HETA 95-0386-2582
Cooper Power Systems
East Stroudsburg, Pennsylvania

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PREFACE

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Veronica Herrera-Moreno, M.D., of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS), and Daniel J. Habes, M.S.E., C.P.E., of the Applied Psychology and Ergonomics Branch, Division of Biomedical and Behavioral Science (DBBS). Desktop publishing by Patricia C. McGraw.

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Health Hazard Evaluation Report 95-0386-2582
Cooper Power Systems
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SUMMARY

On February 1 and 2, 1996, National Institute for Occupational Safety and Health (NIOSH) representatives conducted a Health Hazard Evaluation (HHE) at the Cooper Power Systems plant in East Stroudsburg, Pennsylvania, in response to a confidential request submitted by employees in the Assembly Department. The request concerned repetitive motion resulting in carpal tunnel syndrome and other musculoskeletal disorders.

Work practices and operations were observed during a walk-through inspection of the Assembly Department. The ergonomic evaluation included video taping and subsequent analysis of the job tasks to assess repetition and posture.

Confidential medical interviews were conducted with all "assemblers" from the Assembly Department, and review of the Occupational Safety and Health Administration (OSHA) Log and Summary of Occupational Injuries and Illnesses (Form 200) for the previous six years.

The ergonomic evaluation determined the presence of stereotyped repetitive motions in the Assembly Department jobs as the most notable upper extremity ergonomic stressor. Other stressors observed were higher than necessary muscular effort to fasten nuts onto certain bolts, awkward and unsupported trunk postures resulting from the wide variety of chairs in use in the department, pinch grips to pick up nuts, washers, and other small parts that are located on work table tops, and awkward postures of the shoulder to retrieve parts that are not conveniently located within the reach envelope of the worker.

All 14 "assemblers" from the department, present during the NIOSH site visit, were interviewed. Ten (71%) reported work-related neck, shoulder, elbow or hand pain, resulting in six of them missing work or being assigned light duty during the preceding year. One worker had bilateral carpal tunnel surgery.

The OSHA 200 logs from January 1, 1990, until December 31, 1995, showed a total of 129 entries. Of the 39 entries from the Assembly Department, 14 (36%) were for musculoskeletal disorders, including neck strains, shoulder strains, elbow tendinitis, forearm strains, wrist and hand disorders (one case of carpal tunnel syndrome). Three entries were for musculoskeletal disorders other than upper extremities.

NIOSH investigators conclude that the highly-repetitive jobs, awkward postures, and pinch grips present a considerable risk for development of work-related musculoskeletal injury to workers. Suggestions for work station redesign and tool substitutions to reduce the risk of injury to workers are contained in the Recommendations section.

KEYWORDS: SIC 3452 (bolts, iron, and steel: not made in rolling mills), 3479 (galvanizing of iron and steel and end formed products, for the trade), ergonomics, musculoskeletal disorders, repetitive assembly tasks, piece rates, wage incentive systems, carpal tunnel syndrome, cumulative trauma disorders, CTDs, shoulder and neck pain.

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INTRODUCTION

On September 8, 1995, the National Institute for Occupational Safety and Health (NIOSH) received a confidential employee request for a health hazard evaluation (HHE) at the Cooper Power Systems plant in East Stroudsburg, Pennsylvania. The request concerned repetitive motion resulting in cases of carpal tunnel syndrome and other musculoskeletal disorders in the department where power line hardware is assembled. The specific operation mentioned in the request was "threading nuts onto bolts" by the "nutting room assemblers."

On February 1 and 2, 1996, a team of NIOSH investigators conducted a site visit at Cooper Power Systems that included an opening conference, a walk-through inspection of the facility, confidential medical interviews of "assemblers," review of the Occupational Safety and Health Administration (OSHA) Log and Summary of Occupational Illnesses (form 200), and videotaping of the jobs in the Assembly Department.

