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SEPTEMBER 1990
CALDWELL MANUFACTURING CO.
WILLIAMSPORT, MARYLAND

NIOSH INVESTIGATORS
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I. SUMMARY

In August, 1988, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Caldwell Manufacturing Company to evaluate carpal tunnel syndrome among employees in the assembly department. The Williamsport, Maryland facility manufactures window balance systems. This request was prompted by an August 1988 inspection by the State of Maryland Occupational Safety and Health program. They indicated that the assembly jobs involved ergonomic stressors conducive to the development of carpal tunnel syndrome and recommended that the company request that NIOSH conduct an ergonomic study. In response to this request, NIOSH conducted an ergonomic assessment at the Williamsport facility. The main objective was to evaluate jobs and make recommendations to minimize the risk for carpal tunnel syndrome in this workplace. At the time of our investigation, there were five medically confirmed cases of carpal tunnel syndrome (three treated by surgical intervention) and six additional possible cases - based on duration, type, location, and severity of symptoms - among the 28 assembly workers. In 1988, the OSHA 200 log incidence rate for hand/wrist cumulative trauma disorders was 23.4 per 200,000 hours worked. The incidence rate for all repetitive trauma in the fabricated structural metal product industry, according to the Bureau of Labor Statistics 1988 survey was 14.8 per 200,000 hours worked.

All of the assembly jobs involved risk factors commonly associated with carpal tunnel syndrome: repetitive hand/wrist manipulations, in combination with varying degrees of force and deviated wrist positions. Two tasks were determined to represent the greatest risk: pulling springs to attach them to window liners, and hooking springs onto window liners. In addition, defective material and pressure to increase production were identified as contributing factors.

On the basis of this investigation, NIOSH investigators concluded that a carpal tunnel syndrome hazard existed at the Williamsport, Maryland window manufacturing facility of the Caldwell Manufacturing Co. Recommendations to minimize risk are given in Section VII.

KEYWORDS: SIC 3442 (metal doors, sash, frames, molding and trim), SIC 3089 (plastics, products not elsewhere classified), manufacturing, assembly, window, carpal tunnel syndrome, cumulative trauma disorder, awkward wrist postures, repetition, force.

II. INTRODUCTION

In August, 1988, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Caldwell Manufacturing Company to conduct a health hazard evaluation at their Williamsport, Maryland window manufacturing plant. The request was prompted by an August 1988 inspection by the State of Maryland Occupational Safety and Health (MOSH) program. MOSH indicated that the assembly jobs involved ergonomic stressors conducive to the development of carpal tunnel syndrome among the assembly workers and recommended that Caldwell request that NIOSH conduct an ergonomic study. In response to this request, NIOSH conducted an investigation at the Williamsport facility on October 12-13, 1988. The main objective was to evaluate jobs and make recommendations to minimize the risk for carpal tunnel syndrome in this workplace. Preliminary findings and recommendations were reported to Caldwell Manufacturing Company in a letter dated December 22, 1988.

III. BACKGROUND

Caldwell Manufacturing, which began operations at the Williamsport facility in 1982, employs approximately 65 hourly workers in the manufacture of window balance systems. At the time of our survey five different product lines were being manufactured. These included Rib Tite, Thermoflex, and Trim Tilt 1, 2, and 4. Rib Tite is the longest running product at Caldwell, followed by Trim Tilt 1 and 2, Thermoflex, and Trim Tilt 4. These products are either made from stamped roll-form aluminum or extruded vinyl; both metal fabrication and extrusion operations are performed at this plant.

Approximately 30 employees, all female except for 2 material handlers, work in the assembly department. This department has one or more assembly lines for each product, with approximately three to six workers at each line. All of the assembly jobs involve risk factors commonly associated with cumulative trauma disorders of the upper extremity: numerous hand/wrist manipulations, in combination with varying degrees of force and deviated wrist positions.

IV. METHODS

A. Medical Evaluation

The medical evaluation included review of the OSHA 200 logs, pertinent medical records and confidential interviews with all of the 28 assembly workers.Questions asked of workers during the interviews included name, age, length of employment at Caldwell, previous employment, symptoms experienced since beginning work at this plant, date of onset, location, type, severity and timing (nocturnal, continuous or intermittent), duration of symptoms, medical and surgical treatment, past medical history, hobbies, most difficult job tasks, and suggestions for changes in assembly procedures or tools used.

1. Case definition

A possible case of work-related carpal tunnel syndrome was said to exist if:

a. On interview, the employee reported pain, numbness or tingling affecting the median nerve distribution of the hand(s).

b. Symptoms lasted at least one week or occurred on multiple occasions.

c. Symptoms were severe enough to awaken from sleep.

d. There was evidence of work-relatedness: symptoms began since starting work at a job involving recognized risk factors for carpal tunnel syndrome. These risk factors include repetitive hand movements, force, non-neutral hand positions, and direct pressure over the median nerve.

