HETA 94-0214-2508
MAY 1995
MCD, Inc.
ANNISTON, ALABAMA

NIOSH INVESTIGATORS
Susan Burt, M.Sc., M.S.N.
Cheryl Fairfield-Estill, M.S., P.E.

SUMMARY

In March 1994, the National Institute for Occupational Safety and Health (NIOSH) received a management request from MCD, Inc. to conduct a health hazard evaluation (HHE) in Anniston, Alabama. The request was prompted by concerns about musculoskeletal disorders among employees working on the microwave oven assembly lines. NIOSH investigators conducted a site visit at the plant from October 31 - November 2, 1994. The medical evaluation included a review of the Occupational Safety and Health Administration (OSHA) log of occupational injuries and illnesses, workers' compensation records, and confidential interviews with employees. Interviews focused on work history, work-related musculoskeletal symptoms, medical treatment, and employees' suggestions for improving work conditions. The ergonomic evaluation consisted of observation of all jobs on one assembly line, noting whether employees were exposed to repetitive motions, force, and awkward postures. The NIOSH lifting equation was also used to evaluate three lifting jobs.

Using available data from OSHA logs of recordable injuries and illnesses, the incidence rates for disorders associated with repeated trauma exceeded the average for this industry. Most of these were tendon disorders of the upper extremities, (hand/wrist and shoulder tendinitis, de Quervain's [thumb] tendinitis, epicondylitis [elbow]), and carpal tunnel syndrome. Several physical ergonomic stressors were observed by NIOSH investigators, including highly repetitive tasks, awkward postures resulting from workstation design, and force requirements for some jobs that may exceed acceptable levels for a mostly female workforce. Specific engineering controls by type of job and more general administrative controls are included in the recommendation section of this report.

On the basis of this evaluation, NIOSH investigators concluded that work-related musculoskeletal disorders were occurring at MCD, Inc. in Anniston, Alabama. Recommendations to prevent and control musculoskeletal disorders are provided.

KEYWORDS: SIC 3631 (household cooking equipment), ergonomics, work organization, musculoskeletal disorders, carpal tunnel syndrome, pneumatic hand tools.

INTRODUCTION

In March 1994, the National Institute for Occupational Safety and Health (NIOSH) received a management request from MCD, Inc. in Anniston, Alabama, to conduct a health hazard evaluation (HHE). The request was prompted by concerns about musculoskeletal disorders among employees working on the microwave oven assembly lines. NIOSH investigators conducted a site visit at the plant from October 31 - November 2, 1994. The main objective was to identify ergonomic hazards present in the microwave oven assembly jobs, and to make recommendations to reduce or eliminate these hazards.

BACKGROUND

The plant opened in 1971, when it was owned by Magic Chef. Maytag bought the plant in 1988, and the current private owner purchased it in 1992. Two hundred forty-two of MCD, Inc.'s employees work on assembly lines. Four assembly lines produce microwave ovens, and a fifth assembly line produces dehumidifiers. The "A" line operates on two shifts; the other microwave oven lines operate on one shift. The dehumidifier line operates for approximately six months of the year, from January to June, with two shifts. Metal parts for the microwave ovens and dehumidifiers are fabricated on site, but plastic parts are purchased from off-site suppliers.

The average length of employment at the plant is 6.8 years (longer in the assembly department, shorter in the fabrication department). Forty-two percent of employees are female. There are no females in fabrication, welding, or painting operations. There is one female in the maintenance area. Sixty percent of assembly line employees are female. The average age of employees is 35 years. There is an on-site first aid room, and a full-time safety and health coordinator. There is an employee representative, selected by management, on the health and safety committee. There is no union at the plant.

In June 1994, the assembly lines were reorganized to manufacture new models of microwave ovens. The new ovens have fewer parts and require fewer assembly steps. As a result of the change to the new products, there are five to six fewer jobs per assembly line. This reduction in the number of employees is taking place through attrition rather than layoffs. However, the number of hours per week that employees work has been reduced, largely because of difficulty obtaining an adequate supply of parts for the new product line. Following a change in ownership of the plant in 1988, there were reductions in hourly wages. Since then, pay increases have occurred, but wages have not reached 1988 levels.

Process Description

The shell (cavity) of the microwave oven is stamped and welded in the fabrication area of the plant. From the fabrication area, the cavity of the microwave is transported by overhead conveyor to the paint department where it is painted white. From the paint department, the cavity is usually stacked in a holding area until it is ready to be assembled. When required, the cavity is put on a conveyor which transports it to the assembly line.

For the assembly operation, the microwave ovens travel on a conveyor line at a constant speed of about 12 feet per minute. Each assembler adds parts, attaches screws, connects electrical wiring, adds outer casing, or performs quality control. There are also a few sub-assembly areas where workers prepare parts before they are attached to the microwave. Although not on the moving assembly line, these jobs are driven by the speed of the assembly line. Assemblers usually have their own work stations and the product travels past them on the assembly line. Each worker has 20 seconds to perform a task. The oven travels on the line until it is completed, tested, and packaged. Finally, the package is loaded onto a pallet. A fork lift truck transports the loaded pallet into a truck.

EVALUATION CRITERIA

Musculoskeletal disorders occur in workers whose jobs require repetitive exertion, stressful postures, force, and lack of adequate rest or recovery.[1] Vibration and sustained static loading, which occurs when the muscles are held in fixed positions for prolonged periods, are additional risk factors for musculoskeletal disorders.[2,3] Risk factors for upper extremity musculoskeletal disorders are common in many manufacturing and assembly jobs in industry. The household appliance manufacturing industry has the third highest rate of disorders associated with repeated trauma, following the meatpacking industry, and motor vehicle manufacturing.[4] Examples of upper extremity musculoskeletal and related disorders include tendinitis, tenosynovitis, de Quervain's syndrome, epicondylitis, ganglionic cyst, carpal tunnel syndrome, rotator cuff syndrome, and hand/arm vibration syndrome. These disorders are described below.

