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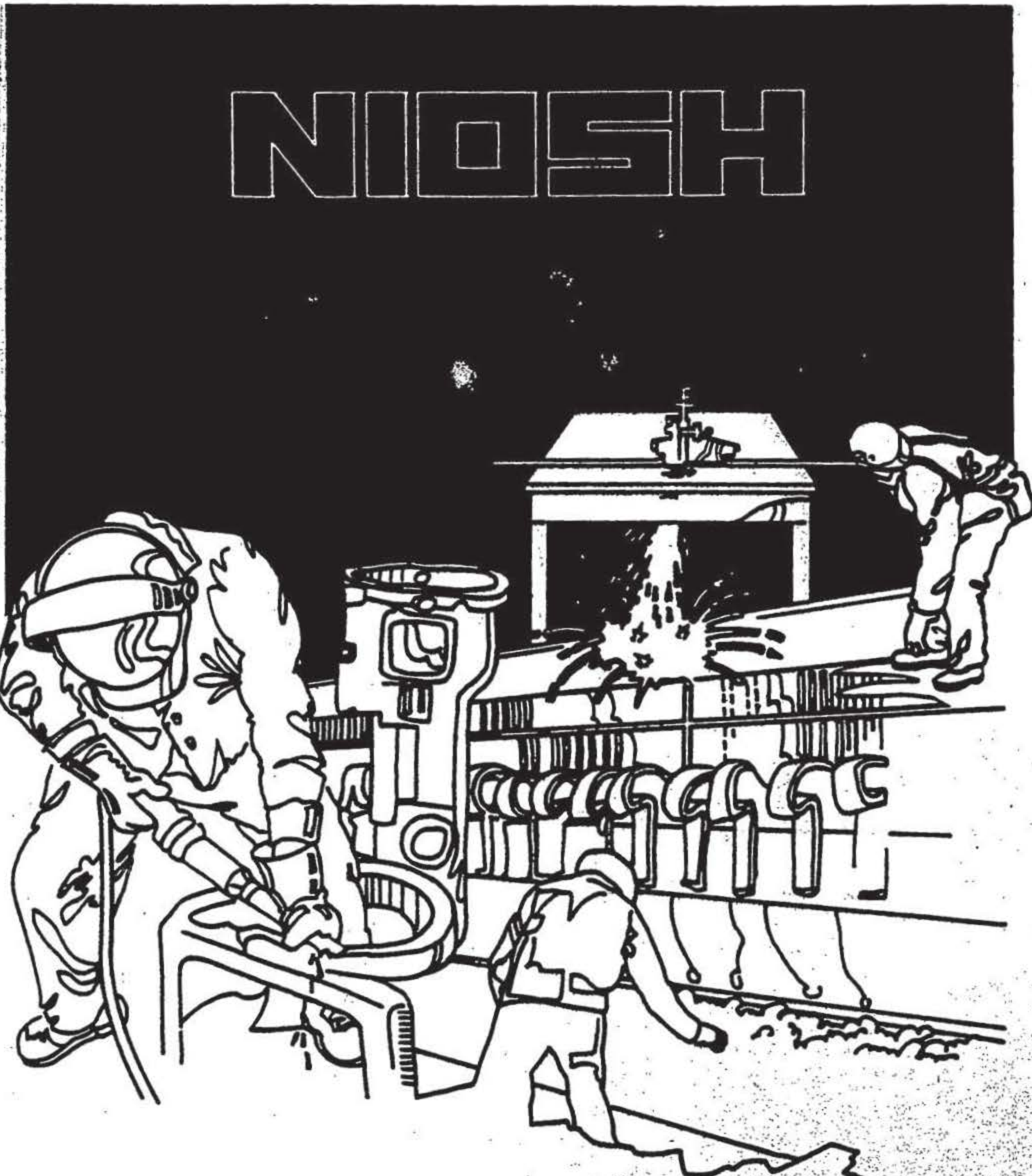


# Health Hazard Evaluation Report

HETA 85-480-1771
GENIE HOME PRODUCTS
SHENANDOAH, VIRGINIA

## 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 85-480-1771
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GENIE HOME PRODUCTS
SHENANDOAH, VIRGINIA

NIOSH INVESTIGATORS:
Daniel J. Habes
Craig L. Anderson

## I. SUMMARY

On August 8, 1985, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation from Local 174 of the International Union of Electronic, Electrical, Technical, Salaried and Machine Workers (IUE) located in Shenandoah, Virginia. NIOSH was asked to investigate the health effects of repetitive motions required by many of the jobs at Genie Home Products, Inc. The Company produces remote control garage door openers, motorized remote control switches, heavy duty rotators, and antenna rotors. The request listed an incidence of cumulative trauma disorders (CTDs) by department including tendinitis, carpal tunnel syndrome, tenosynovitis, and neuralgia, along with nondescript ailments such as soreness, swelling and tingling of the hands, arms, and wrists.

On May 6, 1986, NIOSH investigators conducted an ergonomic and medical evaluation of jobs in the plant.

The ergonomic evaluation consisted primarily of a plant walkthrough and detailed study of selected jobs, either those for which the incidence of complaints had been high, or for which there was Union concern. Videotapes and 35mm slides were taken to aid in the analysis of the aforementioned jobs.

The medical evaluation consisted of an inspection of medical record summaries for the years 1984, 1985, and the first three months of 1986.

During the course of the plant walkthrough some problem areas were noted, but the main focus of the evaluation was a comparison of jobs which had been modified for purposes of reducing ergonomic stress to the former method of performing the jobs.

Although Genie Home Products, Inc. has experienced relatively high rates of hand/wrist cumulative trauma disorders (CTDs) in the past, the Company's record has improved steadily over the past two years. This is largely attributed to Management and Union recognition of the problem and their willingness over the last two years to implement ergonomic improvements in those jobs where workers have experienced CTDs. The NIOSH ergonomic survey indicated that the Company still has some minor job design problems. Recommendations intended to aid in the elimination of these remaining problem situations are included in this report.

KEYWORDS: SIC 3699 (electronic, electrical, technical, and salaried machine workers), cumulative trauma disorders, carpal tunnel syndrome, manual work, circuit board assembly, air-powered tools.

## II. INTRODUCTION

On August 8, 1985, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation from Local 174 of the International Union of Electronic, Electrical, Technical, Salaried and Machine Workers located at Shenandoah, Virginia. NIOSH was asked to investigate the health effects of repetitive motions required by many of the jobs at Genie Home Products, Inc. The request listed an incidence of cumulative trauma disorders (CTDs) by department including tendinitis, carpal tunnel syndrome, tenosynovitis, and neuralgia, along with nondescript ailments such as soreness, swelling and tingling of the hands, arms, and wrists.

