U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES ■ Public Health Service
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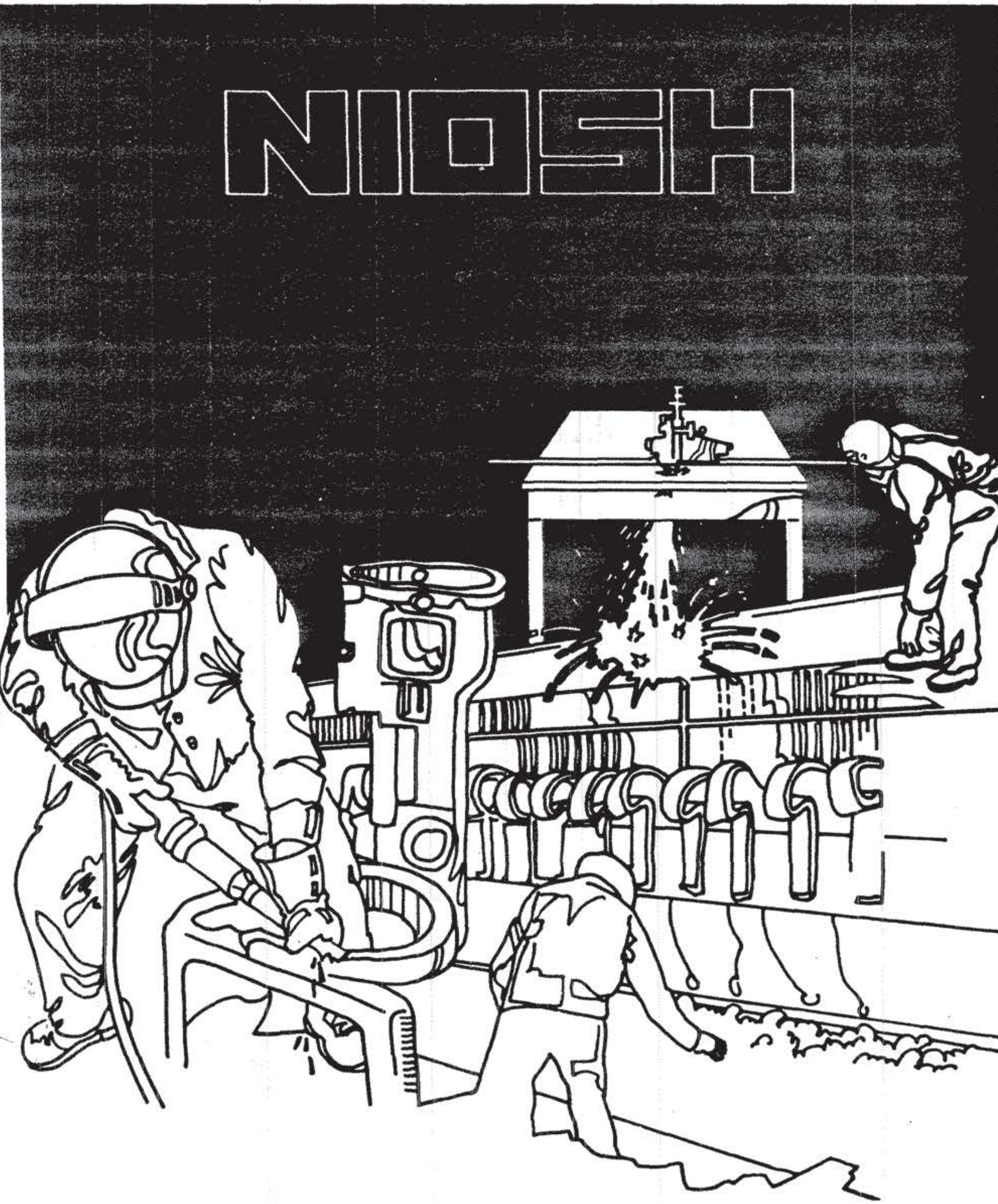

Health Hazard Evaluation Report

HETA 81-217-1086
MILLER ELECTRIC COMPANY
WOONSOCKET, RHODE ISLAND

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

HETA 81-217-1086
April 1982
Miller Electric Co.
Woonsocket, Rhode Island

NIOSH INVESTIGATOR:
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I. SUMMARY

On June 24, 1981, the National Institute for Occupational Safety and Health (NIOSH) provided technical assistance to the Providence, Rhode Island Area Office of the Occupational Safety and Health Administration (OSHA) by conducting an ergonomic assessment at the Miller Electric Co., Woonsocket, Rhode Island. Fifty-six cases of cumulative trauma disorders of the hand and wrist had occurred at the plant since 1973. Thirty-four of these cases were ganglion cysts on the hand or wrist.

The company manufactures electrical extension cords and cordsets. The production workforce of about 415 employees consists predominantly of women. They wind and trim wire, assemble and pack cordsets, and mold plug housings onto stripped cord. Jobs evaluated through the use of 8 mm movies and photographs were found to require repetitive flexion and extension of the wrist, radial and ulnar deviations, and some pinching. Past studies have shown these postures and movements to be associated with the occurrence of musculoskeletal disorders of the hand and arm such as tendonitis, tenosynovitis, carpal tunnel syndrome, and ganglion cysts.

Examples of stressful motions in particular jobs are wrist flexion while inserting blades into the fixture on the Miller Molder; extension and ulnar deviation of the wrist while performing the blading operation; and open hand pinching while packing light socket assemblies.

On the basis of job observations and analyses conducted during this investigation, NIOSH determined that a hazard of developing musculoskeletal disorders of the hand and wrist exists at the Miller Electric Company. These disorders are likely to continue unless work practice modifications are implemented. Recommendations for reducing the biomechanical stresses required by these jobs through workplace redesign and administrative controls are presented in this report.