A medically confirmed case of work-related carpal tunnel syndrome was said to exist if the above criteria were met and the employee had sought medical care and was diagnosed as having carpal tunnel syndrome. Medical records were reviewed to confirm diagnosis.

2. Annual Incidence Rates

Annual incidence rates were calculated by dividing the number of employees with entries on the OSHA 200 log for hand and/or wrist symptoms suggestive of carpal tunnel syndrome by the total number of hours worked by employees in the assembly department for the year. This ratio is then expressed as x cases per 200,000 hours worked. (200,000 hours is the number of hours worked by one hundred full-time workers in one year - 100 workers x 40 hours x 50 weeks.)

B. <u>Ergonomic Evaluation</u>

The goal of the ergonomic evaluation was to identify jobs with known ergonomic risk factors for carpal tunnel syndrome and other cumulative trauma disorders, and to make recommendations to eliminate or reduce risk factors. All jobs in the Assembly department were videotaped and photographed, with the exception of the Trim Tilt 1 & 2 product lines. These two product lines were scheduled to be eliminated due to decreased consumer demand. A total of 12 jobs were included in the evaluation. These jobs are listed in Table 1 by location and specific product being assembled at the time of our videotaping. For each job videotaped, we obtained information concerning number of employees, task elements, number of pieces assembled during the workshift, tool use, description of the work station including measurements of table and/or conveyor heights, difficulties workers percieved in the job, and suggestions to improve different portions of their job.

The job analysis included an assessment of repetitiveness, awkward hand, wrist and shoulder postures, and muscular force requirements. All of the job analysis data were collected based on a review of the videotapes in real time and at slow speeds. Repetitiveness was assessed by measuring two parameters, cycle or subcycle time and number of hand movements per day. Cycle time measures the time to produce one unit and was calculated from the average of at least 10 cycles, with the exception of the Rib Tite packer job which had a long (>2.5 min) cycle time. Cycle time begins with a movement and ends with the same movement on the next item being assembled. Cycle time was used to characterize those jobs where the product was individually assembled, i.e., where assembly task elements were performed in sequential order on one unit then repeated for succeeding units. (For example, a worker performs tasks 1, 2, and 3 on unit A then repeats the assembly procedure on units B, C, etc.) Subcycle time was used to characterize those assembly jobs where the product was assembled in batches. When assembling the product in batches, the worker performed each task element separately on all units in the batch before proceeding to the next batch. (For example, a worker performs task 1 on all of the units, then task 2, 3, etc, until all of the units are completely assembled). Subcycle time provides a better estimate of repetitiveness than cycle time given that many of the manipulations for each task element were similar in terms of ergonomic demands. Subcycle time was calculated by determining the time required to perform a given task element on a per piece basis. Since the time required to perform these tasks varied, a range of subcycle times are provided for the batch-assembly jobs.

The number of hand movements made per day was determined by counting the number of hand/wrist postures which deviated from neutral for each unit assembled and multiplying this value by the number of units assembled by the worker during the shift. The deviated hand/wrist postures which were noted include: flexion, extension, ulnar deviation, radial deviation, and pinching. (Figure 1)

Other postures evaluated involved the arm and the shoulder. Pronation and supination describe the movement of the forearm. Pronation is the counterclockwise rotation of the forearm toward the body. Conversely, supination is the clockwise rotation of the forearm away from the body. Movement from full supination to full pronation or vice versa requires a 180 degree rotation of the forearm and wrist. Supinating or pronating from the neutral position involves a 90 degree rotation. Shoulder postures evaluated included extension, flexion and abduction. Shoulder extension occurs when the arm is moved behind the body; flexion occurs with the arms extended in front of the body. Shoulder abduction occurs when the upper arm is moved laterally away from the body as in when a "chicken wing" posture is assumed. (Figure 2)

Extreme postures were documented for all task elements of the 12 jobs evaluated. Extreme wrist postures were defined as: flexion (>75º), extension (>50º), radial deviation (>10º) and ulnar deviation (>20º). Extreme shoulder postures were defined as: flexion (>90º), extension (>20º) and abduction (>90º). If there were extreme shoulder postures, then pronation and supination of the forearm was also noted.