BACKGROUND

Cooper Power Systems, a division of Cooper Industries, Inc., manufactures and supplies pole line hardware to the utility industry. The company has been conducting business in the Northeastern Pennsylvania area since 1925. Their products are made from hot-rolled mild steel, most of which is hot-dip galvanized after fabrication. The main manufacturing processes are hot forging, press work, arc-welding, threading, pickling and washing, galvanizing and assembly. The process has remained relatively the same for the past 77 years. Some automation has taken place in the Galvanizing and Assembly Departments.

The plant is relatively small, employing fewer than 200 production workers. The Assembly Department, which includes the jobs where nuts are fastened to bolts, had 14 workers performing assembly jobs (assemblers), at the time of the NIOSH site visit.

The request was specific to the bolt fastening operations in the Assembly Department. The requestor reported that some of the galvanized bolts are sent from the Galvanizing Department to the Assembly Department with too much coating on them. The excess coating makes it difficult to fasten nuts onto bolts by hand or with the various types of manual, automatic, and semi-automatic tools used to attach nuts.

METHODS

Ergonomic

The ergonomic evaluation consisted of a walk-through inspection of the Galvanizing and Assembly Departments to view the jobs being performed, and some discussion with employees. Subsequent videotaping of each job in the Assembly Department was conducted. The purpose of the video tapes was to document the postural demands and repetitiveness of the jobs. This information was extracted from the video through playback analysis either in real time, or in slow motion.

Galvanizing Department

There are two main lines in the Galvanizing Department: line #1 and line #2. At each, parts are pre-cleaned (pickled) before being dipped into the galvanizing baths. The galvanized coating is a mixture of 98% zinc and about 1% lead that is between 840 and 860 degrees F when applied. The two lines differ in the way parts are placed in and removed from the baths, and in the way excess galvanizing is removed from parts. The requestors of the NIOSH evaluation felt that the differences in production methods between line #1 and line #2 may have accounted for the upper extremity symptoms that workers were experiencing.

Assembly Department

Nuts are assembled onto bolts using a variety of methods reflecting different degrees of technology and production run sizes. These jobs were observed at a variety of manual, semi-automatic, and fully automatic work stations. The job names were: whirlybird, manual nut fastening, lag-screw clevis, air-driven nut runner, and fully automatic nut runner. One of the work stations was equipped with an air-powered driver which seemed to assemble nuts with less effort than that required at the manual and semi-automatic work stations, and resulted in fewer rejected parts.

A fork lift operator delivers the parts to the workstations. Incoming pieces that are coated with too much galvanizing material can be threaded with a nut by extra effort from the worker, but only to the point of maximum torque capability of the fastening mechanism. If available torque is insufficient to attach the nut to the bolt, the assembly is rejected. Rejected parts were observed to be thrown onto the floor or onto piles of nuts and washers located at the work station.

Other types of assembly operations that do not include fastening nuts onto bolts, namely riveting and staking, were also performed in the Assembly Department. Workers participate in a job rotation system among the various assembly stations. Two workers voluntarily do not rotate through the assembly jobs.

Each worker wore white cloth gloves with plastic-reinforced fingers and palms. Some of the workers were sitting on high-backed wooden chairs and the others sat on metal stools. Many of the chairs were modified with a variety of pads, pillows, and foam rubber to suit the comfort preference of the individual worker. One worker who seemed to be the most efficient at performing a semi-automatic operation used the back of the chair for leverage when inserting the bolt into the nut fastening mechanism. Each nut fastening work station was also equipped with a pronged tool that could be used to pull tangled bolts from the delivery chute.

All direct workers in the Assembly Department are paid straight piece rate with unlimited incentive. That is, a worker's hourly pay can be increased by whatever amount the piece rate is exceeded. Workers are not paid for rejected parts, which is why there is concern about incoming parts coated with too much galvanizing. This situation is aggravated by the fact that rejected parts often require more of the worker's time and because parts are not generally rejected until extra effort has been devoted to completing the assembly. At times, the worker can overcome the excess galvanizing with extra effort and produce a good part.

Normal work shift for day workers is 7 a.m. to 3:30 p.m. with a 12 minute break in the morning, one-half hour for lunch, and a 12 minute clean-up allowance in the afternoon. At the time of the NIOSH evaluation, a nine-hour shift was in effect which necessitated starting work an hour earlier with the same break and lunch schedule.