On May 6, 1986, NIOSH investigators conducted an evaluation of the job tasks at Genie, consisting of a plant walkthrough and a review of medical record summaries.

## III. BACKGROUND

Genie Home Products, Inc. of Shenandoah, Virginia produces remote control garage door openers, motorized remote control switches, heavy duty rotators, and antenna rotors. At the time of the evaluation, the plant employed about 150 workers, most of whom were women. There are four main job classifications at the plant: inspector, stock handler, maintenance worker, and assembler. Ninety-nine percent of the production workers are assemblers.

At the time of the HHE request, which was August, 1985, there were 31 workers who had filed injury reports and 20 who had filed Worker's Compensation First Reports, 13 of which were included in the aforementioned injury reports list. This incidence rate and a safety tour report prepared by the Health and Safety Director of the IUE in October 1984, enabled the Company to recognize problem areas and initiate remedial measures. As a result, many of the problem areas cited in the HHE request had undergone change between the time of the request and the conduct of the evaluation.

## IV. EVALUATION DESIGN AND METHODS

The ergonomic job analysis consisted of a complete plant walkthrough. Normal procedure is to focus attention mainly on problem areas, particularly those detailed in the HHE request. Because many work stations had been redesigned since the request and the plant was relatively small, each department was visited. This approach provided an opportunity to evaluate the changes made and to determine if problem job tasks still existed in any departments. To aid in this effort, selected jobs were videotaped and where appropriate, 35mm stills were taken. Videotaping facilitates motion and posture analyses away from the plant site; still pictures provide an immediate hard copy representation of key jobs. In one area of the plant, where a special process is used to manufacture relays, the company requested that videos and stills not be taken.

## V. EVALUATION CRITERIA

There is evidence in the literature that cumulative trauma disorders (CTDs) are associated with repetitive and forceful movements of the joints and muscles (1-4,7). Examples include tendinitis, tenosynovitis, carpal tunnel syndrome, ganglionic cysts, epicondylitis, myositis, and bursitis. These disorders affect the nerves, tendons, and tendon sheaths of the upper extremity. The reported causal factors of these ailments, particularly those found in the workplace, are the force of an exertion, the posture of the hand/arm during the exertion, and the frequency of the movement. The postures most often associated with upper extremity CTDs are wrist extension and flexion, ulnar and radial deviation of the wrist, open-hand pinching, twisting movements of the wrist and elbow, and shoulder abduction. CTDs are considered in many cases to be work-related because these types of postures and movements are required in many manufacturing and assembly jobs in industry. Occupations for which a high incidence of CTDs is known to exist include electronic components assembly, textile manufacture, small appliance manufacturing and assembling, meat processing and packing, fish filleting, and buffing and filing. What is common to all of these jobs is repetitive, stereotyped movement of the hand, arm, and wrist coupled with varying degrees of muscular exertion. The incidence of CTDs among these and other industries has not yet been established, but incidences as high as 44 cases per 100 workers per annum are known to exist (5).

Because occupational factors are considered to be major in the development of these disorders, few non-occupational antecedents of CTDs are identified or reported. Examples of non-occupational risk factors include: woodworking, tennis, weight lifting, knitting, and sewing. All of these activities impose similar physical demands as manual work on the musculo-tendinous system.

The carpal tunnel syndrome, an entrapment disorder affecting the median nerve, is associated with other common conditions such as pregnancy, menopause, obesity, diabetes, use of oral contraceptives, gynecological surgery, rheumatoid arthritis, acromegaly, and gout (6). Since a number of these conditions are unique to women, their risk of carpal tunnel syndrome may be elevated. This may explain in part why carpal tunnel syndrome occurs from 3 to 10 times more often in women than in men.

The first step in conducting an ergonomic evaluation of high risk jobs is to identify and document the nature and frequency of both awkward and static postures. Videotapes and 35mm still pictures are often taken to aid in this job analysis. If the preliminary analysis suggests that the work requires excessive muscular force, the investigators may need to measure muscle tension to determine aspects of the work task that contribute to excessive force. Muscle tension is measured using surface electromyography (EMG) (7). One study found that workers performing jobs with force levels of 4 kilograms or more were four times as likely to develop a hand/wrist CTD as those workers whose jobs required muscular exertions of 1 kilogram or less (8). In the absence of techniques like EMG, force can be estimated by weighing tools used and objects handled, or through use of psychometric techniques for judging the amount of effort required to perform a certain activity.

Both the length of job cycles and frequency of movements present additional risk for CTDs. Job tasks with cycle times lasting 30 seconds or less were found to have an incidence of upper extremity CTDs three times greater than those jobs where the cycle time was greater than 30 seconds (8). In studies reporting an incidence of CTDs, where the the number of hand movements were recorded, the range was from 5000 to 50,000 repetitions per day (9-15). The work activities were varied and included the following: cutting poultry, keystroking, hand sanding/filing, and packing tea, etc. Because of the complexity of the repetitive motion patterns, it has been difficult to define a critical frequency factor for defining a CTD risk. As such, any inferences drawn from studies describing the contribution of frequency of movement or job cycle time as causative factors in the development of CTD's involves a degree of professional judgement.

Consequently, the current strategy for reducing the risk of CTDs for a certain task is to minimize exposure to job factors that are biomechanically stressful, i.e., high force, awkward postures, and high repetition rates. This is most effectively achieved through the redesign of work stations, tools, or work methods that are identified through job analysis as risk factors for CTDs.

In as much as this HETA was mostly an "audit" of previously made ergonomic changes, along with an evaluation of jobs which had not changed since the original request, no rigorous evaluation criteria had to be applied. Rather, job conditions were measured against a "real time" visual assessment of the degree and extent of the ergonomic hazards described above.