Muscular force exerted, an important factor in the analysis of biomechanical load on the worker, was evaluated subjectively with the exception of two particularly difficult task elements-sliding tubes into liners in the Thermoflex final assembler job and pulling/hooking springs in the Rib Tite job. Quantitative measurement of the force required to perform these two tasks was made on the window liner samples the company provided us, using a calibrated Chatillon Model DFG 50 digital force gauge. Muscular force requirements of the 12 videotaped assembly jobs were assessed for determination of overall (average) and peak effort levels. Overall effort level was subjectively assessed using a scale of 1 to 5 (1= easiest, 5= most difficult). Factors involved in assigning an overall effort level include the number of forceful manipulations in a cycle, the amount of waiting involved in each cycle, extreme postures, size and type of tool used, size and weight of the product handled. Peak effort level is a subjective measure of the maximum force exerted in a cycle, again using a 1 to 5 scale.

Jobs were rated for ergonomic risk for the purpose of prioritizing interventions to eliminate or reduce risk. The levels of repetitiveness and force were determined using the following criteria:

Level of Repetitiveness

Low: less than 10,000 movements per day
Medium: 10,000 to 20,000 movements per day
High: more than 20,000 movements per day

Level of Force

Low: 1-2
Medium: 3
High: 4-5

The number of movements per day is presented as a range in Table 1. This is because the number of movements per piece was multiplied by the actual number of pieces assembled during the observed workshift and also by the calculated number of pieces that would be assembled during a workshift if the assembly tasks were done for a complete workshift at the observed speed. The discrepancy in the two numbers occurs because the first method may underestimate the number of repetitions per day, since it may not fully describe all the movements the worker makes in a day. This can occur if a worker finishes one job and then does another job in the same day or if not all of the movements required are included in the job analysis. The second method may overestimate the number of movements performed in a day if the observed speed is faster than usual or if work is interrupted (product flow interruptions, set up time, etc.) To determine the level of repetitiveness, the average of the two numbers was used.

Jobs were then scored for overall ergonomic risk by assigning values to their repetitiveness and force categories (1 for low, 2 for medium, and 3 for high), and adding repetitiveness and force scores for an overall risk score for each job. For example, snapping shuttlecocks during tube assembly required 19,000 movements per day (medium repetitiveness = 2), and average and peak force of 1-2 (medium force = 2). Therefore, the overall score for ergonomic risk would be 4, meaning a medium level of overall ergonomic risk.

Overall Level of Ergonomic Risk

Low: overall score of 2
Medium: overall score of 3-4
High: overall score of 5-6

V. RESULTS

A. Medical

OSHA 200 logs were available for 1986 through 1988. In 1986, there were no hand or wrist disorder entries on the log. In 1987, there were 2 entries for hand and wrist pain, and a total of 78,000 hours worked by employees in the assembly department, resulting in an incidence rate of 5.1/200,000 hours. Neither of these disorders resulted in lost work days in 1987, although one was subsequently diagnosed as CTS in January, 1988, and underwent surgery in April, 1988. In 1988, there were 9 entries for carpal tunnel syndrome or hand/wrist pain, and a total of 77,000 hours worked in the assembly department, resulting in an incidence rate of 23.4/200,000 hours. One of the 1988 entries had also appeared on the 1987 OSHA 200 log, but in 1988 there were 42 lost work days and 11 restricted work days recorded for this employee. The remaining 8 entries had not previously appeared on an OSHA 200 log. Five of the 9 entries in 1988 resulted in lost work days, ranging from 4 days to 45 days lost, for a total of 112 lost work days (and 11 restricted work days) from hand/wrist disorders in 1988.

All of the 28 current assembly workers were interviewed on October 12-13, 1988. All were female, ranging in age from twenty-three to forty-six. Duration of work at Caldwell, Inc. ranged from three months to six years.

Of these 28 workers, there were five medically confirmed cases of carpal tunnel syndrome (three had been treated by surgical intervention at the time of the investigation) and five other possible carpal tunnel syndrome cases.

Other health effects reported included numbness in the ulnar nerve distribution (3), ganglionic cysts (1 employee had 2 ganglionic cysts removed, and one was noted during the interview with another employee), tendinitis (diagnosed in 3 employees), elbow pain (1), neck pain (1), and shoulder pain (1).

B. Ergonomic Evaluation

The results from job analyses are presented in Table 1. Based on repetitiveness and force (see section IV), the jobs representing the highest ergonomic risk are pulling and hooking springs on the Rib Tite assembly line, and the final assembly on the Thermoflex line. These jobs were rated high in both repetition and force. Three other jobs fell into the category of high overall ergonomic risk because of either high repetition and medium force (building liners on Thermoflex, and loading the table/assembly on Trim Tilt 4), or medium repetition and high force (pulling and hooking springs on right hand liners on Rib Tite). Packing boxes on Rib Tite was rated as medium repetition and medium force. Several jobs were rated as high repetition and low force (snapping shuttlecocks and pressing top clips on tube assembly, and loading the table and inserting speedlocks and shuttlecocks on Rib Tite). The two remaining jobs were rated as medium repetition and low force (attaching the top clip at station #3 on tube assembly, and wrapping on Trim Tilt 4.(Table 2)Awkward postures were required by every job observed in the assembly department. Wrist extension, ulnar deviation, shoulder flexion, extension, and abduction, pinching, and extreme reaching are noted by job in Table 1. Awkward postures result in a biomechanical disadvantage and increased force to accomplish a task. Wrist flexion and extension can cause increased friction of the tendons of the wrist against the carpal bones or the tough ligament that line the carpal tunnel, resulting in inflammation.[1] A research study demonstrated increased pressures within the carpal tunnel as a result of wrist flexion and extension[2]

