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(1)(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.

Mention of company names or products does not constitute endorsement by the National Institute for Occupational Safety and Health.

HETA 94-0040-2496
March 1995
AE Goetze
Lake City, Minnesota

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I. SUMMARY

On April 28-29, 1994, researchers from the National Institute for Occupational Safety and Health (NIOSH) conducted an evaluation of musculoskeletal disorders of the upper limbs and back at a piston and piston sleeve manufacturing company. The three objectives of this evaluation, requested by company management and labor, were to 1) identify which jobs posed the greatest risk for musculoskeletal disorders and disease; 2) conduct an ergonomic evaluation of jobs in three different departments which showed a history of musculoskeletal disorders; and 3) provide guidelines for establishing an ergonomics program to reduce musculoskeletal disorders for this company.

NIOSH researchers reviewed Occupational Safety and Health Administration (OSHA) 200 logs from 1992 through April 1994. The OSHA 200 logs showed that from 1992 to 1994 an average of 18 percent per year of the piston sleeve machinists, 8 percent of the piston machinists, and 9 percent of the aluminum foundry molders had musculoskeletal disorders. A symptom survey and ergonomic evaluation were targeted for these jobs.

A questionnaire was administered to the workers to assess their perceived physical workload and musculoskeletal discomfort associated with the job. The Borg scale was used to assess the perceived physical workload, and the Corlett-Bishop body parts map diagram was used to determine the location and severity of symptoms. The piston sleeve machinists reported their work as "hard," piston machinists "somewhat hard" and the aluminum foundry molders reported their work as "fairly light." The results of the workers' report of musculoskeletal pain showed that the back and hand/arm were the most commonly reported body locations for all three departments.

Job analysis of the piston sleeve machinists, piston machinists, and aluminum foundry molders showed potential risk for musculoskeletal injury. The piston sleeve machinists and piston machinists were at risk for back injury due to a combination of repetitive and sometimes awkward postures required to manually handle their product during machining. The piston sleeve machinists were at greater risk for back injury than the piston machinists because they handled larger parts, which weighed more. The aluminum foundry molders were at risk for back injuries and hand and wrist disease due to a combination of awkward posture and static loading while pouring molten aluminum into molds. Lifting devices, gravity feed racks, and adjustable height and positioning palletizers should reduce the risk of back injuries among piston sleeve machinists and piston machinists. Improved work

practices and a support device to hold the ladle during pouring of aluminum should reduce the risk of injury to the molders.

On the basis of the information collected during this period, NIOSH researchers determined that potential for overexertion injuries to the back exists among piston sleeve machinists and piston machinists. Highly repetitive work cycles and extended reaches during manual material handling of parts are the primary risk factors for these jobs. The potential for hand and wrist injuries (i.e., cumulative trauma disorders), also exists in the aluminum foundry molders department. Prolonged static postures during pouring of aluminum into molds are the primary risk factors. Recommendations to reduce risk for musculoskeletal injury and disease in problem jobs, along with guidelines for establishing an ergonomics program, are in Sections VI and VII of this report.

Keywords: SIC 3592 (Piston Sleeve, and Piston Manufacturing) Musculoskeletal Disorders, Manual Materials Handling, Cumulative Trauma Disorders, Metal Milling, Pistons, Ergonomics, Workstation Design, Engineering Controls.

II. INTRODUCTION

On October 29, 1993, NIOSH researchers received a Health Hazard Evaluation and Technical Assistance request from AE Goetze, a piston sleeve and piston manufacturing facility located in Lake City, Minnesota. The request was for an ergonomic assessment of piston sleeve machinists, piston machinists, and aluminum foundry molders. In addition, the company wanted information on setting up an ergonomics control program to reduce and prevent musculoskeletal disorders among its workers.

This facility has approximately 275,000 square feet of manufacturing space. The plant has 506 employees and two work shifts. It manufacturers approximately 10,000 to 15,000 pieces per month. The average age of the workforce is 38 years; 90 percent of the employees are male. This plant has a grey iron foundry, aluminum foundry, piston sleeve machine shop, piston machine shop, and maintenance shop.