KEYWORDS - musculoskeletal disorders, ganglion cysts, ergonomics, repetitive hand tasks, cumulative trauma disorders

II. INTRODUCTION AND BACKGROUND

In June, 1981, the National Institute for Occupational Safety and Health (NIOSH) provided technical assistance to the Providence, R.I. Area Office of the Occupational Safety and Health Administration (OSHA) at the Woonsocket, R.I. plant of the Miller Electric Co. The objective was to conduct a preliminary ergonomic evaluation of the demands upon the musculoskeletal system by jobs from which the workers have incurred a large number of cumulative trauma disorders of the arm and wrist. These disorders include tendonitis, carpal tunnel syndrome, and in particular, ganglion cysts.

Located in a community of 47,000 near the Massachusetts border, the plant manufactures electrical extension cords and cord sets. The current workforce consists of 415 production workers, mostly women with little previous industrial experience. Work involves winding of wire, assembly and packing of cordsets, molding of plug housings, and "blading." The latter is a punch press task where the "tines" or blades of a cord or cordset are attached to wire ends. Some degree of repetitive motion of the hands and wrists is required while performing these tasks. In many cases these motions are coupled with forceful muscular exertions of the hand, wrist, and arm.

The company has been the subject of two inspections by the Providence Area OSHA Office within the last two years. The problem of cumulative trauma was recognized on the first inspection, but the industrial hygienists were unable to determine the cause and were unaware of any solutions.

The problem of cumulative trauma disorders was again recognized during the second inspection, which was initiated because of an unrelated complaint. During this investigation, the industrial hygienist determined that since 1973, 56 cases of ergonomically related injuries had been recorded. It was at this time that a technical assistance request was submitted to NIOSH by the Providence Area Office of OSHA.

Prior to these inspections, health and safety conditions at Miller Electric Co., were evaluated by the company's insurance carrier regarding establishment and maintenance of an occupational health program in the plant. The studies by the insurance carrier were conducted in 1976 and in 1979. In each of these evaluations, the problem of ganglion cysts and other cumulative trauma disorders was noted, particularly in the cordset and trimming areas. It was recommended by the insurance carrier that the company should seek to solve this problem through engineering controls in order to improve its poor "loss ratio". However, the insurance company reports did not contain any suggestions as to how Miller Electric could reduce the number of cumulative trauma disorders occurring on these jobs. They did recommend job rotation but the company said it was impossible. There are no engineers in the plant who evaluate problem workplaces or tool designs from the standpoint of developing appropriate controls.

III. EVALUATION PROCEDURES

On June 24, 1981, the plant was visited by the NIOSH investigator accompanied by an Industrial Hygienist from the NIOSH regional office in Boston and two industrial hygienists from the Providence office of OSHA, one of whom had conducted the earlier health investigations. Prior to the visit, plant records were reviewed. They indicated that between March 1973 and November 1980, 56 cases of cumulative trauma disorders (OSHA code 26) were recorded. The distribution of cases was as follows:

Ganglions of the wrist or hand	34
Tendonitis	5
Tenosynovitis	8
Carpal tunnel syndrome	1
Other	8
	56

Of these, 49 are women and 7 men. Among the jobs which accounted for a large number of these were: Bartell Bunches (2), Miller Molder (9), Moslo Molder (2), Blading (8), Wire Stripping (5), Spooling (7), Assembly and Packing (7), and Testing (5).

Each of these jobs was evaluated in detail. The ergonomic evaluation consisted of informal interviews with employees to further understand the symptoms they were experiencing and a work methods assessment for purposes of documenting work postures and types of motions which could contribute to the occurrence of these symptoms. Still pictures and 8mm movies were taken to assist in the work methods assessment.

IV. EVALUATION CRITERIA

The specific types of postures that were of interest in this evaluation include: wrist flexion and extension, ulnar and radial deviations of the wrist, and open hand pinches. There are few quantitative criteria such as frequency, total number and extent of these postures that clearly delineate hazards. Jobs requiring the repetitive use of these postures, particularly in conjuntion with high muscular force demands of the hand and wrist have been linked to common cumulative trauma disorders such as carpal tunnel syndrome, tenosynovitis, and ganglion cysts.[1-3] Currently, the extent of hazard is based on an evaluation of the types of postures assumed on the task and the frequency of occurrence of each type, coupled with application of professional judgement and comparison with available literature.

V. WALK THROUGH OBSERVATIONS

A. General Impressions

Housekeeping in general appeared to be adequate. The third and fourth floors, where the molding and assembly take place were well lit, relatively quiet, and clean. The first and second floors, where the wire spooling operations occur, were dimly lit, a bit noisy and cluttered with some oil on the floor. There were no particular odors present anywhere in the building, even where plastic molding was taking place. The observed jobs were all highly repetitive, requiring pinch grips, ulnar deviations, twisting movements, wrist flexion, and some wrist extension.

B. Job Observations

The following is a brief description of the basic tasks in each of the jobs studied along with a discussion of the biomechanical demands each job imposes on the hand, wrist, and arm.

Bartell Bunches

The particular job observed in this area consisted of wire being wound from many small spools onto a large one. The small spools, which weigh 40 pounds, are situated on a grid-like structure where they are all threaded to the large spool (Fig. 1).

As a given spool runs out of wire, it must be manually replaced. Because the spools are stacked five high on this grid, about a foot apart, a variety of biomechanically stressful postures are required to replace a spool. Figure 2 shows the ulnar deviation of the left hand and the twisting of the right hand which is required to replace the fourth highest spool.

Perhaps the most stressful aspect of this job is the cutting of excess wire off of a nearly used up spool. Because the end of the wire would have to be located and restrung onto a new spool, a given spool is never allowed to completely run out. Instead, when nearly spent, the wire is cut and easily attached to the new spool. The excess wire is then cut off the old spool with a common knife. Repeated motions ranging from full ulnar to full radial deviation of the wrist are required to cut this wire (see Fig. 3). There is a small sign posted in this area indicating that spools should be allowed to fully run out of wire before being replaced.