It was also noted that some of the material being assembled was defective (some liners were bowed and some holes were incompletely punched out, for example). Working with defective materials requires increased force and multiple attempts to assemble parts, resulting in increased repetition and force, while slowing the assembly of the products. Pressure to increase production compounds these problems.

VII. RECOMMENDATIONS

Recommendations are presented below by specific product line.

Tube Assembly

The assembler at station #1 has to turn completely around and bend over to obtain springs from boxes on a pallet. A better method of providing the worker with parts would be to position the pallet of material to the side of the worker and use a load leveler so that the boxes of springs can be raised, as needed, to a comfortable working height. Bending was also observed while the worker obtained tubes. Use of a load leveler and tilting of the tube box toward the worker would make this aspect of the job easier to perform.

As the worker at station #1 would complete her work she would pile the partially assembled tubes on top of one another until they were unmanageable to move or contain. We believe a better method of providing the worker at station #2 with tubes once they are completed by the worker at station #1 should be investigated. If the worker could place finished parts into a bin which fed worker #2 by gravity, the pile up situation could be eliminated. Care would have to be taken to make sure that worker #1 did not have to reach too high (no more than elbow height) to fill this bin.There should be a gravity feed bin at station #2 for parts retrieved with the left hand to eliminate the pile of parts on the table. This would reduce the amount of pinching needed to pick up the small parts. Also, this worker pushes finished parts to her right and behind her. A slide or roll conveyor should be introduced to deliver the parts to the next position with worker #2 pushing them to her right.

The worker at station #3 needs a better way to dispense with finished parts. She grabs a handful of them a places them in a barrel on her right. The barrel is tilted toward her, but she has to get up from her seat and twist to reach the barrel. A hole in the work table with a barrel under it would allow her to just push the parts aside when she is finished with them. A gravity feed bin for getting incoming parts (which is done with the left hand) would make it easier.

Seated workers at stations 2 and 3 positioned their forearms against the edge of the table to complete their work. Plans to contour and/or pad the table edge were underway at the time of the evaluation. This modification should eliminate any direct pressure on the forearms.

Workers at station #3 indicated that sometimes they have to force the top clip onto the tube if tube holes are improperly aligned or if the tube is too thick. This problem can be solved by insuring that the tubes meet quality control specifications before they are accepted by the assembly department.Workers indicated that the beige 'shuttlecocks' are more difficult to snap on the springs than those previously used (white), since they were made of different plastics. Caldwell's plan to switch back to the white shuttlecocks when the beige supply is exhausted should resolve this issue.

Thermoflex

Holes for speed locks and dust plugs are too small in some of the liners to enable workers to easily insert these items into the liners, necessitating the use of a screwdriver. Apart from slowing down the assembly operation, use of this tool also introduces additional stressors to the job (increased force requirements, wrist flexion, pressure on palm). Better quality control and/or design modification of extruded liners or the parts are needed to eliminate this problem.

Several employees mentioned that it was more difficult to slide tubes onto Thermoflex #3 liners as compared to Thermoflex #1 liners, which were videotaped by NIOSH investigators. Reportedly, more force was needed to push the tube, especially on the speed lock side of the liner, because there is less clearance as compared to the #1 product. It is recommended that Caldwell explore ways to modify the liner, tube, and/or speed lock to minimize force requirements needed to accomplish this task.Some of the liners which were bowed tended to slide above the angle iron guide when workers pushed the tubes onto the liners. Also, working with these defective bowed liners requires more force for workers to insert the tubes. Improving the quality of the liners such that only straight liners are used would eliminate this problem. Increasing the height of the guide is also recommended.

Workers were observed bending and reaching into barrels to retrieve parts. Barrels with false bottoms should be used, especially for smaller parts. Also, a roll conveyor could be used to transport the assembled liners directly to the boxing area.

<u>Rib Tite</u>

Pulling and hooking springs is probably the most demanding job in the assembly department. Considerable force and dexterity are required, especially for the larger springs. For the 'right hand' liner, even greater force and dexterity are required since the spring loop has to be split. Caldwell's plans to partially automate this job with a device that pulls the spring should greatly reduce the force requirements of this job.Bending and reaching tasks associated with the 'loading table' job could be reduced through use of a load leveler and tilting of boxes containing component parts toward the worker.