## VI. RESULTS

### A. Medical Summary Review

The company provided summaries of injury and worker's compensation reports along with related job activities, symptoms, and illnesses for 1984, 1985, and January through March, 1986. The 1984 Union count, which was slightly different from that of the Company for the above categories was also included in these summaries. Injury and Worker's Compensation First Reports (WC) involving the upper extremity were as follows:

| | Union | Company | | |
|---|---|---|---|---|
| | 1984 | 1984 | 1985 | 1986 |
| Injury Reports | 31 | 41 | 21 | 1 |
| WC | 20 | 27 | 5 | 0 |

The following categorical breakdowns most clearly define the extent of the CTD problem:

Number of Reports by Job

| | Union | Company | | |
|---|---|---|---|---|
| | 1984 | 1984 | 1985 | 1986 |
| Job Activities | | | | |
| Manual Circuit Board Building | 18 | 11 | 10 | 1 |
| Lifting | 2 | 5 | 1 | 0 |
| Pulling Arbor Press Handle | 2 | 6 | 2 | 0 |
| No Information | 4 | 8 | 5 | 0 |

Number of Reports by Illness/Symptoms

| | Union | Company | | |
|---|---|---|---|---|
| | 1984 | 1984 | 1985 | 1986 |
| Illnesses | | | | |
| Knot/Cyst | 5 | 3 | 2 | 0 |
| Carpal Tunnel Syndrome | 3 | 3 | 0 | 0 |
| Tendinitis | 15 | 17 | 3 | 0 |
| Symptoms | | | | |
| Sore Arm | 6 | 11 | 7 | 0 |
| Finger Pain/Numbness | 3 | 3 | 3 | 0 |
| Swelling | 7 | 11 | 2 | 1 |
| Knot(Ganglionic Cyst) | 0 | 4 | 4 | 0 |
| Wrist Pain | 0 | 8 | 4 | 0 |

Number of Reports by Department

| | Union | Company | | |
|---|---|---|---|---|
| | 1984 | 1984 | 1985 | 1986 |
| **Department** | | | | |
| **32(Board Building)** | | | | |
| Injury Reports | 14 | 18 | 12 | 1 |
| WC | 9 | 13 | 3 | 0 |
| **33 (Testing)** | | | | |
| Injury Reports | 4 | 6 | 1 | 0 |
| WC | 0 | 1 | 0 | 0 |
| **34 (Antenna Rotators)** | | | | |
| Injury Reports | 8 | 11 | 0 | 0 |
| WC | 6 | 6 | 0 | 0 |
| **35 (Stators)** | | | | |
| Injury Reports | 2 | 4 | 4 | 0 |
| WC | 5 | 5 | 1 | 0 |

Incidence rates (#cases/200,000 work hours or 100 workers per annum) for arm/wrist related injuries were available for 1984 and the first five months of 1985. These figures were 10.5 and 4.0, respectively. For comparison, the 1982 Bureau of Labor Statistics (BLS) industry average for SIC #3699 "electrical machinery, equipment and supplies, not elsewhere classified" was 9.6.

B. Ergonomics Evaluation

1. General Description/Impression of Typical Job Activities

A survey of departments 31, 32, 33, 34, and 35 constituted our plant evaluation. All job tasks were reviewed, but emphasis was placed on those jobs for which any type of musculoskeletal problem had been recorded. In addition, an ergonomics evaluation was conducted on those jobs where there has been a history of problems and the company had introduced some type of tool or workplace redesign.

The most common jobs in department 31, where relays are made, are the Bacci winder and various press and winding operations. The Bacci winder requires workers to sit at a large machine where small gauge wire is wound by hand (three turns) to start the operation of the machine. In August 1986, this job was scheduled to be redesigned so that the windings on the relay are started by the machine. This modification reduces the manual portion of the job to loading and unloading lightweight parts from the Bacci winder. Other winding jobs require the operators to wind wire around 3-5 pound stators while holding the stators in one hand.

Two types of jobs were looked at in Department 32: "board stuffing" and a press job formerly called the arbor press. Manual board stuffing requires right-handed workers to hold small circuit boards in their left hand and insert components with the right hand (Figure 1A). After the components are set in place, the ends are twisted and then clipped with a small cutting tool. The boards are constantly being turned over and twisted, requiring many stressful hand movements, including wrist extension and open-hand pinching. Using this method, 44 pieces/hour were required to meet the work standard.

In September 1985, several semiautomatic board building machines, called "Dynacam"s were introduced in Department 32. With this machine, the worker sits at an adjustable tilted work surface that holds two circuit boards in a fixture (Figure 1B). The components are inserted manually, taken from small bins located in front of the operator, but the leads are clipped by the machine after activation of a foot pedal. The worker no longer has to hold the board or clip by hand. Piece rate using this method is 24/hour. The number of pieces built per hour is less because the Dynacam must be loaded and unloaded, and the operator must wait for the machine to clip the leads. Built by hand, the worker had complete control over the speed of the operation. The revised method is slowed down by the action of the Dynacam.

One aspect of this modified work station still in development is the placement and design of the foot pedal. At the time of the survey, the pedal, which had a foot guard on it, was placed on a piece of plywood under the work station (Figure 2). This tended to raise the legs and restricted knee room. In some of the workstations, a wedge was added to the system to give the operators leverage for easy activation of the control. The leverage, or fulcrum point, resulting from this wedge was forward, about midfoot under the arch. This arrangement also caused one leg to be higher than the other, further restricting knee room. In addition, the foot pedal was not located in a fixed position, and the wedge was not connected to the foot pedal. This condition allowed the foot pedal to move, and the wedge to move in relation to the foot pedal, enabling a variety of counter-productive foot pedal and wedge orientations to be possible.

The arbor press is activated by a long handle. The placement of this handle required workers to reach from above shoulder height and pull down to operate the machine. This control has been eliminated. The current arrangement is such that the press is located on a bench table where a seated operator (a) places parts located in boxes on either side of her on the press, (b) activates the press with a two-button control, and (c) places finished parts in bins behind her. The small parts used are difficult to handle, causing the operator to assume a pinch grip to grasp them. The activation of the buttons requires the wrists to be in flexion because the control buttons are located about 6 inches above benchtop height (Figure 3). Placement of the finished assemblies into the bins also requires the operator to flex the wrists (Figure 4). There was no support for the elbows and the chair in use was not adjustable and lacked a suitable back rest.

Only one job was examined in Department 33. It consisted of manually inserting a 9 volt battery into a transmitter called the "sending unit." This job was recognized as a potential hazard by the Company and the workers, as it was identified in the HETA request as a potential hazard. To perform the job, a seated worker grasps a circuit board/battery connection unit with the left hand and simultaneously reaches for a standard 9 volt battery with the right hand. The two are aligned, and the connection is made with a brisk extension of the right wrist, using the benchtop as a pivot point (Figure 5).

A crimping tool was used in an earlier attempt to modify this job, but proved unsatisfactory. The Company plans to eliminate the current battery connecting strip and place the battery directly into the sending unit, using a spring-loaded connection system.