Miller Molder

Plug housings are molded onto bladed wire ends during this operation. The Miller Molder is a flat circular machine with four fixtures mounted radially at 45^{o} intervals. The blades are inserted into the fixture, a cover is closed and the table is rotated 45^{o} to the molding portion of the machine where plastic is injected into the fixture to form the housing. While this is taking place, blades are inserted into another fixture, and so on. Figure 4 shows this fixture.

The blades are positioned in the fixture with the left hand and inserted with the right hand. Many finger manipulations, primarily with the wrists flexed are required to insert these blades, which appear to fit very snugly into the fixture. As such, a high level of muscular force is required (see Fig 5). The cover is closed and the table is rotated with the left palm. This causes the hand to be in an extended position. The machine is manually unloaded, requiring both hands. About 2,300 of these molded plugs are formed in an average day.

Moslo Molder

This is an operation where plug housings are molded onto heavy duty cable such as on cords for a washer or dryer. It is a very similar operation to the Miller Molder except that it involves a press type machine that does not rotate. Four cables are inserted into a fixture, the press comes down and molds the plug, and four more cables are inserted into another fixture. Figure 6 illustrates this process.

There are several biomechanical stresses of the hand and wrist imposed by this job. The three blades mounted on each cable must be twisted 90^{o} so that they can be inserted into the fixture. As in the Miller Molder, these blades are very difficult to position into the fixture, placing a high muscular demand on the hand and wrist. The height of the work surface, which causes the wrist to be in ulnar deviation, and the weight of the cable further increase the load on the wrist.

Blading

Blading is a press operation where blades are affixed to stripped cable. The strands of the cable must be separated and aligned into a slot so that the blades can be properly stamped onto it. When aligning this cable into the machine, the wrist is extended and ulnarly deviated. The heavier the cable, the greater is the biomechanical demand on the hand and wrist. Approximately 5,000 cables are bladed in this manner in a typical day. Figure 7 illustrates this operation.

Wire Stripping

Wire is stripped by inserting the end into a table-like machine fixture which "bites" the sheathing from it. The wire is positioned with the right hand requiring some finger manipulation. Stock to be stripped is held constantly in the left hand. There is some bending of the wrist while performing this job and the primary biomechanical stress appeared to be the jolt received by the hand when the machine stripped the wire. Figure 8 illustrates this operation.

Another stripping job, called the "rowboat strip" has had some occurrences of cumulative trauma disorders. It is called rowboat strip because the wire is stripped when a lever similar to the rudder control on a rowboat is manually activated. This movement requires considerable force with the hand in a position of ulnar deviation.

Spooling

This job is shown in Figure 9. Various sizes of wire spools are wound from a large spool during this operation. The operator loads the machine with an empty spool, guides the wire and pulls it to ensure that the spool is wound neatly and tightly, and then replaces the full reel with another empty one. The primary stress incurred on this job is the requirement to pinch the wire as it is wound onto the reel.

Assembly and Packing

Three jobs were looked at in this area: socket assembly, extension cord packing, and socket packing.

Socket assembly involves the positioning of parts such as the socket housing, an extension cord, and a cardboard collar into place and then securing them together by pushing them against a fixture mounted horizontally on the edge of a table. In order to verify that these components are aligned properly, the operator inserts a plug which is held constantly in the right hand. If it slips in easily, the socket is assembled correctly.

Figure 10 shows the assembly being forced upon the fixture. Much force is required to do this and the right hand is in slight extension and ulnar deviation. The primary biomechanical stress associated with this job is the requirement to hold the length of cable in the hand constantly during the assembly process and the ulnar deviation of the wrist that occurs while the alignment is tested (Figure 11).

In packing extension cords, a loosely wound cord is taken from a hanger, placed on a flat bed machine and pushed through a device that encases it in a cardboard sleeve. Biomechanical stresses on the hand and arm are increased as the length and gauge of the cord being packed increases.

Some hand and finger manipulation is required to place the cord onto the machine properly, but generally this is a well designed job.

One of the products manufactured in this plant is a light socket assembly that, instead of having a conventional plug on it, has cable ends which fit onto an automobile battery to draw its power. In order to illustrate this unique feature, the item is packed with these cables attached to the socket housing so that they can be seen through the window of the package (see Fig. 12). Since 2,600 of these sockets are packed daily, 5,200 open hand pinches are required by each worker per day in packing this product. This light socket contains a light bulb which is screwed in before packing. At 4 twists per light bulb, the requirement is 10,400 twists per worker, per day. This operation is not performed by the same person described above (see Fig. 13).

Cable Testing

All extension cords are tested for continuity before packing. This is done by inserting the plug end of the cord into an outlet mounted on the electrical test apparatus. These plugs fit very tightly in the outlet so there is a high level of muscular force required to insert and withdraw them from the continuity test fixture. In addition, the wrist is in a position of ulnar deviation when the plug is inserted and removed.

In another area of the plant, an operator was observed using a new machine to test light, two-pronged extension cords (see Fig. 14). With this device all that is needed is to make contact with the test fixture to perform the continuity test. The requirement to insert and remove the plug is eliminated.

VI. CONCLUSIONS

As can be seen from the above descriptions, the movements and postures described earlier which have been linked to cumulative trauma disorders of the hand and wrist are very much a part of the pattern of hand motions required by workers performing the jobs that were observed by the NIOSH investigators.

Assuming an average workforce of about 400, the yearly incidence rate of cumulative trauma disorders at Miller Electric since 1973 has averaged 2 per 100 workers. The national average occupational illness incidence rate of cumulative trauma disorders in manufacturing reported by the Bureau of Labor Statistics[4] for the year 1975 is about 0.1 per 100 workers. On this basis, NIOSH concludes that hazards exist at Miller Electric Co. that contribute to the occurrence of cumulative trauma disorders of the hand and wrist.