The job of attaching speed locks and shuttle cocks to the liners was too demanding for the new hire assigned to this job since she could not keep up with the pace set by the experienced workers. As a result, the experienced workers assisted the new employee, thus adding more work to their job. We believe that new employees should be given an adequate 'break-in' period to give them a chance to build up to the speed attained by the experienced workers. Apart from this observation, we also observed that attaching of the speed locks exerted point pressure on the index finger and thumb, especially when the holes for the speed locks are too small. This problem is similar to that observed in the Thermoflex assembly line, and our recommendations regarding better quality control and/or design modifications of assembled components would apply here as well.

At the time of our survey we noted three aspects of the packing job which required the worker to use considerable force and/or awkward wrist postures. First, we observed that packing of liners into boxes was difficult especially when the last 5 liners were placed into the bottom of the box. Cardboard separators, placed in the box when they are first assembled, reduces the clearance and makes packing of the liners a tight fit. There is no reason that the separators should be in the box when liners are packed. Rather, they should be stored in a location easily accessible to the packers (i.e, on shelves suspended above the conveyor). Second, the staple gun was too heavy and awkward for its intended use. Counterbalancing or replacement with a lighter gun would reduce the force requirements associated with the use of this tool. Lastly, the packer should avoid lifting/stacking boxes on top of one another while they are on the conveyor line. There is no reason the boxes cannot proceed down the line in single fashion.

<u>Trim Tilt 4</u>

This assembly line had some of the same problems as identified for the Thermoflex line regarding accessibility of parts to the worker, quality control of the liners, and sliding of liners above the table guide. Our preliminary recommendations addressing each of these problem areas in Thermoflex apply here as well. As for the quality of the liners, Caldwell indicated that this problem has been corrected such that workers would no longer need to use a circular file to enlarge the countersunk screw holes. Since the job of loading the table and assembling the liners requires the use of two hand tools which both result in direct pressure on the hand, Caldwell should investigate breaking this job into two so that the same worker would not have to use both hand tools.

At the time of this survey Caldwell staff had developed two hand tools for use by assemblers on this line. The slider tool is a good alternative to manual sliding of springs up the liner. Although this tool represents a big improvement in the way this task is performed, following our visit, we recommended further modifications. Specifically, the handle should be lengthened, to reduce reaching, and angled so that the worker can maintain the wrist in a neutral position. Caldwell indicated that these modifications have been made since our visit.

A fastener tool was created to facilitate hooking springs onto the liner, to eliminate the use of a hand hook, which required force and awkward wrist rotation. This tool seems to be an improvement for some of the liners, but has the following disadvantages: the handle is too short and could exert pressure on the palm in the area where nerves pass through the hand. Also, for the small springs with loops that are difficult to separate, several attempts are necessary to attach the loop to the liner. Several attempts are also necessary to hook springs onto defective liners (notched out, bowed, or used liners). Following our visit, we suggested attaching a padded hilt for the hand to push against, increasing the size of the handle (to eliminate pressure on the palm) or using a spherical handle, changing the angle of the handle to eliminate the need to bend the wrist, and possibly modifying the tool bit to facilitate the spring hooking task.

The wrapper job (gluing a strip of foam to the surface of assembled liners and boxing them) presented the following problems: the work area was congested, the worker had to turn completely around to obtain rolls of foam, and the worker had to flex her wrist to access the glue container. Caldwell's proposed plan to automate this operation would eliminate these problems.

General Recommendations

Many of these jobs are too highly repetitive. Any job approaching 20,000 movements per shift should either be slowed down or have workers added to the line. For the jobs requiring only light force, it may be adequate to reduce repetitiveness to about 12- 15,000 movements per day, but only if the other problems resulting in awkward postures are solved. These problems, already stated in the recommendations for each job, include a need for better location of parts, appropriately designed bins to hold parts and a means to dispense with finished parts, improved handles on tools that are used, better quality control of materials to reduce the force and number of attempts required to assemble parts, and to eliminate the need to enlarge holes with a screwdriver or other tool. For jobs with greater force requirements, reducing repetitiveness to less than 10,000 movements per day is recommended.

VIII. REFERENCES

1. Armstrong, Thomas J., "An ergonomics guide to carpal tunnel syndrome", Ergonomics Guides, 1983, American Industrial Hygiene Association.

2. Szabo, Robert M., and Chidgey, Larry K., "Stress carpal tunnel pressures in patients with carpal tunnel syndrome and normal patients", Journal of Hand Surgery, volume 14A, number 4, July 1989.