Medical

The medical portion of this HHE included a review of OSHA Log and Summary of Injuries and Illnesses (Form 200) for 1990-1995 and voluntary, confidential interviews with all 14 "assemblers" present during the NIOSH site visit. These interviews were coordinated by the Personnel Office. Information obtained from the interviewed employees included work history, medical history, work-related symptoms experienced, and employees' perception of the job.

EVALUATION CRITERIA

Musculoskeletal disorders occur in workers whose jobs require repetitive exertion, stressful postures, force, and lack of adequate rest or recovery. 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. 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 micro trauma 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. As muscle exertion increases, blood flow to the muscles decreases, resulting in fatigue. When forceful exertion is combined with repetitive movements and stressful postures, harmful effects are exacerbated.

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. 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 Upper Extremities Musculoskeletal Disorders (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 carpal tunnel syndrome (CTS) has often been nonsignificant[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]

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 flexors, 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 tendin. 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 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.

RESULTS

Ergonomic

Analysis of the videotapes of the Assembly Department jobs indicated that at the time of the NIOSH evaluation, workers were producing parts at a rate of 135-206% of piece rate, and rejects ranged from 0- 7.3%

The most notable ergonomic stressor for upper extremity injury in the Assembly Department jobs was the presence of stereotyped repetitive motions. When considering the number of pieces produced per hour, and the number of repetitive motions needed to complete each assembly, it is evident that the Assembly Department jobs result in repetitive movement rates that are comparable to other types of jobs where the occurrence of cumulative trauma disorders is commonly seen [43-45]. This is particularly the case when one considers that normal piece rates are routinely exceeded. Other ergonomic stressors observed were higher than necessary muscular effort to fasten nuts onto certain bolts; awkward and unsupported trunk postures resulting from the variety of chairs used in the department; pinch grips to pick up nuts, washers, and other small parts that are located on work table tops; and awkward postures of the shoulder to retrieve parts that are not conveniently located within the reach envelope of the worker. This latter factor is most closely associated with the use of the pronged tool for retrieving stuck and tangled bolts from the gravity-feed bins.

Medical

OSHA 200 Logs Review

For the six year period of January 1, 1990, through December 31, 1995, there were 129 entries on the OSHA 200 logs. Of these 129 entries, 31 were for upper extremity disorders associated with repetitive trauma, 14 of which were from the Assembly Department (Table 1). These 14 cases in the Assembly Department were: elbow tendinitis (7), wrist disorders (3), carpal tunnel syndrome (1), finger tendinitis (1), forearm tendinitis (1), and cervical radiculopathy (1).

Table 2 shows the annual incidence rates for upper extremities disorders based on the analysis of the OSHA 200 logs. The incidence rate of upper extremity disorders associated with repetitive trauma almost doubled from 1990 to 1991 and remained very high for 1992. Since 1992, there has been a consistent decrease in incidence, both in the plant and in the Assembly Department.

The incidence rates for upper extremity disorders associated with repetitive trauma (Table 3) were higher in the Assembly Department than in the rest of the plant every year, as reflected by the rate ratios.

Medical interviews

According to the plant personnel office, which coordinated the interviews, all workers with the job title of assembler were interviewed. Of these 14 workers, 9 were male and 5 were female. The

average age was 46 years (range of 30 to 59). The average years worked at Cooper Power Systems was 15 (range of 2 to 34), and the average years worked in the Assembly Department was 14 years (range of 2 to 34).

None of these workers reported having significant outside hobbies at risk for upper extremity MSD. Two workers related having been diagnosed with arthritis. The most frequent work-related symptom in the preceding year was hand pain, mentioned by 8/14 workers (57%), 2 of whom sought medical attention for their pain. Four workers (including these last two) reported having been assigned light duty for less than 5 days; two of them reported having missed work in the last year because of this hand pain. All eight workers mentioned that their hand pain started after working in the current job and that the pain gets worse with work activities. One of these eight workers had had carpal tunnel syndrome surgery.