While it is true that manufacturing and assembly jobs such as those found at the Miller Electric Co., will necessarily require some degree of stereotyped, repetitive motions of the hand and arm, the cumulative trauma to those parts of the body can be minimized through good workplace and tool design. Simple improvements such as proper table and chair heights, hand tools which minimize fatigue, fixtures which reduce the load on the arm and hand, and changes in assembly and packing methods which reduce hand motions are examples of measures which can be taken. There is potential for these kinds of changes in many of the jobs observed by the investigators. These will be elaborated in the Recommendations section.

VII. RECOMMENDATIONS

Bartell Bunches

The greatest potential for reduction in the demand on the musculoskeletal system for this job is the elimination of the need to cut wire from a spent spool. Presumably this is done so that new wire can be wound on a completely empty spool. The question that comes to mind is: if it is acceptable to splice the new spool of wire from the cut end when replacing an empty spool, why is it not acceptable to leave the excess on a spent spool and splice the new wire onto it when tne spool is rewound. In other words, there seems to be no reason why the excess wire should be cut off of a spool that is replaced. If this is not possible, the company should enforce the rule that wire be allowed to wind completely off of a spool before replacing it. A device which stops the end from going past a certain point so that it can be easily strung back to the new spool could be developed to make this alternative attractive to the worker.

There is less which can be done to reduce the stresses resulting from replacing the spools in this area. Because of their weight, and the range of heights at which they must be positioned, a certain amount of biomechanical demand cannot be avoided. However, making the worker aware of what wrist postures should be avoided (in this case ulnar deviation) in replacing these spools could reduce the trauma to the left hand. Providing a stool or a ladder to be used when replacing the highest spool would enable the wrist to remain in a neutral position. An air powered tool for bolting the cover on the spool would eliminate the twisting motion of the right hand. However, unless steps are taken to select a low vibrating tool or isolate the worker from the vibration, this recommendation may not be a better alternative.

Miller Molder

As can be seen in Figure 5, the left hand is flexed while the blades are being positioned because of the location of the cover when it is open. If the design were altered such that the cover opened a full 180° rather than about 90°, the left hand could assume a neutral position. Musculoskeletal demand on the right hand could be reduced if the blades did not fit into place so tightly. A design in which the blades are secured by a fixture on the cover or a mechanism which tightens around the blades when the machine is activated could be considered. In addition, a foot operated pedal that rotates the table would reduce movements (usually in an extended position) of the right hand.

Mosler Molder

The simplest way to reduce forearm and hand stresses in this job is to provide support for the weight of the cable as the blades are inserted in the fixture. A simple platform or table is all that is needed. A stool or platform to stand on would allow the worker to insert the blades without leaning over the machine and would enable the wrist to assume a neutral position while doing so. A tool or fixture that would eliminate the need to twist the blades into position before inserting into the fixture would greatly reduce the demand on the right arm. A separate press operation for performing this could be considered. Lastly, as in the Miller Molder, a system which reduces the amount of force needed to place the blades into the fixture is needed.

Blading

Support for the weight of the cable and adjustment of the chair height so that the wrist can assume a neutral position are the easiest and most immediate steps which should be taken regarding this job. An automatic feed system in which the strands of the cable are separated and aligned by the machine would be the ultimate improvement in this job because holding these strands open causes a high muscular demand on the hand and wrist. In this case, the operator would only have to load and unload the cables.

Wire Stripping

Workplace height and chair height adjustment so that the wrist position is neutral is the primary recommendation for this job. Since the cable that is stripped is light, there is little to benefit from a cable support system. However, a bin located near the stripping machine to provide easy access to unstripped material would eliminate the need to grab a number of cables and hold them in the hand while feeding into the machine. This would reduce static muscular force demands on the hand. An automatic feed system that would require the operator to merely guide the wire into the machine is the design change which would most reduce the biomechanical demands of this job. By this change, the machine, rather than the hand would absorb the shock or "bite" of the stripping mechanism.

The "rowboat strip" could be mechanized and operated by a foot pedal. This would eliminate the manual actuation that is currently required. A more conservative recommendation is to provide a wrist splint so that the rowboat lever can be pulled without ulnarly deviating the wrist.

Spooling

Two-finger pinches were earlier described as postures which result in high intra-Orist forces and thus increase the risk of developing a cumulative trauma disorder. Since this job requires continual pinches of this nature, the recommendation is to eliminate the need to guide and pull the wire manually as it is wound. A simple device such as a vise mounted on a stand could be used to produce the necessary tension on the wire to wind it tightly and uniformly.

Assembly and Packing

1. Socket Assembly

   An immediate step which could be taken to reduce the postural and muscular stresses on the hand and wrist caused by this job is to adjust the chair height or tilt the fixture so that the assembly components can be pushed together with the wrists in the neutral position. A test fixture should be supplied that would eliminate the need to constantly hold the plug in the hand. This should be mounted near the assembly fixture and tilted or positioned in a similar manner.

   Ideally, this job should be restructured so that parts are loaded into a cartridge and crimped together by a foot actuated press or plunger.

2. Light Socket Packing

   While it is recognized that the attachment of the battery cables to the socket housing and the inclusion of a light bulb are desirable marketing features, the packing system for this product should be redesigned to display them in some other way. The elimination of over 5,000 open-hand pinches and more than 10,000 arm twists per day would seem to justify such a packaging change. One possibility is to position the cable ends and the light bulb in the light socket and secure them in place with shrink wrap.

3. Cable Testing

   Workplace height and chair height adjustment so that the plug can be inserted into the test fixture with the wrist in a neutral position is recommended for this job. An adjacent table or platform that supports the weight of the cable, particularly for the heavy duty extension cords, is a recommendation that should be considered. The ultimate design recommendation for this job already exists in the plant. A test fixture similar to the one shown in Figure 14 should be provided for all the cable test jobs. As noted earlier, such a design nearly eliminates the postural and muscular demand on the hand and wrists that exists with the current style test fixture.