III. PROCESS DESCRIPTION

The NIOSH evaluation focused on piston sleeve machine shop workers, piston machine shop workers, and aluminum foundry molders. Detailed descriptions of the work activities for these jobs are presented in Section V of this report.

A. *Piston Sleeve Machining*

There are approximately 83 employees in the piston sleeve machine shop. Piston sleeve machining requires 17 steps to complete. The major steps consist of manually getting rough forged piston sleeves weighing approximately 28 lb from a wire basket. The piston sleeve is then milled on three different lathes (preparation, penturn, and finish turn). After milling on the finish turn lathe, the piston sleeve is put in a Barnes drill, which bores and polishes the inside of the piston sleeve. Following this, the piston sleeve is manually checked for calibration, then stamped and put in a finish wire basket. It takes approximately 188 seconds to complete the work cycle. Of the 17 steps to complete the work cycle, the piston sleeve is manually handled 14 times. At this work pace, approximately 134 piston sleeves can be milled per 8-hour day. The basic elements to perform this job are shown in Table 1.

B. *Piston Machining*

There are approximately 155 employees in the piston machine shop. The heavy duty line #3, first operations piston machining job, was evaluated by NIOSH researchers.

This job consists of ten steps to complete. The major steps consist of manually getting rough forged pistons weighing approximately 11.5 lb from a wire basket. The piston is milled on three different lathes (skirter, roughing, and finishing). After milling, the piston is placed in the finish wire basket. The milling process from start to finish takes approximately 46 seconds per piston. The piston is manually handled for each step from the beginning to the end of the work cycle. The finished weight of the piston is 9.3 lb. At this work pace, approximately 548 pistons can be milled per 8-hour day. The basic elements to perform this job are shown in Table 2.

C. *Aluminum Foundry*

There are approximately 45 employees in the aluminum foundry. The permanent mold process tasks for casting aluminum alloy pistons were analyzed by NIOSH researchers. The principle elements of this job are 1) use of a metal ladle to scoop approximately 2 lbs of molten aluminum from a tub, 2) carefully pouring the aluminum into the piston mold machine, 3) removing the molded part from the machine when cool, and 4) placing the part on an 6 foot inclined conveyor which transported the piston to a receiving basket. The mold operator used two mold machines per workstation. At this work pace, approximately 163 aluminum pistons can be made per 8-hour day. The worker evaluated said that he makes approximately 126 pistons per day. The basic elements to perform this job are shown in Table 3.

IV. DESIGN AND METHODS

NIOSH researchers conducted an evaluation on April 28-29, 1994. The evaluation consisted of a review of Occupational Safety and Health Administration (OSHA) 200 logs, administration of standardized symptom questionnaire to a sample of workers in the three areas evaluated, and a detailed ergonomic evaluation of three jobs. These jobs were 1) piston sleeve machining, 2) piston machining, and 3) aluminum foundry molders. These jobs were selected for evaluation based on conversations with management and labor about the jobs having a history of high rate musculoskeletal disorders, and confirmation of these rates as reported in the 200 logs.

A. *Epidemiologic Assessment*

A medical officer interviewed 21 randomly selected piston sleeve machinists, 21 randomly selected piston machinists, and all six aluminum foundry molders, all from the first shift. The interview was performed on the shop floor using a standardized questionnaire (see Appendix A). From the questionnaire, information was gathered about age, gender, job function, and symptoms possibly related to musculoskeletal disorders.