IX. AUTHORSHIP AND ACKNOWLEDGEMENTS

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X. DISTRIBUTION AND AVAILABILITY

Copies of this report are temporarily available upon request from NIOSH, Hazard Evaluations and Technical Assistance Branch, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through: the National Technical Information Service (NTIS), 5285 Port Royal, Springfield, Virginia 22161. Copies of this report have been sent to:

l. Caldwell Manufacturing Co.
2. Maryland Occupational Safety and Health

For the purpose of informing affected employees, the report should be posted by Caldwell Manufacturing Company in prominent places that are accessible to employees, for a period of 30 calendar days.

TABLE 1
JOB ANALYSIS RESULTS FOR THE ASSEMBLY DEPARTMENT
CALDWELL MANUFACTURING
WILLIAMSPORT, MARYLAND
HETA 88-361
OCTOBER 12-13, 1988

JOB NAME	Assembly Line	Product Being Assembled[1]	Cycle (C) Or Subcycle(s) Time(SEC)	Manipulations Per Day[2]	Awkward Postures	Force Avg/Peak	Comments
Snap Shuttlecock	Tube Assembly	Thermoflex 375-30 (batch assembled)	1.5-2[S]	19,100-27,300	Wrist Extension, Shoulder Flexion pinching	1/2	
Press Top Clip	Tube Assembly	Thermoflex 375-30 (indiv. assembled)	3.5[C]	16,600-29,200	Shoulder Extension pinching	1/2 1/2	
Press/Twist Top Clip	Tube Assembly	Thermoflex 375-30 (indiv. assembled)	5.5[C]	12,550-14,300	Pinching	1/2	
Build Liners	Thermoflex	Thermoflex 375-28 (batch assembled)	1-3.5[S]	22,500-32,700	Shoulder Flexion, Pinching, Extreme Reaching, forearm pronation	2/3	Point Pressure applied to fingertips, tools used
Final Assembler	Thermoflex	Thermoflex 375-28 (batch assembled)	1-7.5[S]	17,700-29,900	Wrist Ulnar Deviation with extension, pinching	2/4	Point Pressure applied to fingertips
Load Table	Rib Tite	Rib Tite 3'2" left (batch assem)	1-3[S]	16,100-24,300	Extreme Reaching, Neutral Wrist Shoulder Flexion	1/2	
Insert Speed Lock/ Shuttlecock	Rib Tite	Rib Tite 3'2" (left) (batch assembled)	3-3.5[S]	29,200-29,500	Wrist Ulnar Deviation	1/2	Point Pressure applied to fingertips

TABLE 1 CONTINUED
JOB ANALYSIS RESULTS FOR THE ASSEMBLY DEPARTMENT
CALDWELL MANUFACTURING
WILLIAMSPORT, MARYLAND
HETA 88-361
OCTOBER 12-13, 1988

JOB NAME	Assembly Line	Product Being Assembled[1]	Cycle (C) Or Subcycle(s) Time(SEC)	Manipulations Per Day[2]	Awkward Postures	Force Avg/Peak	Comments
Pull/Hook Springs (10")	Rib Tite	Rib Tite 3'2" (left) (indiv. assembled)	6^{C}	21,100-27,400	Wrist Ulnar Deviation Pinching Shoulder Flexion	2/4	Point Pressure applied to fingertips
Pull/Hook Springs (10")	Rib Tite	Rib Tite 3'2" (right) (indiv. assembled)	9^{C}	14,800-17,600	Wrist Ulnar Deviation	3/4	Point Pressure applied to fingertips
Pack Boxes	Rib Tite	Rib Tite 3'2" (l+r) (indiv. assembled)	165^{C}	11,100-13,600	Wrist Extension and ulnar Deviation, extreme reaching, pinching, shoulder abduction	2/3	
Load Table/Assemblers	Trim Tilt 4	Trim Tilt 4 4'll" (batch assembled)	$l\text{-}7.5^{S}$	20,700-22,100	Wrist Ulnar Dev., Pinching	2/3	Point Pressure Applied to fingertips, tools used
Wrapper	Trim Tilt 4	Trim Tilt 4 4'll" (indiv. assembled)	$3l^{C}$	13,700-16,400	Wrist Ulnar Dev., Shoulder Abduction	1/2	