As can be seen from the above, many of the recommendations made do not involve expensive equipment, hiring of experts, or retraining the workforce in order to be implemented. They are simply good workplace design considerations. Little progress can be expected, however, unless an engineer is assigned to this area of the company who can evaluate ergonomic job stresses and design and implement appropriate controls.

Other more general recommendations are:

1. Implement an awareness program alerting workers, supervisors, and engineers to the potential hazards from these jobs and the specific movements and postures that result in cumulative trauma disorders. This program should be initiated with an orientation/ training session covering the major cumulative trauma disorders, their symptoms and causes. In the case of ganglion cysts, the most prevelant disorder in the plant, workers should be informed that the symptoms are pain, burning sensation, or an ache on the back of the wrist along extensor tendon sheaths or on the palm of the hand along flexor tendon sheaths. Workers and supervisors should be made aware that common movements associated with this disorder are manipulations made with the wrist extended, repeated twisting of the wrist, or the sudden and forceful use of a tendon or joint. Engineers should be encouraged to design workplaces and tools which minimize these types of movements and postures. Similar treatment should be given to other common disorders such as carpal tunnel syndrome and tendonitis/tenosynovitis regarding this program.

2. In conjunction with this awareness program, encourage workers to report injuries when symptoms are in their early stages and provide an adequate medical staff and medical form to enable specific disorders to be associated with specific jobs.

3. Implement a job rotation program. Even though it has been said that job rotation is impossible, the possibility should be explored because of the potential for reducing the concentration of biomechanical trauma which some workers receive.

VII. REFERENCES

1. Armstrong. T. and Chaffin, D. "Carpal Tunnel Syndrome and Selected Personal Attributes" JOM 21:481-486, 1979.

2. Hymovich, L. and Lindholm, M. "Hand, Wrist and Forearm Injuries, the Result of Repetitive Motions" JOM 8(11):575-577, 1966.

3. Welch, R. "The Causes of Tenosynovitis in Industry" Ind. Med. 42(10):16-19, 1972.

4. Occupational Injuries and Illnesses in the United States by Industry, 1975, Bulletin 1981. U.S. Department of Labor, Bureau of Labor Statistics, 1978, p 23.

VIII. AUTHORSHIP AND ACKNOWLEDGEMENTS

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IX. DISTRIBUTION AND AVAILABILITY

Copies of this report are currently available upon request from NIOSH, Division of Standards Development and Technology Transfer, Technical Information Branch, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After ninety (90) days the report will be available through the National Technical Information Service (NTIS), Springfield, Virginia 22161. Information regarding its availability through NTIS can be obtained from the NIOSH Publications Office at the Cincinnati, Ohio address.

Copies of this report have been sent to:

1. Miller Electric Co., Woonsocket, Rhode Island

2. U.S. Department of Labor, OSHA, Region I

3. U.S. Department of Health and Human Services, NIOSH, Region I

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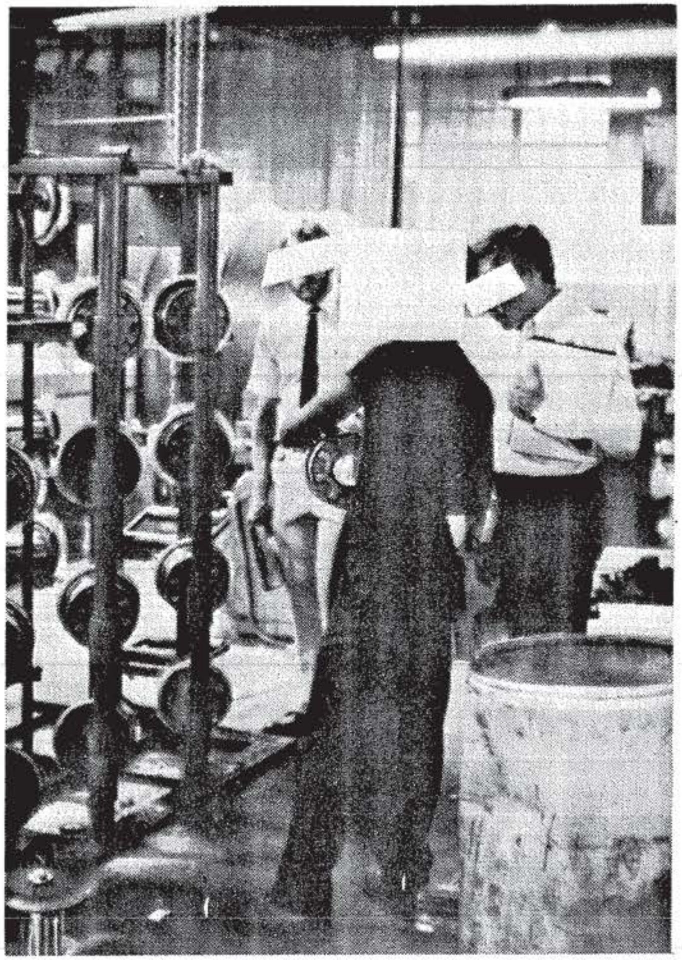

Figure 1: Bartell Bunch Area

Figure 2: Wrist postures required to replace a spool in the Bartell Bunch Area.