Stressful postures include wrist extension and flexion, ulnar and radial wrist deviation, open-handed pinching, and shoulder abduction and flexion. It is particularly important to ensure adequate recovery time from repetitive or static exertions, to allow for resumption of blood flow to the active muscles, and to avoid fatigue and microtrauma to the soft tissues and joints of the body [5,6] As repetition rate increases and joint and tissue stress accumulates, the risk of musculoskeletal injury increases.[7] As muscle exertion increases, blood flow to the muscles decreases, resulting in fatigue.[1] When forceful exertion is combined with repetitive movements and stressful postures, harmful effects are exacerbated.[8]

Vibration transmitted to the hand via vibrating hand tools, such as pneumatic drills and grinders, has been associated with hand arm vibration syndrome (HAVS), described below.[9] It has been previously demonstrated that the use of pneumatic screwdrivers during assembly of small appliances can result in worker exposures that exceed the International Standards Organization exposure guidelines for hand-transmitted vibration.[10, 11] The health effects of HAV from power hand tools depend on the amplitude, direction, and frequency spectrum of the tool's vibration during use, as well as the extent of use.[12]

In addition to physical risk factors, several psychosocial and work organizational characteristics of jobs have been associated with musculoskeletal problems. These include working under time pressure, lack of control over various job aspects, high workload without adequate recovery time, and a perceived lack of support from supervisors.[13] The extreme division of labor into narrow, rigidly defined tasks that are repeated continuously throughout a work day, such as assembly line work, can lead to the overuse of single muscle groups and joints, and may result in fatigue or injury.[14]

Non-occupational risk factors for UEMSDs include hobbies and recreational activities such as woodworking, tennis, weight lifting, knitting, and sewing. While these activities also may stress muscles and tendons, full-time employees usually do not devote as much time to them as they do to work. Employees with musculoskeletal symptoms also tend to limit or eliminate activities outside work that exacerbate symptoms, in order to be able to continue to perform their jobs. A musculoskeletal disorder can be considered work-related if it is caused or exacerbated by work. Age and gender have also been associated with these disorders. In the case of carpal tunnel syndrome, preexisting medical conditions have been associated with its onset, including diabetes mellitus, hormonal factors (pregnancy and hysterectomy), gout, thyroid disorders, and lupus erythematosus. In clinical studies, women have been reported to have higher rates of carpal tunnel syndrome than men,[15] but in workplace studies where men and women perform the same jobs, the difference in rates of CTS has often been non-significant.[16,17, 18] These conflicting findings may be explained by the fact that women are more often employed in jobs that involve repetitive, hand-intensive work.[19]

Carpal tunnel syndrome (CTS) is characterized by pain, numbness and tingling in the first three fingers, resulting from compression of the median nerve as it passes through the wrist. It has been suggested that compression of the median nerve may occur following inflammation of the finger flexor tendons, which also pass through the rigid carpal tunnel.[20] Although CTS is the most commonly diagnosed nerve entrapment disorder, it occurs much less commonly than other musculoskeletal disorders such as tendinitis. Tendinitis is the inflammation of the tendon tissues, and tenosynovitis is the inflammation of the synovial sheaths that surround the tendons. This results in pain along the tendon, and sometimes swelling.[21, 22] Trigger finger is a stenosing (constricting) tenosynovitis that can cause a painful snapping of the finger or locking of the finger in the flexed position. It has been associated with flexing against resistance, such as pulling a trigger on a tool, and is described as the narrowing of a finger flexor tendon sheath and/or nodular enlargement of the tendon. De Quervain's syndrome is stenosing tenosynovitis of the thumb, and has been associated with gripping and opening tools such as scissors. Tennis elbow, or lateral epicondylitis, causes pain at the outer side of the elbow and into the forearm. It is associated with wrist extension and supination. Rotator cuff syndrome causes pain in the outer shoulder (deltoid area), and sometimes a catching sensation on movement. The proposed mechanism is the repeated catching of the tendons that rotate the upper arm between two bony prominences. It is associated with overhead work, such as automotive assembly or welding. The definitive sign of HAVS is the fingertips turning white or "blanching". Symptoms of HAVS include numbness and tingling of the fingers, pain occurring in response to cold exposure and upon return of circulation, and reduction in grip strength and finger dexterity. These symptoms are believed to result from damage to the nerve supply of the hand; however, the exact mechanisms by which vibration affects the nervous and vascular systems are not completely understood. Exposure to cold temperatures and smoking can contribute to the onset of HAVS.[23,24,25]

METHODS

Medical Evaluation

The medical evaluation included a review of the Occupational Safety and Health Administration (OSHA) logs of occupational injuries and illnesses from 1991-1994, workers' compensation records, and confidential interviews with employees. Interviews focused on work history, work-related musculoskeletal symptoms, medical treatment, and employees' suggestions for improving work conditions.

Incidence rates for disorders associated with repeated trauma (DART) in the assembly department were calculated using OSHA log data and compared to industry rates calculated by the Bureau of Labor Statistics. Included in this category are disorders due to repeated motion, vibration, or pressure; carpal tunnel syndrome, synovitis, tendinitis, bursitis, Raynaud's phenomenon, and noise-induced hearing loss. Incidence rates were calculated by dividing the number of cases of DART by the number of full-time employees in the assembly department.