Department 34, where antenna rotators are made, ceased operation in September 1984 and was restarted in February 1985. Because many air-powered wrenches and screwdrivers are used in this department, it has historically been a problem area for hand/wrist disorders. Three classes of air powered tools were in use in department 34: wrenches with torque ranges of 7 in.-lb., 30 in.-lb., and 80-120 in.-lb. One modification the company has introduced to lessen the problem with these tools is to install suspension devices and torque limiters on the heavy duty screwdrivers (Figure 6). These eliminate the need for the operator to support the weight of the tool and serve to isolate the worker from high torque levels. All air-powered tools except the low torque variety (7 in-lb.) have been equipped with the torque limiters.

Another job on the same line in department 34 where a modification had been made was the operation in which a rubber weather shield is installed on the antenna rotator. This shield was previously installed by hand using a screwdriver (Figure 7). To perform the job, the wrist had to be completely rotated while in a flexed position. The worker also had to secure the rotator housing with the left hand.

The redesigned arrangement employs a suspended crimping device, which when positioned over the housing with the shield in place, attaches the shield with one downward thrust. The job is performed with little force and the wrists are in the neutral position (Figure 8).

Other job modifications implemented in this department included (1) addition of a "nut cup" in a rotator assembly operation which snaps a nut into a magnetic nut driver, eliminating the need for manual insertion and (2) the substitution of hex head screws for conventional slotted screws to eliminate "hand starting" in a rotator housing assembly job.

Another common activity performed in Department 34 which has historically been associated with hand/wrist disorders is packing. In this operation, antenna rotators were packed in boxes. The job design features a long packing line, intended for two operators, but at the time was running with one. The worker begins by reaching over the line to get some cardboard packing material, which is formed by hand. The two main pieces of the rotator assembly to be packed are located on pallets on the side and in back of the operator. The assemblies are placed on the packing material along with some hardware, the cardboard is folded over and the unit is pushed down the line. When enough rotators have accumulated, the operator walks to the end of the line to place them in prefabricated boxes. A fixture holds the horizontally-oriented box open. The assembly is slid in, and the box is pushed off the line to its upright position. The boxes are then sealed with an air powered stapler. Six packaged rotators are then placed in a larger box, which is sealed with the same stapler and placed on a pallet. These boxes are stacked two high to a height of about 40 inches, requiring the worker to abduct the shoulder and flex and ulnarly deviate the wrist to operate the unsuspended stapler (Figure 9).

Other hand intensive jobs evaluated in department 34 included the testing of the antenna rotator control unit and assembling the dial for the control unit. In testing the control unit, the worker plugs in a number of units, and turns each dial one full turn, requiring wrist extension and ulnar deviation. In assembling the dial, the worker makes many manipulations, including the forcing of a "C" clip into place with a straight handled tool and seating the dial cover by pounding it with the butt of a screwdriver. Neither of these jobs, however, has presented a hand/wrist problem.

In department 35, "fields" are made for Genie controls and automatic switch-offs. The field is the space where magnetic force is generated in a motor. Many of the jobs require handling of 3-5 lb. stators in performing soldering and lacing operations. A stator is the stationary part of a motor, inside of which the rotor turns.

Stators are manufactured and inspected on the "winding-connect" line. The Company intends to install conveyors, which will eliminate much of the handling on the winding-connect line. At the end of the line, where the stators are inspected, the worker places them in a cardboard box. An improvement which has already been made is the addition of a pallet to hold the the box which has wheels and a handle. This brings the box to a more workable height and allows the fully loaded container to be moved easily.

A job called "taping down" requires a seated operator to twist loose wires and form a pocket between adjacent coils to attach a thermostat to the stator. To form this pocket a hammer and a wedge is used (Figure 10). A new smaller thermostat and a new Bacci press for forming the stator coil will eliminate the hammering operation in the future.

Soldering on this line also involves handling of the stator. Wires are attached to the stator by hand and then it is lifted to make contact with a vertically oriented "solder pot" located away from the worker under a ventilation pipe. This arrangement isolates the worker from the solder, but requires a long reach to perform the operation (Figure 11).

Another job specifically mentioned in the HETA request is called "lamination welding." Layers of laminated rings are placed on a mandril to form the stator housing. In the past, these rings were fitted very tightly and required many manipulations and considerable force to be slid down the mandril. The Company's solution was to redesign the mandril so that it could be retracted while being loaded and then expanded to fit the laminated rings tightly. The rings are then welded together by the machine (Figure 12).

The last job examined in this department was the winding of stators. In this operation, coils of wire are wound and secured to the stator housing. The coils of large stators are attached automatically by the winding machine, while those of small stators are made on a machine requiring manual handling to attach the coils. Both methods employ a "transfer tool," which aids in directing the wire from the winder to the stator. Because use of the transfer tool requires many complex manipulations it is a source of stress to the worker. The Company plans to introduce new transfer tools made of lightweight plastic which will reduce the force required to use them (Figure 13).

## VII. DISCUSSION

Regardless of which 1984 incidence numbers are used, the Union's (31) or the Company's (41), the incidence of CTDs for 1985 (21) and the first three months of 1986 (1) represent significant improvement in the problem for Genie Home Products. These figures are even more impressive when one considers that some degree of hand/wrist disorders will likely occur in any company that manufactures small items, particularly when assembly with air-powered tools is involved. For the year 1984, the Company's rates were slightly higher than the 1982 industry average for incidence of hand/wrist disorders, perhaps inspiring some of the job modifications set into place. Genie Home Products also enjoys a good relationship with both the Local and International Union, whose safety and health personnel have a keen awareness of ergonomic problems contributing to hand/wrist disorders.

There are still some job design problems at Genie that need to be addressed. The Company, however, seems to know where these inadequacies are, and has embarked upon an improvement program consisting of capital expenditure for automated machinery and the addition of small items such as jigs and fixtures to streamline assembly methods. As evidence of the Company's commitment to reducing injuries, despite potential increases in cost, they introduced the Dynacam to aid in board building, which was effective in reducing injuries, but slowed production rates. This machine is also somewhat unpopular with the workers because it paces the work and eliminates the potential for high incentive system earnings.

Many of the job interventions made at Genie, particularly the torque limiters on the air-powered nut drivers, represent technology and design that not only reduce stressful work postures, but also facilitate production. As such, these design concepts have the potential to benefit other industries performing similar jobs or using similar tools.

