________________________
________________	________________	_________	__________________________
________________	________________	_________	__________________________

Appendix C: Anthropometric Measurements of U.S. **Women** (in or lb) (NASA, 1978)

Measurement	Source	Mean	Percentile of Population		
		(s.d.)	5th%	50th%	95th%
Elbow height, standing	2	41.09 (1.48)	38.6	41.1	43.6
Elbow rest height, sitting	3	9.40 (1.2)	7.1	9.2	11.1
Eye height, sitting	1	29.02 (1.2)	27.1	29.0	31.0
Functional Forward Reach	4	* (1.8)	25.2	28.0	31.1
Hand breath	1	2.97 (0.15)	2.72	2.99	3.23
Knee height, sitting	3	19.56 (1.07)	17.8	19.6	21.5
Popliteal height, sitting	3	15.63 (1.1)	14.0	15.7	17.4
Sitting height	3	33.34 (1.43)	30.9	33.5	35.7
Shoulder Height	4	* (2.4)	47.7	51.6	55.9
Stature	3	63.10 (2.59)	58.9	63.2	67.4
Thigh clearance	3	5.40 (0.72)	4.2	5.4	6.9
Waist Depth	1	7.01 (0.66)	5.8	6.6	8.0
Waist Height	1	39.48 (1.77)	36.6	39.4	42.5
Weight	1	140.44 (30.45)	101.9	134.7	198.2

Source
1 - U.S. Air Force Women, 2 - Airline Stewardesses, 3 - National Health Exam Survey of U.S. Civilian Women, 4 - U.S. Civilian Population 1980 (Kroemer, Kroemer, and Kroemer-Elbert, 1990)
* Mean functional forward reach and shoulder height not available, use 50^{th} percentile.

Appendix C. Anthropometric Measurements of U.S. **Men** (in or lb) (NASA, 1978)

Measurement	Source	Mean (s.d.)	Percentile of Population		
			5th%	50th%	95th%
Elbow height, standing	1	43.24 (1.93)	40.1	43.2	46.5
Elbow rest height, sitting	2	9.50 (1.18)	7.5	9.6	11.6
Eye height, sitting	1	31.39 (1.30)	29.2	31.4	33.5
Functional Forward Reach	3	* (2.0)	30.0	32.5	34.8
Hand breath	1	3.49 (0.19)	3.2	3.5	3.8
Knee height, sitting	2	21.3 (1.14)	19.4	21.4	23.3
Popliteal height, sitting	2	17.31 (1.05)	15.4	17.4	19.2
Sitting height	2	35.61 (1.44)	33.1	35.7	38.1
Shoulder Height	3	* (2.4)	52.1	56.2	60.0
Stature	2	68.20 (2.71)	63.7	68.3	72.6
Thigh clearance	2	5.63 (0.67)	4.5	5.7	7.0
Waist Depth	1	8.33 (0.98)	7.0	8.1	10.2
Waist Height	1	41.47 (2.07)	38.1	41.4	44.9
Weight	2	165.13 (27.83)	123.9	163.2	214.1

Source
1 - U.S. Air Force Men, 2 - National Health Exam Survey of U.S. Civilian Men, 3- U.S. Civilian Population 1980 (Kroemer, Kroemer, and Kroemer-Elbert, 1990).
* Mean functional forward reach and shoulder height not available, use 50th percentile.

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