Ergonomic Evaluation

One of the four microwave oven assembly lines was chosen for the ergonomic evaluation. Assembly line A was selected because it was the only line that had two shifts, and therefore allowed more time to observe the operation. Assembly lines A, B, and C were otherwise very similar. Assembly line E was not fully staffed and was not similar to any of the others. Assembly line D was also different; it was used to produce dehumidifiers or perform microwave oven repair, depending on the time of year.

Each of the 64 workers on assembly line A was observed and video taped. Jobs were observed to determine if awkward postures, force, sustained exertion, and repetition existed. If a high force was observed, the force was measured using an AccuForce Cadet digital force gauge (Ametek, Largo, Florida). The NIOSH lifting equation was used to determine the recommended weight limit for lifting tasks. The weight of the lifted parts was quantified using an Ohaus bench scale (Ohaus Corp., Florham Park, New Jersey).

RESULTS

<u>Medical</u>

NIOSH investigators reviewed OSHA injury and illness logs for 1991-1994. Among assembly line employees, there were five entries in 1991 for upper extremity (hand, wrist, elbow or shoulder) musculoskeletal problems that were not due to acute trauma, fifteen in 1992, fourteen in 1993, and fourteen (as of 11/2/94) in 1994. The 1991 annual summary of work-related injuries and illnesses, however, did not include any entries under column 7f, "disorders associated with repeated trauma" (DART). The 1992-1994 logs listed approximately half of these entries under column 7f. A review of workers' compensation records supported that most of the above upper extremity musculoskeletal disorders were associated with repeated trauma.

Incidence rates for DART (number of cases per 100 full-time employees per year) were 2.0 in 1991, 6.0 in 1992, and 5.6 in 1993. If the cases in 1994 continued to occur at the same rate for the remaining two months of the year, the incidence rate for 1994 would be 6.7. The average DART incidence rate for the industry (Standard Industrial Classification [SIC] code 3631) is 1.5 cases per 100 full-time employees.[26]

Confidential interviews were conducted by NIOSH investigators with sixteen employees who were either selected from OSHA logs or who expressed an interest in being interviewed by NIOSH investigators during the walk-through inspection of the plant. The most common upper extremity problem reported was tendinitis; other problems included carpal tunnel syndrome and shoulder pain. Bony enlargement of finger joints was observed in two employees who reported that they had been diagnosed with osteoarthritis; the affected joints were stressed by job tasks. A review of workers' compensation records for 1994 yielded the following diagnoses for upper extremity disorders not associated with acute trauma: wrist tendinitis (7), shoulder tendinitis (2), picondylitis [elbow] (1), de Quervain's [thumb] tenosynovitis (1), carpal tunnel syndrome (2), bursitis [shoulder] (1), and degenerative joint disease [thumb] (1). Although there were no recorded diagnoses of HAVS, one current employee, who used a vibrating hand tool, reported symptoms suggestive of HAVS, and current employees reported that a former employee had been diagnosed with HAVS.

Ergonomic Evaluation

Assessment of Jobs which Use Tools

Sixteen workers on line A used power tools. Seven workers used pistol grip-type pneumatic screwdrivers or nutrunners (which weighed 2.1 lbs.) to ddrive from one to three screws. These screwdrivers had handles which were 1¾ in. By 1 in. Seven workers used in-line type pneumatic screwdrivers or nutrunners (which weighted 1.4 lbs.) to drive from two to four screws or nuts. Two of the in-line screwdrivers were equipped with articulating arms. One worker used an angle head-type pneumatic nutrunner to drive one screw in a small area. These tools were activated by a push trigger (force on the bit) or a finger trigger. All screws had a Phillips head; the workers indicated that the bits needed to be changed either every day or every other day. The type of tool grip (pistol, in-line, angle head) chosen for each job appropriately allowed more neutral wrist postures.

One worker used a small hand-held electric grinder (Dremel, Racine, WI) to grind part of the plastic interlock part. The grinder operated all of the time and the worker held it constantly. The grinder was light (1.1 lbs.). This job was temporary because the interlock part was not manufactured to specifications. The cord for the grinder was positioned across the floor where two other people worked.

Three workers used manual screwdrivers for a job. Their job required them to loosen a screw, make an adjustment on the door interlock, then re-tighten the screw.

Assessment of Wiring Jobs

Eight workers on line A made electrical connections on the microwave ovens. Two workers attached five wires and three workers attached four wires during 20 seconds for each oven. Therefore, as little as four seconds was available for the workers to attach some of the wires. The workers used pliers or their fingers to connect the wires. In some instances they had to use the pliers because the space was too small for their fingers to fit. In other instances they had to use their fingers because the orientation of the wire connection did not allow the pliers to fit. The connection of one of the wires (the diode to the ground) was examined to determine the force required to make the attachment. For three trials, the median force required was 13.8 lbs., with a range of 12.3 to 16.8 lbs.. When using pliers, the worker must not only apply the force to attach the wire, but must also use force to hold the pliers closed.

Assessment of Conveyor

The microwave ovens moved on individual platforms. The platforms were 36.5 inches from the floor. The area beneath the conveyor was open with sufficient room for feet and knees. The microwave ovens were 12 inches high. Therefore, all assembly work on the conveyor line took place from 36.5 to 48.5 inches above the floor.

The conveyor moved at a rate of 12 feet per minute. Each worker had 20 seconds to perform the assembly work assigned to her. Most workers had trouble keeping up with the speed of the conveyor line. Forty-seven of the 64 workers on line A performed their tasks at the conveyor line as the product was moving. Although the other 17 workers were not working directly at the conveyor, their jobs were still paced by the assembly line because they were usually assembling parts for use on the assembly line.