One of the major remaining problems in the plant deals with the manual handling of stators. This is a recognized hazard in Department 35, but is not easily dealt with on a job-type basis. One solution is to establish a system of conveyors linking all the work stations in the department. This would significantly reduce the amount of handling of stators which now takes place.

The Company, of course, has to reconcile any cost of improvements with the potential benefits to remain competitive. Hence, the Company is taking into consideration practical matters such as capital expenditure limitations and production volume forecasts in determining future ergonomic improvements. As the fiscal constraints are lifted, it is likely that many of the problems will be solved, assuming that there is no deterioration in the health status of workers handling stators.

One other notable problem exists: the design and placement of foot controls on the Dynacam machine. Here it will be necessary to try a number of prototypes before a suitable system is devised.

## VIII. CONCLUSIONS

Genie Home Products is a fine example of the positive impact that a concerned and well-informed Union and an equally well-informed and open-minded Management can have on the incidence of musculoskeletal disorders in a workplace comprised of many hand-intensive assembly operations. Left on its own, it is probable that this Company's safety and health record will continue to improve. However, in the interim, the following recommendations are offered for reducing biomechanical demand on the select jobs examined during the course of the HETA.

## IX. RECOMMENDATIONS

### A. Department 31

1. Continue with plans to redesign the Bacci winder so that the turns of wire made by hand are eliminated.

2. For other winding jobs, continue to study ways to eliminate the manual handling of stators while winding operations are being performed. As noted before, a comprehensive solution should be sought because of the number of operations which involve the handling of stators. A system of conveyors, hooks, or preferably belts, mounted at work table height would be a logical starting point for redesign. Such a system would allow workers to remove a stator from the conveyor, perform an operation, and replace it on the line, eliminating the need to stack stators in bins or on tabletops between operations.

B. Department 32

Dynacam

1. Design and adapt a foot pedal for the Dynacam that is adjustable to the extent that it can be used comfortably by all the machine operators. The foot pedal system should be a single unit mounted under the table of the machine. Adjustability and comfort will be enhanced if the toe guard, which restricts movement of the foot, is removed from the pedal. Other design features which could be incorporated (taken from Damon, et al (16)) are:

   a. The pedal should be toe-operated, with the fulcrum at the base of the heel.

   b. The knee angle should be at least 90 degrees and preferably 135 degrees or more. This will define the horizontal distance the pedal is from the edge of the seat pan.

   c. The vertical distance of the pedal from the seat pan can be varied for comfort, but should not exceed 16 inches.

   d. The lateral location of the pedal should be as close to the body's midline as possible, but can stray as far as 3-5 inches when force is not a consideration.

   e. Pedals operated by ankle action should have a maximum travel of about 2 inches, corresponding to an angle of about 10-12 degrees. The angle should not exceed 30 degrees.

   f. For all foot controls, the direction of travel should be down, or away from the body, in line with the long axis of the lower legs, and roughly parallel to the midsagittal plane of the body.

   g. Pedals should be as wide, or almost as wide, as the sole of the shoe, i.e., at least 3.5 inches. Pedal length should be at least 3 inches long.

   h. Pedal shape is not very important as long as the pedal surface is flat and affords a large enough area of contact with the shoe. For pedals continually in use the shape should be rectangular and conform roughly to footgear dimensions.

   One other consideration is to develop a lead clipping system activated by a sideways movement of the knee. Care must be taken not to concentrate stresses on the lateral portion of the kneecap, but provided that the lever travel distance is small and the contact point is well-padded, such a system could solve the problem of foot pedal placement and orientation currently being experienced in the Dynacam area.

2. Provide gravity feed parts bins in the Dynacam area. The upper row of bins has lips on them which the worker must reach over to grasp the small parts inserted into the circuit boards. Due to the restructuring of job elements to reduce the number of parts inserted per operation, the upper row bins are not used as often as before. However, in those instances when the upper row of bins is used, a substitute bin making parts easier to see and grasp, should be provided.

Press Job

1. Relocate the press buttons so that they can be activated with the wrist in a neutral position. As the press is currently oriented, a side-mounted switch with a heat sensitive activation system to eliminate the force needed to press the buttons is recommended. An adjustable chair with arm rests to support the elbows is also recommended. Recessing the press so that the controls are flush with the table would be a substitute for redesigning the controls and would lessen the need for arm support.

2. Reorient finished parts bins so that reaching behind the body with the wrist in a flexed posture to position parts is eliminated. A table-height bin located to the side of the machine would allow the operator to slide finished parts into the bins after the machine is unloaded.

3. Provide gravity feed bins for holding unfinished parts and locate them within arm's reach of the operator. In the present case, the operator grabs a few parts from a box in which the parts are kept, and places them near the press on the table. Not only does this result in reaching for unfinished parts twice, but picking up the small parts from the table is difficult and requires a precision pinch grip. The table also has a sharp edge and should be padded.

C. Department 33

1. Continue with plans to modify the battery insertion into the sending unit to include a spring-loaded connection system.

D. Department 34

Antenna Rotator Packing

1. Streamline the bulk packing of packaged antenna rotators. This is a very well-designed job until the final step, where finished packages are lifted and placed into a larger box and then stapled shut. At the end of the packing line, when the rotators are slid into the box and then dropped 90 degrees onto a platform to be stapled shut, they should be slid into a bulk box that is on a roller conveyor. This way, the individual boxes could be stapled, then the bulk box could be stapled and the entire package could be slid out of the way onto a pallet. Lifting of the individual rotator packages would be eliminated and handling and maneuvering of the large stapler could be avoided. The stapler could be in a fixed, counterbalanced position, relieving the operator of the need to lift it and walk to the location of the bulk boxes while carrying the stapler.

   At the very least, the bulk boxes should be angled toward the worker to minimize the height to which the packages are lifted and the distance they are carried. This arrangement would also eliminate the extreme abduction of the shoulder required to staple the second row of bulk boxes.

E. Department 35

1. Implement as soon as possible planned modifications to reduce the biomechanical load on the workers. Specifically, these are:

   a. the new smaller thermostat on the "taping down" job which eliminates the need to use a hammer and wedge to form the thermostat pocket.

   b. the lightweight plastic transfer tool used on the winding machines.

2. Continue efforts to eliminate the manual handling of stators, a task which is a part of many of the operations in Department 35.