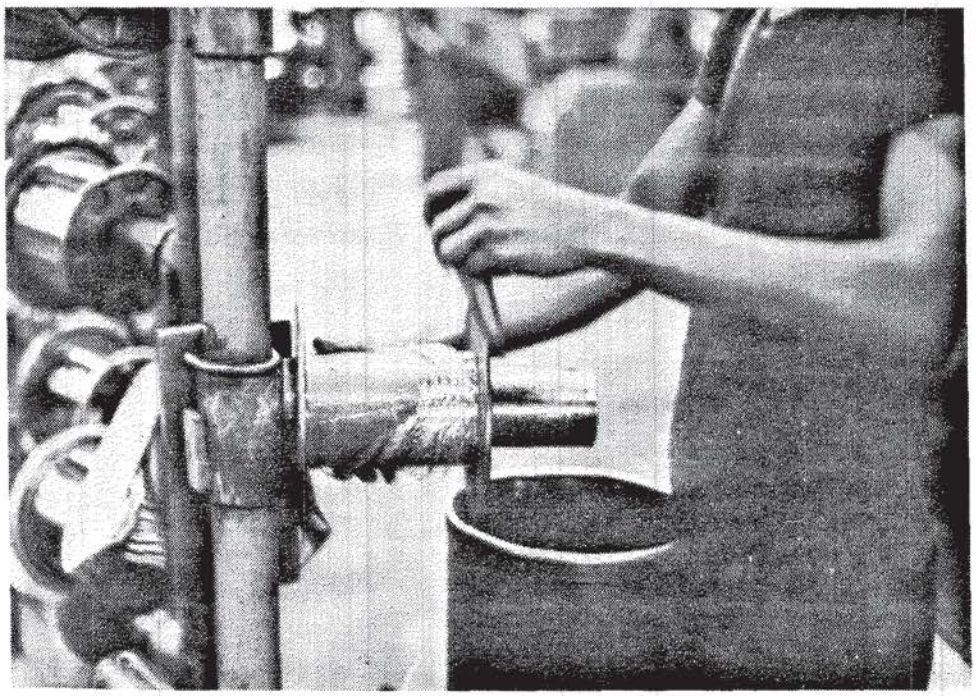

Figure 3: Cutting unused wire from a spool in the Bartell Bunch Area.

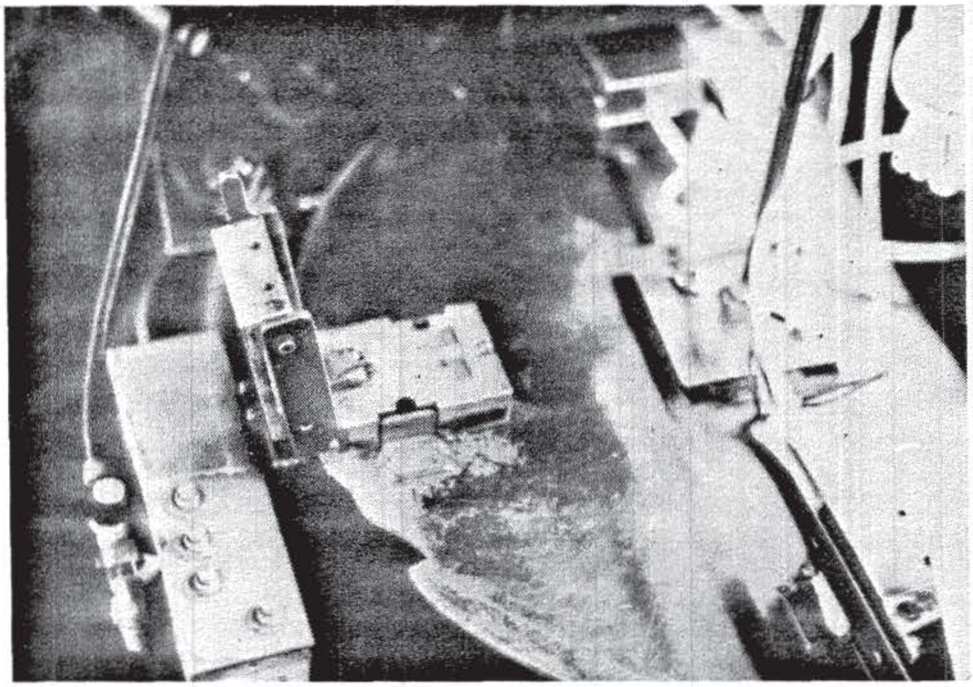

Figure 4: Plug housing fixture and work station of the Miller Molder.