Assessment of Quality Assurance Jobs

Eight workers performed quality assurance work on line A. Most of the quality assurance work involved leakage testing of the microwave ovens with a wand. The wand was very light (0.26 lbs.) and was maneuvered around the front of the microwave ovens to measure the amount of microwave leakage. A measurement above 0.81 milliwatts per centimeters squared (mW/cm^2) was considered unacceptable. Even if a reading of 0.81 mW/cm^2 or greater was found, all other quality assurance measurements were made before the oven was sent to the repair area. Workers reported that occasionally a reading could be as high as 9 mW/cm^2.

Assessment of Lifting Jobs

The first job on the assembly line consisted of two lifts of the cavity. The first lift was from a conveyor to a work bench. The second lift was from the work bench to the assembly conveyor line. While the cavity was on the work bench, the worker used a hand grinder on the cavity. Both of these lifts and the grinding were accomplished in 20 seconds to keep up with the assembly conveyer line. Each of the lifts was computed as a separate task. The microwave oven cavity weighed 10.8 lbs. An assessment of these jobs performed using the NIOSH Lifting Equation[27] [Appendix A]. For taking the microwave oven cavity off the first conveyor and putting it on the work bench, the recommended weight limit is 12.3 lbs. For this task, the lifting index is 0.88. The lifting index is a comparison of the actual weight of the object being lifted to the recommended weight limit calculated using the NIOSH Lifting Equation. A lifting index of 1.0 would be a safe lift for 75% of female workers and 90% of male workers. A lifting index higher than 1.0 would be a less safe lift. The second task of this job consisted of lifting the microwave oven off the workbench and placing it on the assembly conveyor. The NIOSH recommended weight limit for this task is 24.5 lbs. For this task the lifting index is 0.44. Since the job required the worker to perform both of these tasks, a composite lifting index was computed for the job. The composite lifting index for this job is 1.34. The next lifting job required the worker to lift a finished 36.3 lbs. microwave oven from the assembly conveyor onto a styrofoam form located on a roller conveyor. The workers rotated this job with four other jobs, so this job was conducted for only

2 hours per day with a frequency of 3 lifts per minute. The recommended weight limit for this job is 27.7 lbs., and the lifting index is 1.31. The last lifting job required the worker to lift finished microwave ovens (weight:40.2 lbs.) from a roller conveyor and place them on a pallet. Two workers perform this job. The workers rotated this job every two hours among five workers. Therefore, on most days the worker did this job for four hours. The frequency was one lift every 20 seconds, but since each worker only loads every other pallet, the frequency was one lift every 40 seconds. Since loading a pallet required some items to be placed near floor level, some at waist level, and some at shoulder height, this job was analyzed as a three task job. The three tasks were combined for a composite lifting index of 2.59.

DISCUSSION

Based on OSHA logs of occupational illnesses and injuries at this plant, and workers' compensation records, incidence rates for disorders associated with repeated trauma for 1992 - 1994 exceeded the average for this industry. Most of these were tendon disorders of the upper extremities, (hand/wrist and shoulder tendinitis, de Quervain's [thumb] tendinitis, epicondylitis [elbsow]), and carpal tunnel syndrome. There were no diagnoses of HAVS among current employees, according to information reviewed by NIOSH investigators. Because of the similarity of symptoms, HAVS is sometimes confused with CTS. The primary difference between HAVS and CTS is blanching of the fingers with HAVS. Guidelines for differential diagnosis of HAVS are included in Appendix B. Jobs that require the use of vibrating hand tools often also entail risk factors for CTS and other upper extremity musculoskeletal disorders. Two employees had been diagnosed with osteoarthritis, but a possible association with work had not been recognized. In each case, the employee's job involved direct trauma and stress on the affected joints. Also known as degenerative joint disease, osteoarthritis most frequently occurs to people in their sixties. In younger people, it is often associated with recurrent stress and trauma to particular joints. Although genetic and hormonal factors may predispose people to this disease, mechanical factors such as repeated stress from work should not be ignored.[28]

Several physical ergonomic stressors were observed by NIOSH investigators. The assembly jobs were highly repetitive, with a cycle time of 20 seconds. According to Silverstein et al,[29] a cycle time of less than 30 seconds is considered to be highly repetitive. Most assembly jobs at this facility would be rated a 10, "rapid steady motion, difficulty keeping up", the highest rating of a recently published rating scale.[30] The force required to perform the wiring jobs was at an unacceptably high level for a female population, according to published psychophysical studies.[38] Performing assembly tasks resulted in awkward postures in several cases (adjusting interlock brackets, for example). Static muscle loading, that is, using a muscle group continuously without sufficient rest periods, was observed with some hand tools. Although most of the ergonomic stressors observed affected the upper extremities, some low back stressors were also observed. Each of the three jobs that were evaluated using the NIOSH lifting equation exceeded the safe level. Palletizing the microwave ovens was the least acceptable of the lifting tasks evaluated.