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## XI. AUTHORSHIP AND ACKNOWLEDGEMENTS


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|---|---|
| Report prepared by: | Daniel J. Habes<br>Industrial Engineer<br>Psychophysiology and Biomechanics Section<br>Applied Psychology and Ergonomics Branch<br>Division of Biomedical and Behavioral Science |
| Field Assistance: | Craig L. Anderson<br>Epidemiologist |
| Originating Office: | Hazard Evaluations and Technical Assistance Branch<br>Division of Surveillance, Hazard Evaluations, and Field Studies |


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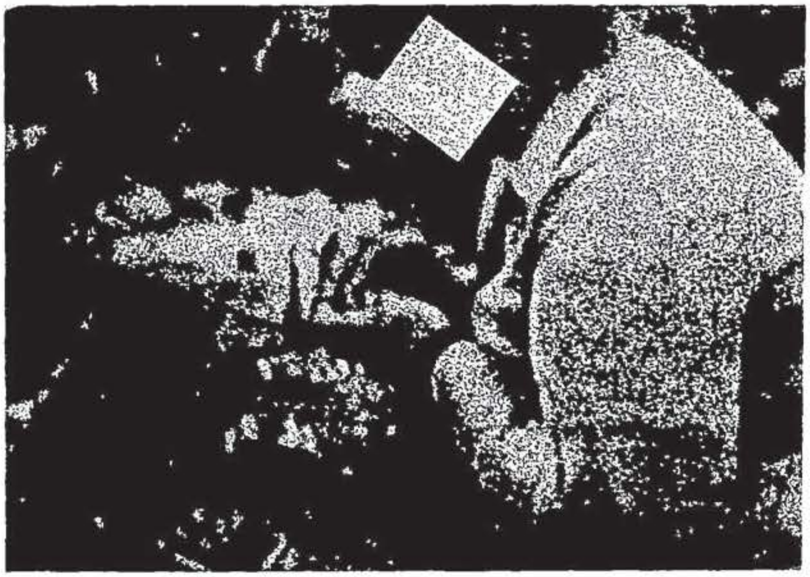

Figure 1A: Operator performing manual "board stuffing." The circuit board is held in the left hand and components are inserted with the right hand.

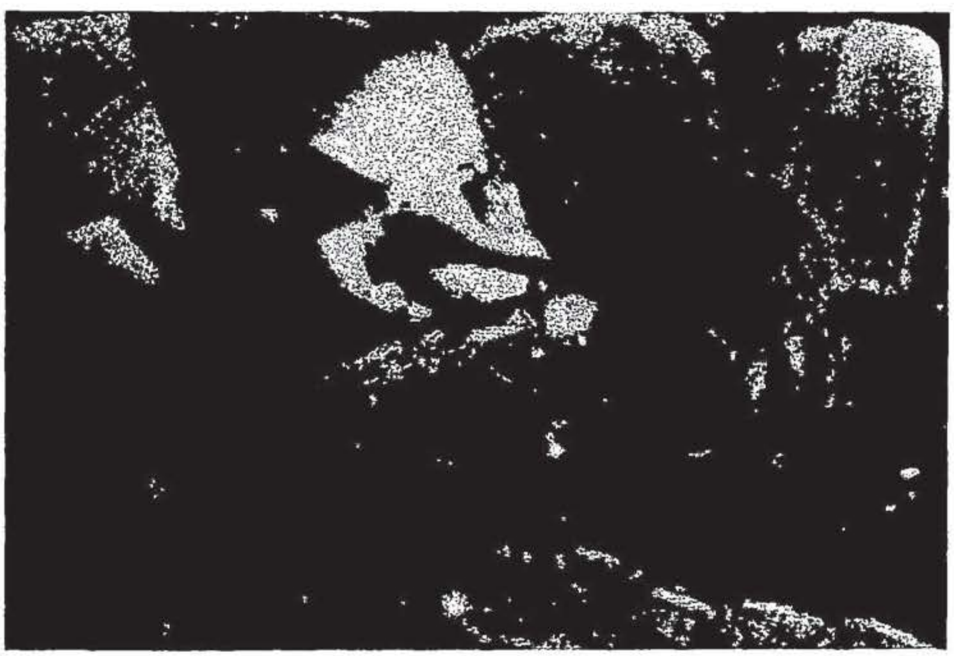

Figure 1B: Building of circuit boards using the Dynacam machine. Two circuit boards are held by a fixture as the operator manually inserts components.

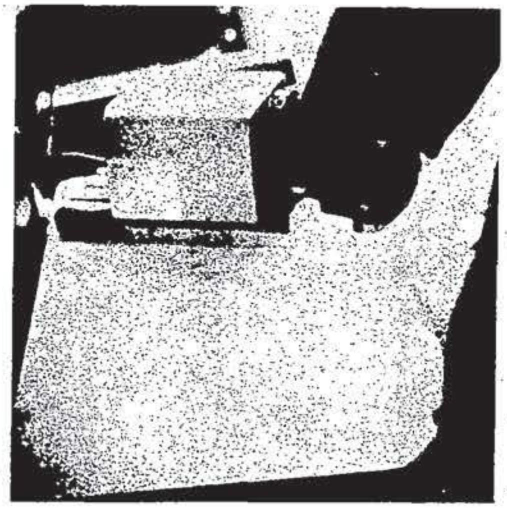

Figure 2: Foot pedal used to activate the lead clipping machanism on the Dynacam machine.

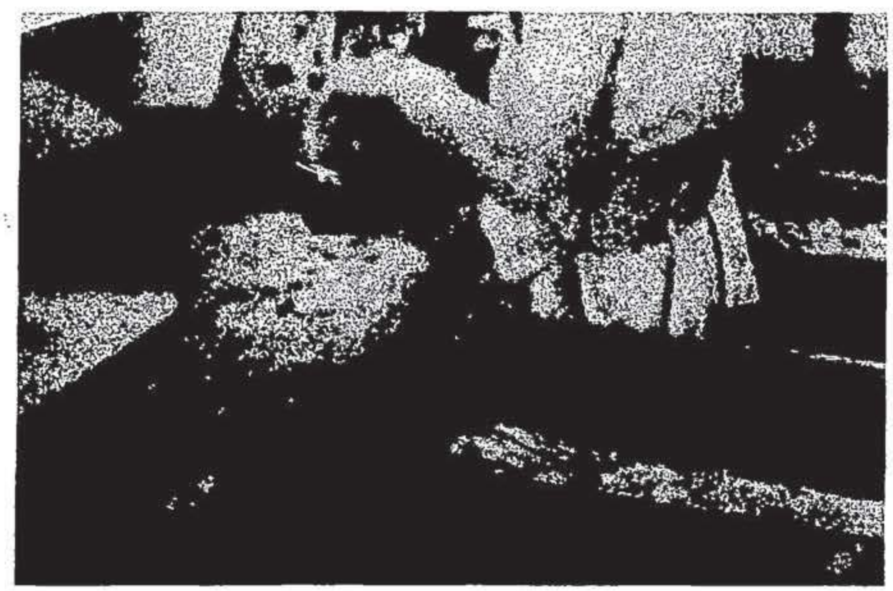

Figure 3: Illustration of wrist flexion required to activate controls on the press job in department 32.