Other work-related symptoms mentioned included shoulder pain, [4/14 workers (28%), without work days missed or light duty assigned], neck pain [3/14 workers (21%), with one worker missing work and having to be assigned to light duty], and elbow pain [2/14 workers (14%), with one worker having to be assigned light duty because of it].

Seven of the 14 interviewed workers (50%) thought that the production rates were too high.

Another concern mentioned during the interviews was that since line #2 had been installed in 1991, the excess galvanizing material in some pieces made the process of fastening the nuts onto the bolts more difficult. Furthermore, they felt that this not only resulted in more hand symptoms, but also increased the number of rejected pieces, for which the workers are not paid.

DISCUSSION

Medical

This plant has a very high incidence rate of upper extremity disorders associated with repetitive trauma. When compared to the latest Bureau of Labor Statistics Report (in press) for occupational injuries and illnesses, the 1994 incidence rate at this plant (352 per 10,000 full-time employees, table 2) for disorders associated with repetitive trauma, is among the 20 highest of private industry groups at the most detailed or lowest SIC level at which rates were calculated and published. The rate is high despite the fact that has declined consistently since 1992. However, the severity of these disorders seems to be fairly low, as reflected by virtually no attributable lost work days.

The fact that the incidence rate of upper extremity disorders associated with repetitive trauma in the Assembly Department doubled from 1990 to 1991, is consistent with the workers' perception of their jobs requiring more effort since the line #2 system was installed. However, the rates have declined since then.

Ergonomic

In general, the jobs in the Assembly Department were designed for quick and efficient fastening of nuts and bolts and other assembly parts. Parts were delivered efficiently to the workplaces, and most jobs were performed with little postural deviation and minimal muscular force. Notable exceptions to these moderate posture and muscle force demands were the need to reach above the shoulder to retrieve tangled bolts with the pronged tool, and the extra effort needed to force nuts onto bolts coated with excessive galvanize material. As stated in the Results section, stereotyped repetition, at some times very high repetition, was a common thread among jobs in the Assembly Department. The stereotyped repetitive motions are a result of the inherent simplicity of the jobs, and the repetition rates are due to the high production demands and, in part, to the unrestricted nature of the incentive pay system in use at the plant.

The incentive system in place at Cooper Power Systems is a mechanism that is popular among workers and management, while at the same time

being a negative factor for worker health and a potential source of conflict within the workers and between workers and management. Workers benefit because they can earn higher pay; management benefits because they can obtain more than a day's work from one worker, which minimizes the overhead costs of additional workers. The conflict within the worker is that the incentive system provides a mechanism for additional pay, but at the cost of increased hand pain and risk of musculoskeletal disorders. They do not want to give up their jobs or the opportunity to earn more, but are becoming less willing to work with the pain they incur on existing jobs that have increased rejection rates, and on new or modified jobs that provide less opportunity to achieve traditional incentive rates due to breakdowns and rejected parts.

The above conditions are likely a temporary situation as the problems resulting from technology improvements are resolved, but conflict between workers and management will continue as long as workers perceive that they are working harder for less pay, and incurring more pain and possible disability while doing so.

CONCLUSIONS

There is a high incidence of upper extremity disorders associated with repetitive trauma among the workers in the Assembly Department at the Cooper Power Systems plant in East Stroudsburg, Pennsylvania.

The high repetition rates of the jobs in the assembly departments pose a high risk of upper extremity MSD development, and the other workplace attributes pose additional risk. The incentive pay system presents a barrier to mitigating the hazards, since it involves a disincentive to reduce repetition rates. However, one of the most effective interventions that could be implemented would be to reduce the rate of stereotyped repetitive motions, a suggestion that would likely be rejected by workers and management alike.

RECOMMENDATIONS

The following recommendations are offered as a means to reduce the postural and muscular demands of the jobs in the assembly department at Cooper Power Systems. As noted above, the magnitude of stereotyped repetitive motion is the most notable of the ergonomic risk factors. However, it is likely that high repetition rates could be sustainable with minor modifications in other workplace attributes as recommended below.