In addition to the physical ergonomic stressors that were observed, NIOSH investigators also noted several psychosocial and work organizational factors that have been associated with musculoskeletal disorders in other studies.[13] These include a lack of influence by workers on the set-up of their workstations, the equipment they use, the availability of materials needed to do the job, the amount of work, and policies and procedures that affect the work group. Employees in the Assembly department work under time pressure, with conflicting demands between maintaining standards of quantity and quality. Production goals have increased at the same time that availability of parts from outside suppliers has become a problem, and many of the available parts fit poorly. Poorly fitting parts require additional force, time, and sometimes the use of additional hand tools to assemble. Many assembly jobs changed as a result of the new models of microwave ovens. For example, the middle interlocks in the new ovens are difficult to reach, and require awkward postures. Also, a job that formerly could be performed with either hand now must be performed with one hand. Workers reported that when their jobs were discontinued, they bid on new jobs based on job descriptions that did not always fully describe the tasks required, and that the new jobs were sometimes more physically demanding. It was also reported that greater restrictions have been placed on changing jobs, and some workers will not be able to bid out of jobs that they feel that they are unable to perform for as long as two years. Job rotation is rarely allowed. There was also a common perception of a lack of support from supervisors. NIOSH investigators observed that some jobs (wiring and mounting plates, for example) seemed more difficult to complete in the time allowed by the speed of the assembly line. There were reports of policies that were punitive toward employees if the line were to stop because of the inability of an employee to keep up with the pace, and for taking more than two consecutive days of valid sick leave, or more than six days per year, even if hospitalized.

A more detailed discussion of ergonomic stressors observed for each type of job follows:

Jobs which Use Tools

Most of the tools weighed 1.4 or 2.1 lbs. One research study[31] found that workers assessed tool weight as "just right" when the weight was between 2.0 lbs. (0.9 kg) and 3.8 lbs. (1.75 kg). Other researchers[32] recommend that power tools weigh 2.5 - 3.8 lbs. (1.12 - 1.75 kg). Therefore, the tools used at this facility are probably not too heavy.

Tool balancers are needed for many of the tools because most of the tools are used intermittently. Using a tool balancer, the worker would spend less time holding the tool or moving it, and the tool would be in the same location and oriented for use. Some of the in-line tools on the sub-assemblies had articulating arms. However, some work stations where a similar task was being performed did not have articulating arms (Articulating arms eliminate the transfer of some of the torque to the worker).[33]

The pistol grip handles had a grip diameter of 1¾ inches. Mital and Kilbsom recommend a grip diameter between 2.0 inches (5 cm) and 2.4 inches (6 cm) for power grips.[32] Armstrong et al. found that hand tools with handle diameters which were 4.7 inches (12 cm) or less were rated as "just right" by workers.[31] Almost all of the tools had handles which were made of metal. Handles should be covered with smooth, slip-resistance material. If the handle is slippery or the hand is sweating, more force will be required to hold the handle. Compressible materials dampen vibration. The grip material should not absorb oil or other liquids and should not permit conduction of heat or electricity. Metallic handles should be avoided or encased in a rubber or plastic sheath.[34]

Angle-head-type tools require the operator to exert more force than pistol grip or in-line tools. For angle-head tools, forces are applied perpendicular to the long axis of the tool, whereas for pistol grip and in-line tools, forces are applied parallel to the long axis of the tool. Therefore, there is a greater tendency for these tools to twist out of the operator's hand. Armstrong et al. found that workers using angle head tools rated the grip force as less desirable than pistol grip or in-line tools.[31]

Phillips-head screws were the main type used at this facility, and the screwdriver bits needed to be changed often. Cederqvist and Lindberg[35] have found that the push force required when using a power screwdriver is lower for a Torx® screw head than for a Phillips screw head (120 N versus 70 N). They also found that just before shut-off torque was reached, a tendency to disengage the screwdriver bit occurred when using the Phillips screw head, leading to the need for extra push force. Also, Phillips-head bits become substantially worn after about 1000 screws, which is less than some operators drive in a shift. (A Torx®-head is a six-point star, as compared to the four-point star of a Phillips head. Torx®-head screws have their driving surface parallel to the axis of rotation and therefore have less risk of disengagement of the screwdriver bit. Many automobile manufacturers, as well as some major appliance manufacturers, have switched to Torx®-head screws. Other brands besides Torx® are available and have the same ability to keep the bit engaged.)

Hand-Arm Vibration Syndrome (HAVS) has been observed in workers who have used vibrating tools that transmit vibration energy to the hands and arms. Hand tools can generate random vibration over a wide frequency range, typically 2 - 2000 Hertz (Hz).[36] Frequencies in the range of 8 to 500 Hz are of concern.[37] The level of acceleration produced by a tool is influenced by many factors, including tool type and weight, operating speed, ergonomics of tool use, environmental conditions, anti-vibration materials used, etc. Vibration levels from hand tool use were not measured during the survey at this facility. NIOSH recommends that exposure to hand-arm vibration be reduced to the lowest feasible acceleration levels and exposure times.[23] NIOSH further recommends that hand-transmitted vibration be reduced by engineering controls and work practices (Appendix B). The worker who was using the hand grinder to re-work the plastic interlock piece was exposed to vibration during her entire work day. The grinder should be made so that it automatically turns on and off as it is being used. The other hand tools had a finger trigger activation or a push trigger (force on the bit).

Wiring Jobs

The workers attach electrical wires at a very fast rate and with a fairly high force. The work was very repetitive (up to 15 times per minute). Silverstein, Fine and Armstrong define high repetition jobs as those with a cycle time of 30 seconds or less, and found that the prevalence of carpal tunnel syndrome was 5.5 times greater for high-repetition jobs compared to low-repetition jobs.[29] The cycle time for a worker to perform all functions on each unit was 20 seconds; however, some workers had to install up to 5 wires per unit for a cycle time of 4 seconds.