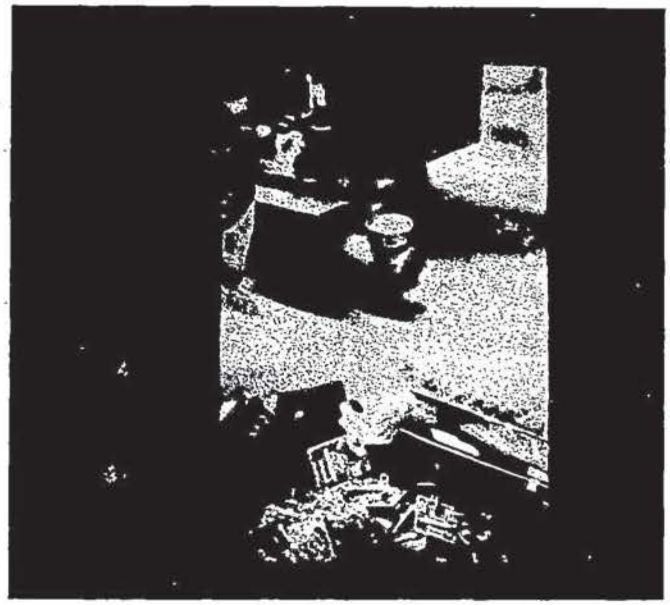

Figure 4: Illustration of wrist flexion required to place finished components into a bin on the department 32 press job. Note the sharp edge of the table top.

Figure 5: Operator inserting the 9 volt battery into a sending unit in department 33.

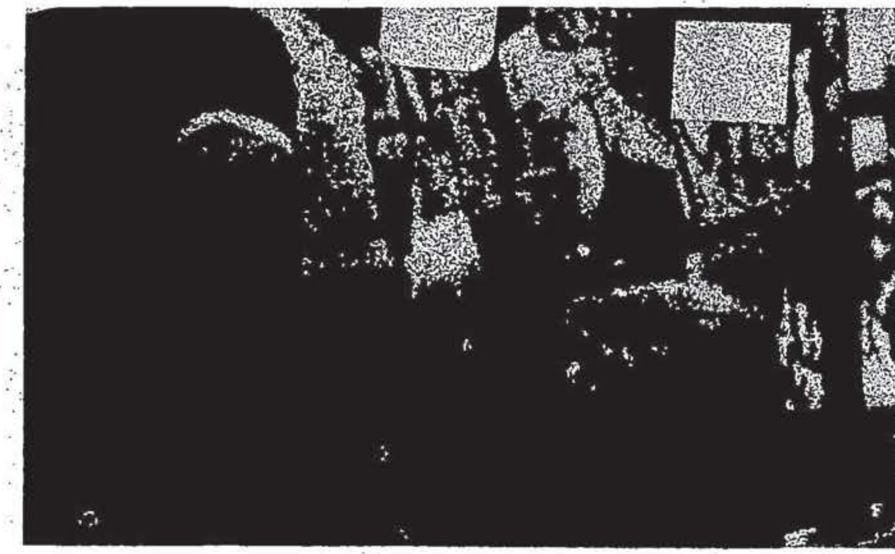

Figure 6: Example of a suspended air-powered screwdriver with a torque limiter in department 34.

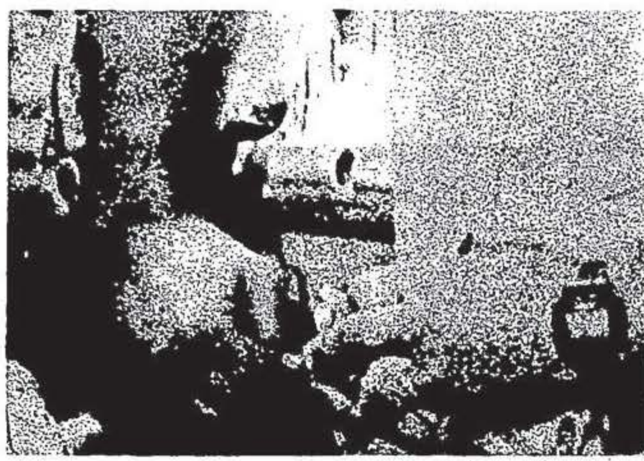

Figure 7: Former method of attaching the rubber weather shield to the rotator housing in department 34. The housing is held by the left hand as the shield is secured with the right hand.

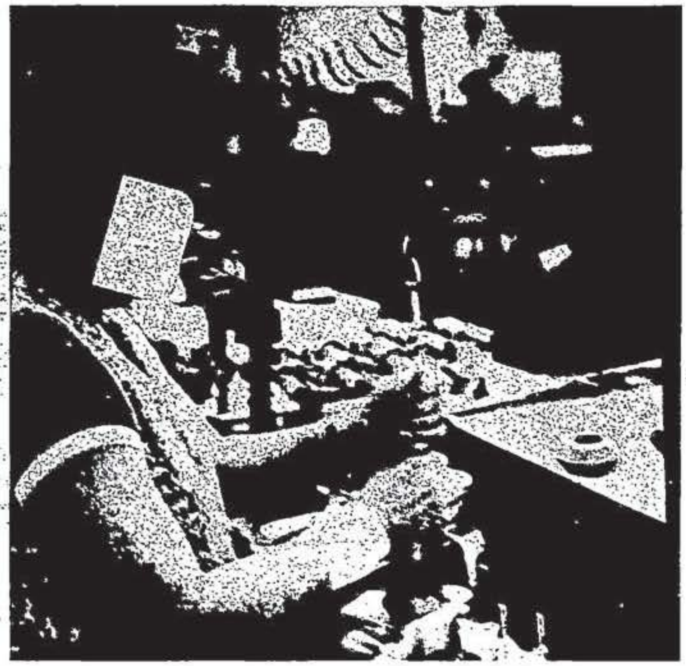

Figure 8: Attaching the weather shield onto the rotator housing with the aid of a suspended crimping device.