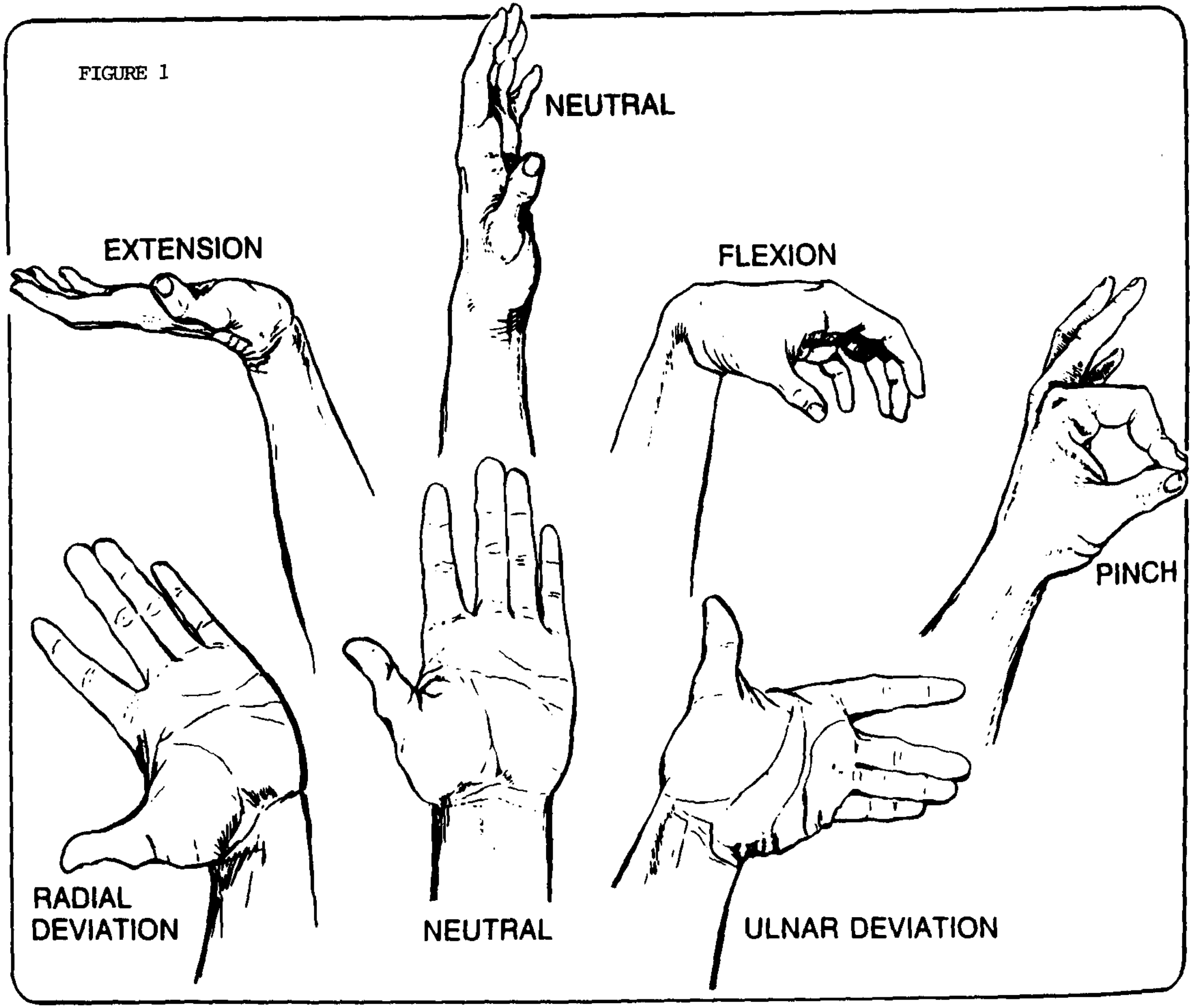
l - repetitiveness for individually assembled 'product' was defined by cycle time; for batch assembled product repetitiveness was defined by subcycle time.

2 - a range is provided since this parameter was measured by 2 methods: (a) movements per piece times the actual number of pieces assembled per shift and, (b) movements per piece times the number of pieces assembled per shift according to the videotape analysis.