Psychophysical studies have determined the acceptable force for female wrist flexion when working 7 hours per day, five days per week.[38] For a repetition rate of 2 times per minute, the maximum acceptable force for female wrist flexion using a power grip (e.g., pliers) was 3.35 for 90% of the female population, 7.26 lbs. for 50%, and 11.20 lbs. for 10%. The maximum acceptable force for female wrist flexion using a pinch grip (e.g., wiring by hand) was even less than that for a power grip. The median force required to attach an electrical wire during microwave oven assembly was 13.8 lbs. Additionally, the cycle time was three units per minute, and workers often installed more than one wire during this period (up to fifteen per minute).

Currently pliers are used for making most of the electrical connections. Other appliance manufacturers use different electrical connectors to minimize the attachment force and use tools which are preferrable to pliers. Some electrical connector manufacturers offer "low insertion terminals," which reduce the force required to connect an electrical wire by 75% or more. Now that some of the large appliance manufacturing companies have switched 100% of their wires to low insertion terminals, it should be easier for smaller companies to also purchase those types of connectors.

A tool can be used to make the electrical connections. NIOSH researchers have modified a tool that other appliance manufacturers use to make electrical connections (Figure 1). Any tool and die shop could use those plans to make the tool. The end of the tool holds the connector so that the worker does not have to use force to hold the connector, as required when using pliers. Also, the tool is designed to move the forces from the small surface area of the fingers to the larger surface area of the hand. However, this tool may require more time to use in the beginning until workers get used to it. Also, not all connections can be made with the tool because of limited access.

If pliers must be used, Carson[39] recommends a handle length of at least 4 inches (preferable 5 inches), so the handle base does not press into the palm, and it should have a spring return. Other suggestions are: no finger grooves; limit handle curvature to no more than ½ inch; the high point of the curve should rest at the base of the palm; each handle should be identical; should be usable in either hand.

Conveyor

The conveyor speed was so fast that workers often could not keep up with the production line. Researchers have developed a 10-point scale for rating task repetitiveness through extensive observation of a large number of jobs. Verbal descriptions of levels of repetitiveness range from "hands idle most of the time, no regular exertions" for 0; to "rapid steady motion, difficulty keeping up" for 10. Most assembly jobs at this facility would be rated a 10 using this rating scale. Therefore, the repetition rate is too high.

Elbsow height of a 5th percentile female is 39.0 inches and a 95th percentile male is 47.4 inches.[40] The microwave oven height is from 36.5 to 48.5 inches above the floor. For most of the line, the height of the conveyor can not be adjusted higher (or closer to elbsow height) because work needs to be performed with in-line tools above the oven. If the line was raised, those workers with in-line tools would have to be elevated with platforms. However, for the most part, jobs that require precision should be about four inches above elbsow height. The line should, therefore, be raised in the area where the workers are adjusting the interlock bracket with a manual screwdriver. These workers are all required to bend over because they need to see the screws that they are tightening. They are also working on the outside circumference where the conveyor turns 180°, causing additional walking. While making their adjustments, the conveyor moves 12 feet (three workers perform this job for a 60 second cycle time per unit), so the worker must walk even more than 12 feet. This area of the conveyor should be raised to four inches above the shortest worker's elbsow height.

Quality Assurance Jobs

NIOSH does not have a recommended exposure limit (REL) for microwave radiation. However, the American Conference of Governmental Industrial Hygienists Threshold Limit Value (TLV) for the microwave frequency (f) of 2450 Mhz (the frequency of microwave ovens) is f/300 (2450 MHz/300) which is 8.16 mW/cm^2.[41] The World Health Organization has endorsed the International Radiation Protection Association (IRPA) guidance of 5 mW/cm^2. In either case, the exposure is time-averaged over 0.1-hr periods, which means that the exposure limit may be higher if a worker is not continually exposed for any 0.1 hr period. The exposure guidance is based on the ability of the microwave to cause heating of tissues. Since each microwave is examined for 20 seconds, 18 microwaves could be examined during a 0.1-hr period. Therefore, 18 microwaves would have to be leaking at least 5 mW/cm^2 for a worker to be overexposed. An attempt should be made to limit any further exposures once a microwave oven is found to exceed the 5 mW/cm^2.

Lifting Jobs

The first lifting job that was analyzed, getting the cavity from the first conveyor, grinding an edge, then putting it onto the assembly conveyor, had a combined lifting index that exceeded 1. Either of the two lifts required to perform this job was acceptable by itself; however, when one worker is required to perform both of these lifts during each 20 second interval, the lifting index (1.34) may be excessive for some workers. This job could be redesigned so that the first conveyor takes the cavity directly to the second assembly conveyor. The worker could then perform the grinding on the assembly conveyor.

The second lifting job analyzed, putting the finished microwave oven into a styrofoam form, also had a lifting index (1.31) above one. Another microwave manufacturer has solved this problem by using a vacuum lift to elevate the oven while the worker puts the styrofoam form and the cardboard box underneath it.

The third lifting job analyzed, palletizing the finished microwave ovens, also had a lifting index above one (2.59). Often the product is placed near floor level or above the head. Those two positions should be eliminated, the floor lift by putting the pallet on a scissors lift. Workers could put each microwave onto the pallet at an acceptable height of approximately 30 inches. The lift would be lowered as needed. For the overhead lift, either eliminate the top row of the pallet or build a pit so that the scissor lift could be lowered below ground level.

RECOMMENDATIONS

Engineering Controls

Jobs which Use Tools

- Install tool balancers or articulating arms for the power hand tools.
- Tool handles should be made of plastic or rubber handles.
- Switch to a screwhead type (e.g., Torx®) which requires less push force than the Phillips head.
- Reduce exposure to vibrating tools by following those suggestions in Appendix A. Provide a trigger or other mechanism to the hand grinder so the worker is not exposed to vibration 100% of the day.