1. Continue replacing less efficient bolt fastening mechanisms with air-powered screwdrivers in the nut fastening positions. The one manual work station equipped with this feature seemed to run with little effort and few rejects.

2. Provide each sitting work station with an adjustable-height chair, with a foot rest and an adjustable back. Such chairs would improve the position of the workers with respect to the work table and the fastening machines, and would provide additional leverage for workers fastening nuts. The introduction of improved seating would likely be most effective in the Whirlybird area.

3. Eliminate the need to reach for tangled parts (mostly bolts and eye bolts) with a pronged garden tool in the nut fastening positions. Reaching for parts is more of a problem at the manual nut fastening work stations (including the one with the air-driven nut fastener) than in the Whirlybird stations because the gravity feed bins are further from the worker at the manual stations. This problem could be addressed by repositioning the parts bins, changing the angle of the parts bins to reduce tangling, or using a small conveyor or chute that routes parts directly to the worker. A vibrating or other agitation system that could loosen parts that are subsequently delivered to the worker is another alternative. The addition of simple gravity feed bins would eliminate the double-handling of parts with pinch grips to retrieve parts from the table

for the manual nut fastening jobs and the lag screw clevis job. A wax pot recessed into the table would reduce shoulder flexion and abduction of the right arm at the lag screw clevis position.

4. Provide a bin or empty box for rejected parts at all work stations. This measure is aimed more at improved material flow than at health and safety, but throwing rejected parts on the floor or on top of piles of nuts is an unnecessary disruption in the smooth flow of materials from the workplaces to the scrap or rework areas of the plant.

5. Review the line #2 galvanizing system for purposes of identifying conditions that may contribute to the excessive coating of parts.

6. Continue with early reporting of upper extremity disorders associated with repetitive movement, and maintain the workers' easy access to health care providers.

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TABLE 1

OSHA 200 LOG TOTAL AND UPPER EXTREMITY
MUSCULOSKELETAL DISORDERS ASSOCIATED WITH REPETITIVE TRAUMA (DART)
ENTRIES AT THE REST OF THE PLANT AND ASSEMBLY DEPARTMENT

COOPER POWER SYSTEMS
EAST STROUDSBURG, PENNSYLVANIA
HETA 95-0386

YEAR	REST OF PLANT		ASSEMBLY DEPT	
	Total	DART	Total	DART
1990	27	5	8	3
1991	14	4	7	3
1992	9	1	5	3
1993	10	2	7	2
1994	14	3	5	2
1995	16	2	7	1
TOTAL	90	17	39	14

(Source: OSHA 200 logs 1990-1995)

DART: Disorders associated with repetitive trauma

TABLE 2

ANNUAL INCIDENCE RATES FOR 10.000 FULL TIME WORKERS
FOR UPPER EXTREMITY DISORDERS ASSOCIATED
WITH REPETITIVE MOVEMENT

COOPER POWER SYSTEMS
EAST STROUDSBURG, PENNSYLVANIA
HETA 95-0386

YEAR	IR* PLANT	IR* ASSEMBLY
1990	523	697
1991	467	1200
1992	274	938
1993	296	625
1994	352	606
1995	214	303

(Source: OSHA 200 logs 1990 - 1995)
IR : Annual incidence rate per 10.000 full time workers

TABLE 3

ANNUAL INCIDENCE RATES FOR 10.000 FULL TIME WORKERS FOR
UPPER EXTREMITY DISORDERS ASSOCIATED WITH REPETITIVE MOVEMENT
ASSEMBLY DEPARTMENT VS REST OF THE PLANT

COOPER POWER SYSTEMS
EAST STROUDSBURG, PENNSYLVANIA
HETA 95-0386

YEAR	IR* ASSEMBLY	IR* REST OF PLANT	RR*
1990	697	455	1.5
1991	1200	220	5.5
1992	938	88	10.6
1993	625	194	3.2
1994	606	275	2.2
1995	303	187	1.6

IR: Annual incidence rate per 10,000 full time workers
RR: Rates ratio