Figure 9: Stapling boxes shut on the antenna rotator packaging line in department 34. Note the shoulder abduction required to handle the unsuspended stapler.

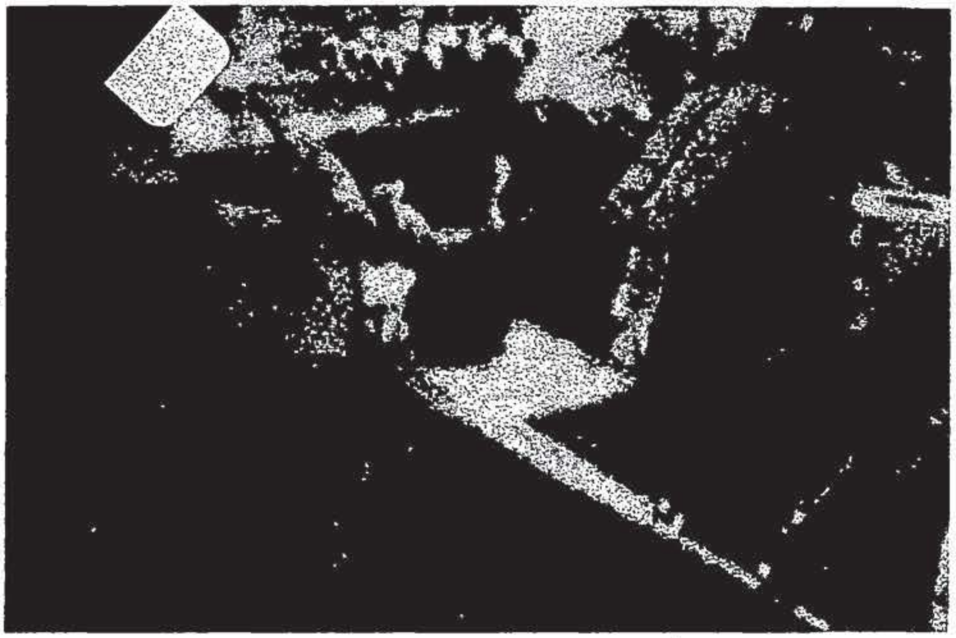

Figure 10: Operator using a hammer and wedge to form the pocket for the thermostat while performing the taping down job in department 35.

Figure 11: Operator holding a stator and reaching for the solder pot in department 35.

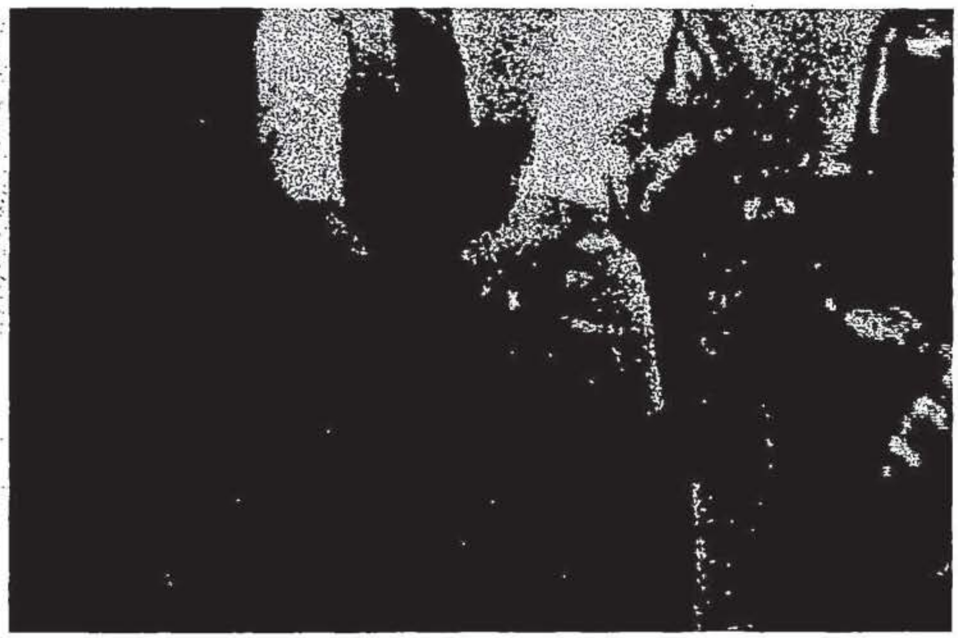

Figure 12: Redesigned mandril in department 35 allowing laminated rings to be easily slid into position.

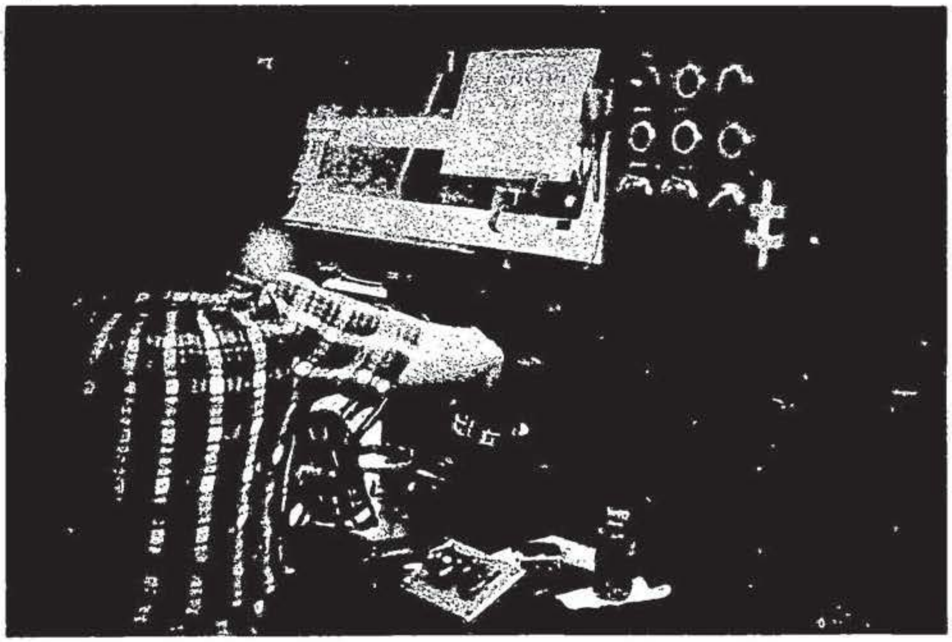

Figure 13: Workers handling the transfer tool used on the (a) automatic stator winding machine and (b) the manual winding machine.