Wiring Jobs

- Switch to low insertion terminals to reduce the force required to connect the wires.
- Provide workers with a tool especially designed to attach electrical wires.
- If pliers must be used, provide handles which are 5 inches long and have a spring return.

Conveyor

- Raise the height of the conveyor line at the location where the workers use manual screwdrivers to adjust the interlock switch.

Lifting Jobs

- Move the conveyor which supplies the cavities so it is directly above the assembly conveyor. The cavity could be brought directly to the assembly line to eliminate two lifts.
- Provide a vacuum lift for putting the microwave oven on the styrofoam form.
- Eliminate lifting to the floor and overhead when palletizing the finished microwaves.

Administrative Controls

- Reduce the speed of the assembly lines. The jobs are very highly repetitive, and almost all workers can be defined as having "difficulty keeping up".
- Establish a comprehensive ergonomics program, including worksite analysis, hazard prevention and control, medical management, and training and education, similar to OSHA's Ergonomic Program Management Guidelines for Meatpacking Plants[42]
- Establish and provide training and education for a joint labor-management ergonomics committee to address issues noted in this report and related concerns as they arise. With appropriate training, the committee could recommend interventions, such as the purchase of new tools and equipment and changes in policies and procedures of the work group, and evaluate the effectiveness of interventions.
- Address current policies that may be counter to the goal of reducing ergonomic stressors and work-related musculoskeletal disorders. For example, increase flexibility in changing jobs, allow job rotation, address the problem of poorly fitting parts, allow sufficient time to remove defective parts from the line, allow for adequate medical evaluation and recovery for musculoskeletal problems.
- Encourage supervisory support of employees who experience musculoskeletal symptoms and disorders through education and training of managerial and supervisory staff.
- Consider alternative work organization methods that broaden employees' skills and tasks, therefore minimizing the physical stress on any single muscle group or joint area. In addition to greater diversity of tasks and longer cycle times,

alternative work organization methods such as job enlargement may result in more employee participation, job satisfaction, and enhanced productivity.[1]

- Use available data on work-related injuries and illnesses to prioritize higher risk jobs for further ergonomic evaluation and intervention.

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AUTHORSHIP AND ACKNOWLEDGEMENTS

Report Prepared by: Susan Burt, M.Sc., M.S.N.
Senior Research Officer
Medical Section
Hazard Evaluations and Technical Assistance Branch
Division of Surveillance, Hazard Evaluations and Field Studies

Cheryl Fairfield-Estill, M.S., P.E.
Industrial Engineer
Engineering Control Technology Branch
Division of Physical Sciences and Engineering

Field Assistance by: Stefan Topolski, Visiting Scientist

Originating Office: Hazard Evaluations and Technical Assistance Branch
Division of Surveillance, Hazard Evaluations and Field Studies

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Appendix A

NIOSH LIFTING EQUATION CALCULATIONS

$$RWL = LC x HM x VM x DM x AM x FM x CM$$

Where:

RWL - recommended weight limit (lbs.).
LC - load constant (always 51 lbs.).
HM - horizontal multiplier (10/H) where H is the horizontal distance of the hands from the midpoint between the ankles (in).
VM - vertical multiplier (1-(0.0075 |V-30|)) where V is the vertical distance of the hands from the floor (in).
DM - distance multiplier (0.82 + (1.8/D)) where D is the vertical travel distance between the origin and destination of the lift (in).
AM - asymmetric multiplier (1-(0.0032A)) where A is the angular displacement of the load from the sagittal plane (°).
FM - frequency multiplier based on the rate of lifting .
CM - coupling multiplier based on the quality of the coupling between the hands and the load.

The weight of a microwave oven cavity was 10.8 lbs. For taking the cavity off the first

$$RWL = 12.3\,lb$$

conveyor and putting it on the work bench, the recommended weight limit is:
The lifting index is a comparison of the actual weight of the object being lifted to the NIOSH recommended weight limit. A lifting index of 1.0 would be a safe lift for 75% of

$$Lifting\ Index\,(LI) = 0.88$$

female workers and 90% of male workers. For this task, the lifting index is:
The second task of this job consisted of lifting the oven off the workbench and placing it

$$RWL = 24.5\,lb$$

on the assembly conveyor. The NIOSH recommended weight limit for this task is:

$$Lifting\ Index\,(LI) = 0.44$$

For this task the lifting index is:

Since the job requires the worker to perform both of these tasks a composite lifting

$$Composite\ Lifting\ Index\,(CLI)\ =\ 1.34$$

equation is computed for the job. The composite lifting equation for this job is:
The next lifting job required the worker to lift a finished 36.3 lbs. oven from the assembly conveyor onto a styrofoam form located on a roller conveyor. The workers rotated this job with four other jobs so this job was conducted for only 2 hours per day with a frequency of 3 lifts per minutes. The NIOSH recommended weight limit for this job is 27.7 lbs. and the lifting index is 1.31.

The last lifting job required the worker to lift finished ovens (weight 40.2 lbs.) off a roller conveyor and place them on a pallet. Two workers perform this job. The workers rotated this job every two hours between five workers. Therefore, on most days the worker does this job for four hours. The frequency was one lift every 20 seconds, however, each worker only loads every other pallet. Therefore, a frequency of one lift every 40 seconds was used. Since loading a pallet requires some items to be placed near floor level, some at waist level, and some at shoulder height, this job was analyzed as a three task job. The three tasks were combined for a composite lifting index of 2.59.