TABLE 2
OVERALL ERGONOMIC RISK SCORES FOR JOBS
CALDWELL MANUFACTURING
WILLIAMSPORT, MARYLAND
HETA 88-361

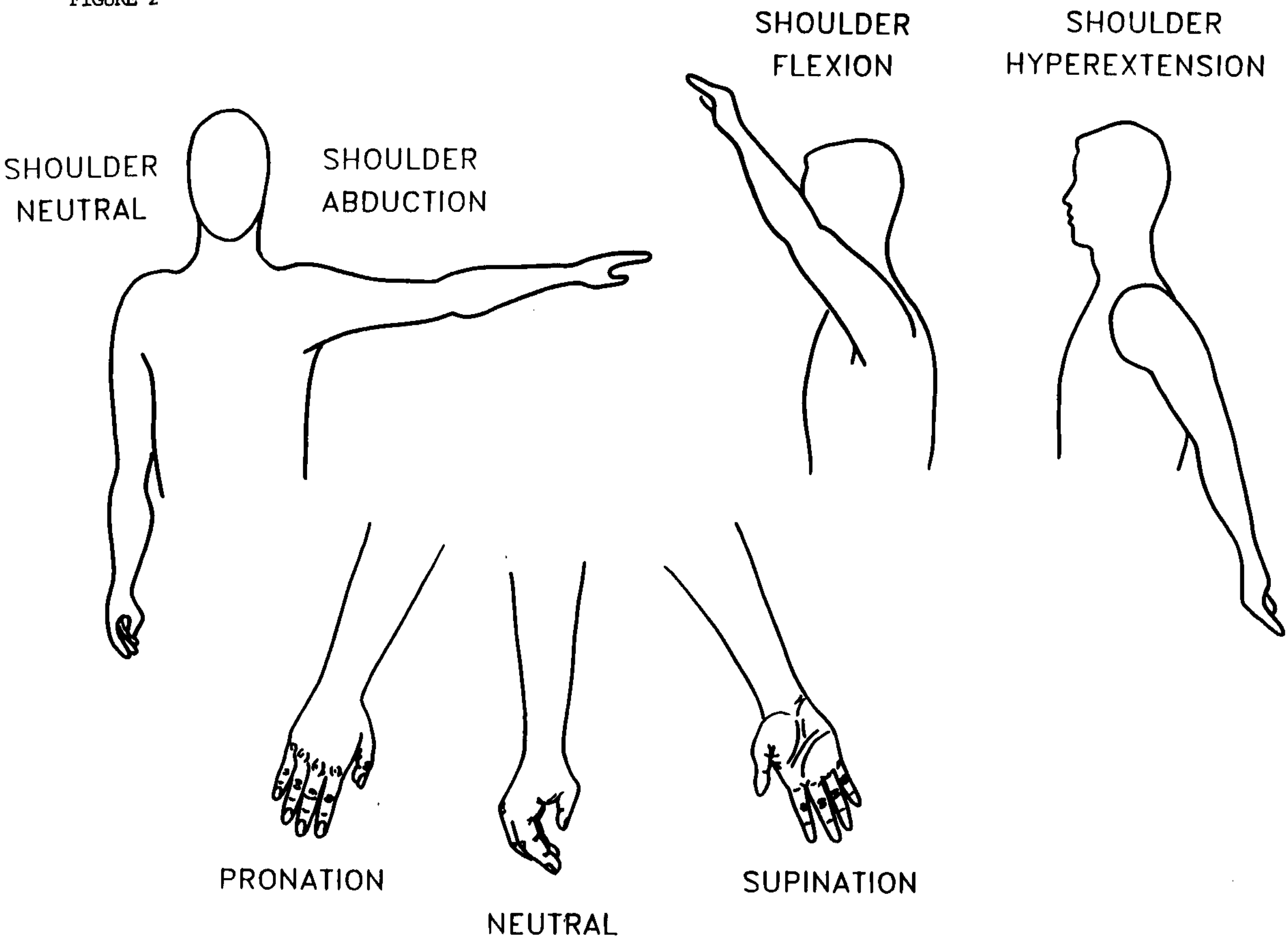
Job Title	Repetitiveness	Force	Overall Score
Snap Shuttlecocks (tube assembly)	3 (High)	1 (Low)	4 (Medium)
Press Top Clip (Medium) (tube assembly)	3 (High)	1 (Low)	4 (Medium)
Attach Top Clip (Medium) (tube assembly)	2 (Medium)	1 (Low)	3 (Medium)
Build Liners (Thermoflex)	3 (High)	2 (Medium)	5 (High)
Final Assembly (Thermoflex)	3 (High)	3 (High)	6 (High)
Load Table (Medium) (Rib Tite)	3 (High)	1 (Low)	4 (Medium)
Insert Speedlock/ (Medium) shuttlecock (Rib Tite)	3 (High)	1 (Low)	4 (Medium)
Pull/Hook Left Springs (Rib Tite)	3 (High)	3 (High)	6 (High)
Pull/Hook Right Springs (Rib Tite)	2 (Medium)	3 (High)	5 (High)
Pack Boxes (Medium) (Rib Tite)	2 (Medium)	2 (Medium)	4 (Medium)
Load Table/Assemble (Trim Tilt 4)	3 (High)	2 (Medium)	5 (High)
Wrap (Medium) (Trim Tilt 4)	2 (Medium)	1 (Low)	3 (Medium)

FIGURE 1



From Putz-Anderson, Vern, Cumulative Trauma Disorders, Taylor & Francis, 1988

FIGURE 2


SHOULDER
FLEXION
SHOULDER
HYPEREXTENSION
SHOULDER
NEUTRAL
SHOULDER
ABDUCTION
PRONATION
NEUTRAL
SUPINATION