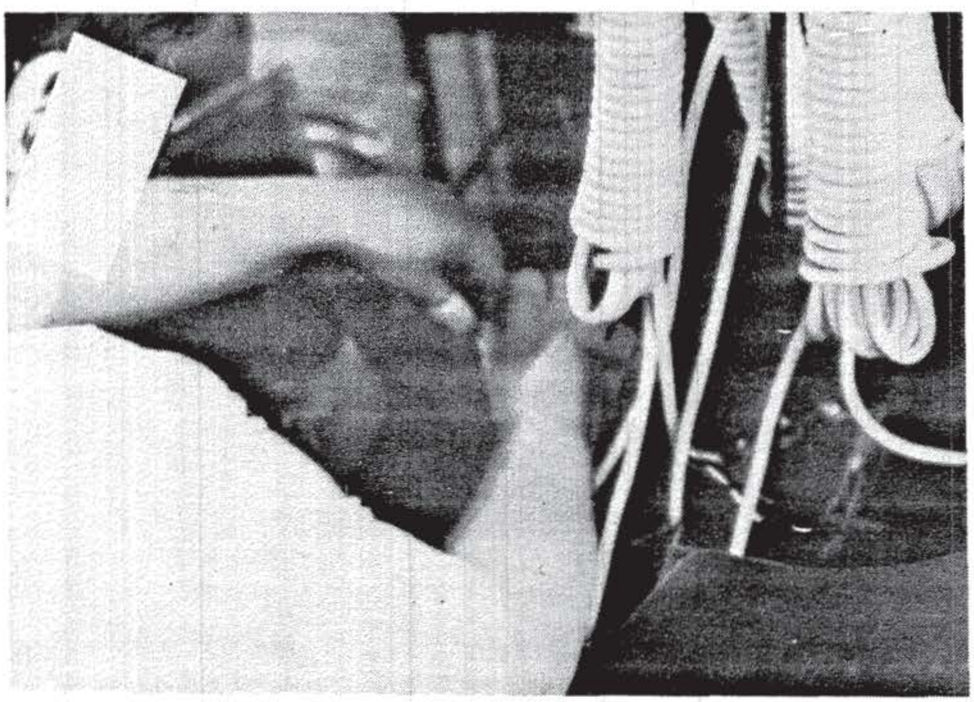

Figure 5: Inserting blades into plug housing fixture on the Miller Molder,

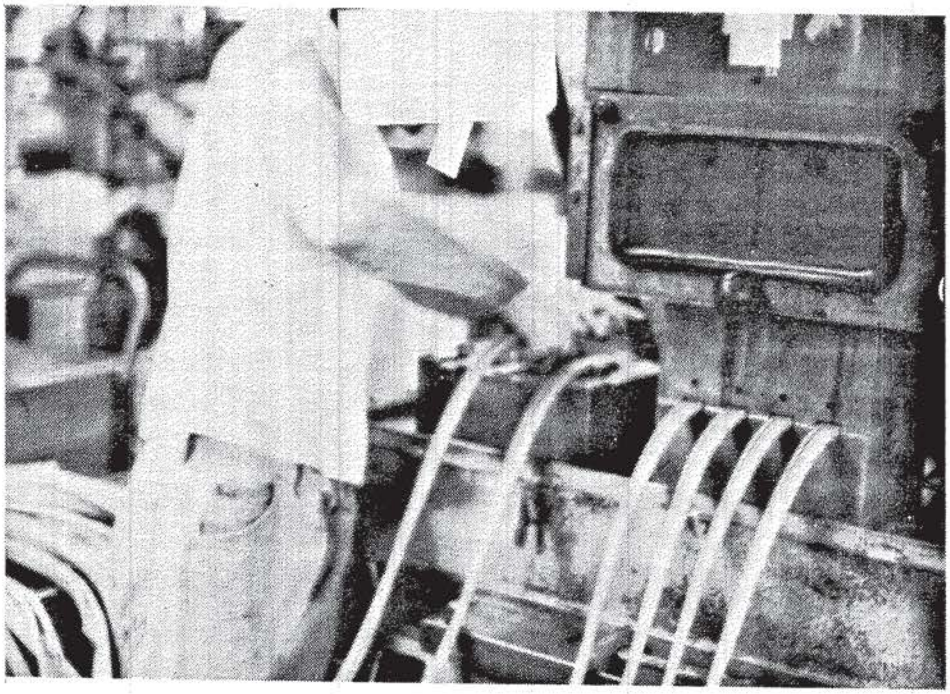

Figure 6: Inserting blades into the plug housing fixture on the Moslo Molder.

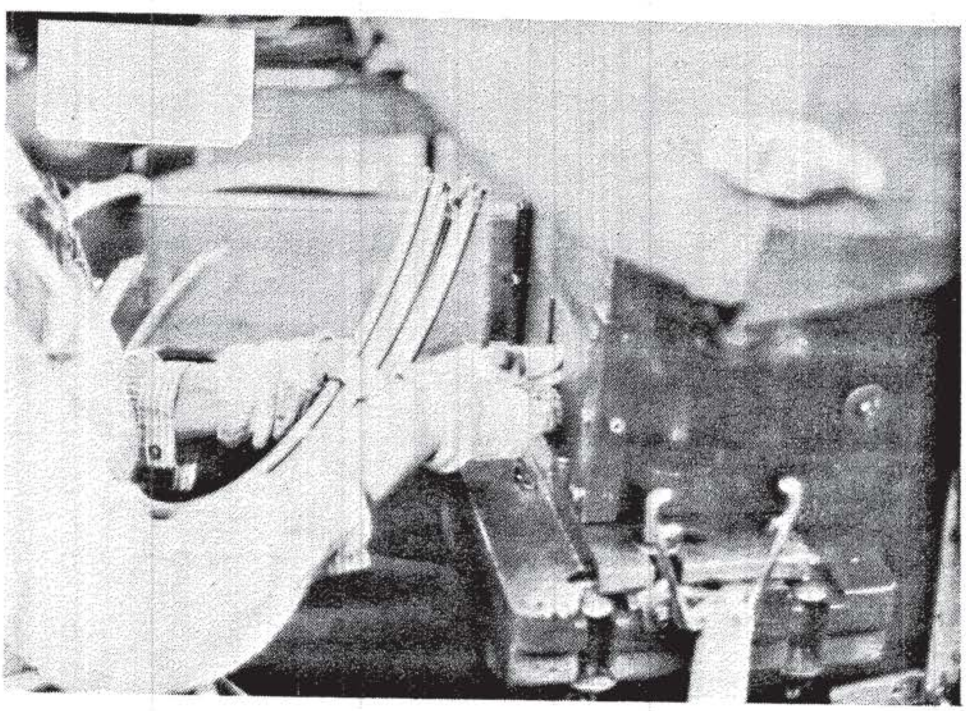

Figure 7: The "Blading" operation.