Appendix B

DIFFERENTIAL DIAGNOSIS OF

	VIBRATION WHITE FINGER (VWF)	CARPAL TUNNEL SYNDROM (CTS) (work - or use - related)
PATHOLOGY	Thickening of the wall of hand/finger arteries, plus blood vessel constrIction (sympathetic nerve stimulation)	Tenosynovitis at the wrist, increase in tunnel pressure to compress the median nerve
SYMPTOMS	Numbness, tingling, pain & blanching in fingers (toes are affected in some) Raynaud's Phenomenon	Pain, numbness and tingling in the area of the median nerve distribution (often nocturnal)
When advanced	Blanching, gangrene, joint degeneration	Thenar muscular atrophy, weakness, manual disability
TREATMENT	Removal from exposure None when advanced	Removal from exposure Rest, wrist splint Carpal ligament release (Not always satisfactory)
WORKERS AT RISK	Chain saw operators, chippers, grinders, jack hammer operators, stone cutters	Assembly workers, burr removers, meat cutters, seamstresses
EXPOSURE FACTORS	Vibration, Cold Required to grip vibrating tools forcefully	Repetitive manual work (force, repetition, posture) May be intesified by vibration and/or cold Required to perform manual work repeatedly
RULE OUT Non-occupational causes	Raynaud's Disease	Diabetes, amyloidosis hypothyroidism, pregnancy, use of oral contraceptives, rheumatoid arthritis. Other conditions to increase carpal tunnel pressure may be caused by hobbies requiring manual work.
PREVENTION	Reduce vibration Provide local warmth	Reduce force, repetition, and/or wrist angles of manual work

(Both VFW and CTS may be present in some workers.)

Table adapted from S. Tanaka, DSHEFS, NIOSH

Appendix C

The following engineering controls and work practices are recommended by NIOSH[23] for reducing the hand-transmitted vibration exposure to the lowest feasible level:

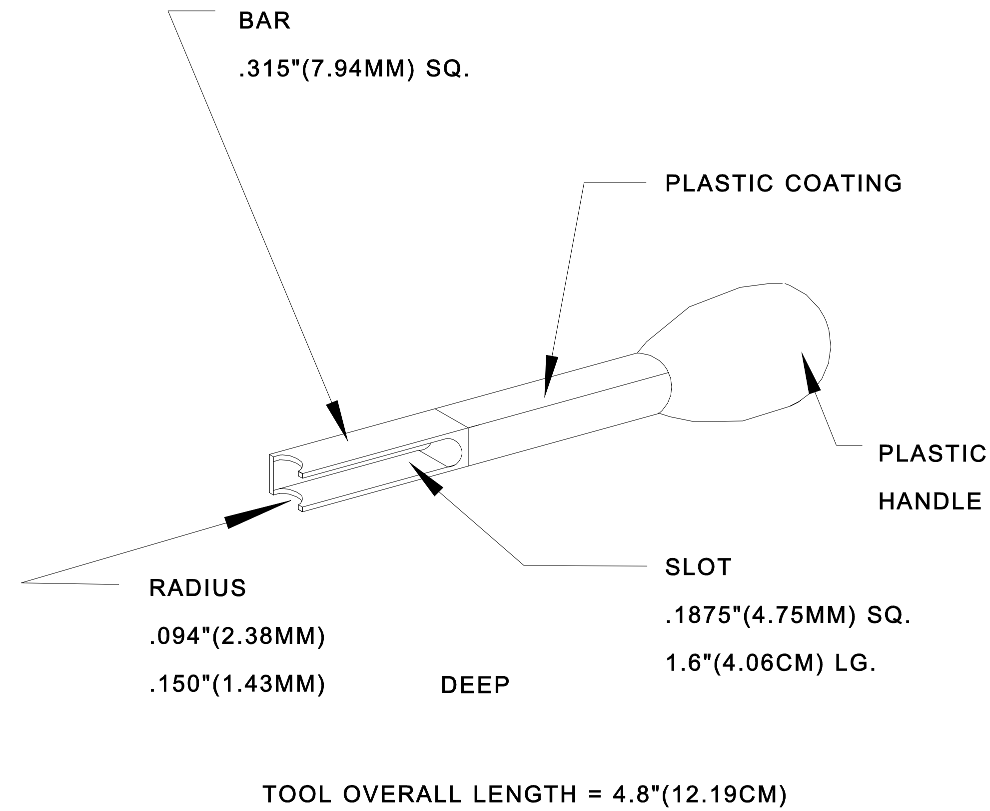
1. The vibration energy of the vibrating tool should be reduced to the lowest level consistent with optimal operations or by changing the process to reduce the requirement for using the tool.

2. The power and weight of the tool should be optimized to levels that minimize vibration but still permit the work to be efficiently performed.

3. The tool manufacturers should furnish data on the vibration acceleration and frequency characteristics of their tools, as measured by a standard test protocol of simulated operation.

4. Work should be modified to minimize vibration exposure. Work modifications include but are not limited to:

- Reducing the number of hours the worker uses the vibrating tool.
- Arranging the work tasks so that vibrating and non-vibrating tools can be used alternately, and assuring that the non-vibrating tools do not introduce other musculoskeletal stress factors.
- Scheduling maintenance breaks as necessary to ensure that tools are sharp, lubricated, and tuned.
- Selecting tools that produce the least amount of vibration consistent with satisfactory performance of the task.
- Designing the work task and workplace to incorporate ergonomic principles to minimize vibration stress.
- Reducing the grip force on the tool handle and the force applied at the tool/workpiece interface in a manner consistent with safety and performance.
- Restricting the use of piecework and incentive pay



SPADE LUG INSERTION TOOL

(PERSPECTIVE VIEW)

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