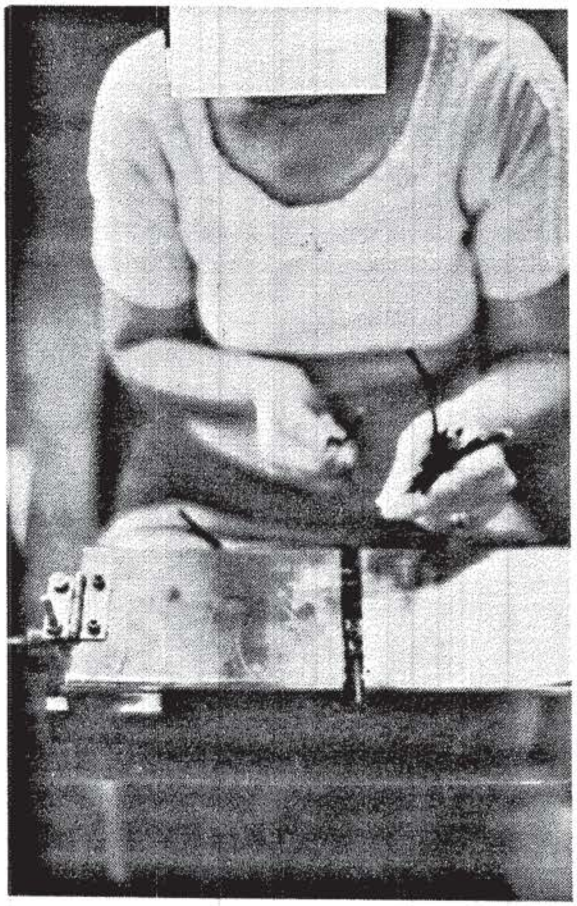

Figure 8: Wire Stripping Operation.

Figure 9: Worker spooling wire.

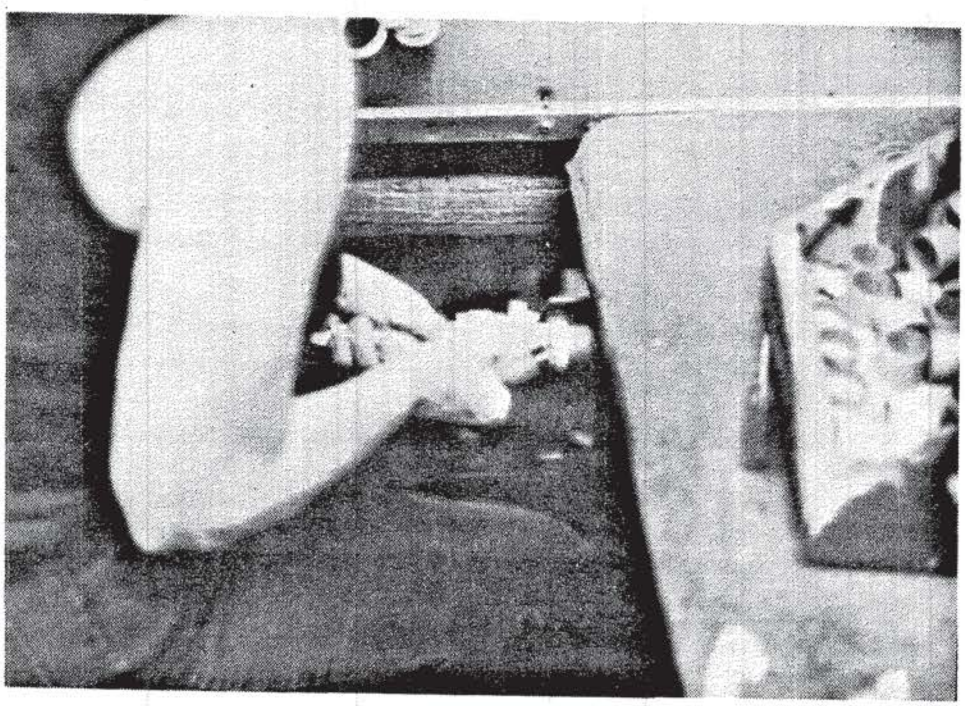

Figure 10: Crimping components together on the socket assembly.

Figure 11: Testing the alignment of components on the socket assembly

Figure 12: Screwing light bulb into light socket assembly before packing.

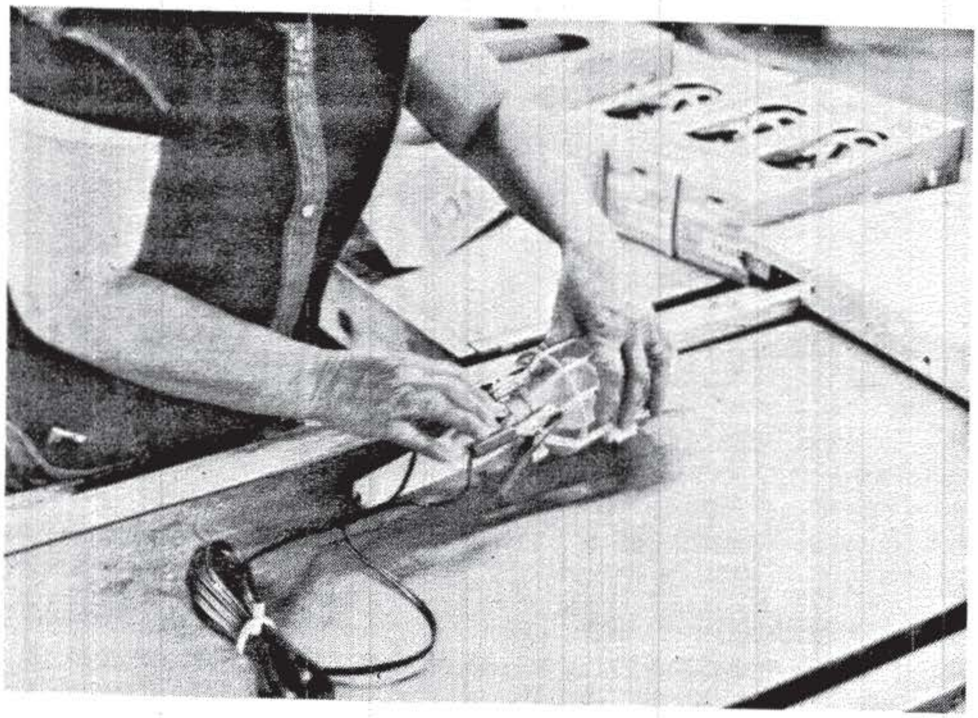

Figure 13: Attaching cable ends to housing on light socket assembly before packing.

Figure 14: Modern cable test apparatus.