1. Assessment of Perceived Physical Workload

The Borg scale was used to assess the perceived physical workload of the selectors' job. This scale consists of a numerical list, anchored by adjectives describing increasing levels of physical effort. The Borg scale was initially developed through laboratory experiments using exercise bicycles and has subsequently been used at the worksite to assess the perceived physical effort of persons performing manual tasks. Studies have shown a good correlation between perceived workload and objective measures of physiologic workload such as heart rate.[1,2]

2. Assessment of Reported Discomfort

Several investigations have used questionnaires to determine the prevalence of musculoskeletal disorders among working populations. A particularly descriptive method for determining the location and severity of complaints is the Corlett-Bishop (1976) body parts map diagram. A number of studies have documented the relationships between complaints of discomfort and inadequate ergonomic work conditions. These questionnaires are useful in identifying which parts of the body are under the greatest stress.[3,4]

B. *Ergonomic Evaluation*

Videotapes of representative workers performing the piston, piston sleeve, and aluminum foundry molder jobs were analyzed at regular speed to determine job cycle time, slow-motion to determine musculoskeletal hazards to the upper limbs during manual material handling tasks, and stop-action to sequence job steps and perform biomechanical evaluations of working postures. All of these video analysis procedures were used to document potential musculoskeletal hazards in performing the job.

Time and motion study techniques were used for the first phase of job analysis.[5] *Work methods analysis* was used to determine the work content of the job. The second phase of job analysis was to review the job for recognized occupational risk factors for Work-Related Musculoskeletal Disorders (WRMDs). These WRMDs risk factors include repetition, force, posture, contact stress, low temperature, and vibration.[6] In addition, biomechanical evaluation of forces which are exerted on the back while performing the task also was performed (see Appendix B for evaluation criteria).[7] This two-phase approach for job analysis and quantification of forces which act upon the body during materials handling forms the basis for proposed engineering and administrative control procedures aimed at reducing the risk for musculoskeletal stress and injury.

V. BACKGROUND

A. *Epidemiologic Studies*

Several case reports have cited certain occupational risk factors which give rise to musculoskeletal disorders.[8,9,10,11] In addition, epidemiologic studies (cross-sectional and case-control retrospective studies) have examined the association between job risk factors (such as repetition, awkward postures, and force) and excess musculoskeletal morbidity.[12,13,14,15,16,17] While more studies are needed to quantify the relationship between job risk factors and musculoskeletal disease outcome, there is enough information to show there is a relationship between the two. Prudent action by company and labor officials to reduce risk factor exposure should result, in time, in a reduction in occupationally-related musculoskeletal disorders.

B. *Upper Limbs*

WRMDs of the upper limbs have been associated with job tasks that include: (1) repetitive movements of the upper limbs, (2) forceful grasping or pinching of tools or other objects by the hands, (3) awkward positions of the hand, wrist, forearm, elbow, upper arm, shoulder, neck, and head, (4) direct pressure over the skin and muscle tissue, and (5) use of vibrating hand-held tools. Because repetitive movements are required in many service and industrial occupations, occupational groups at risk for developing WRMDs of the upper limb continue to be identified.

Engineering controls are the preferred method to reduce WRMDs. Examples include selecting the right tool for the job, using power tools instead of non-power tools, and providing jigs and fixtures to hold and orient parts so the job can be done in a comfortable manner. Administrative controls such as work enlargement and rotation can be used as an interim measure.[18]

C. *Low Back Injuries*

Occupational risk factors for low back injuries include manual handling tasks,[19] twisting,[20] bending,[20] falling,[21] reaching,[22] lifting excessive weights,[20,23,24] prolonged sitting,[21] and vibration.[20,25] Some nonoccupational risk factors other than physical stress for low back injury include obesity,[26] genetic factors,[27] and job satisfaction.[28,29] Controlling and preventing job-related low back pain can be accomplished, in part, through the evaluation of jobs and the identification of job risk factors. Redesign of jobs can lead to the reduction of these risk factors and good job design initially will prevent back injuries. Multiple approaches such as job redesign, worker placement, and training may be the best methods for controlling back injuries and pain.[30]

D. *Ergonomic Control Programs*

There are seven basic elements needed to establish an ergonomics program:[31]

- Management commitment,
- Labor involvement,
- Training and education of management and labor on the principles of ergonomics,
- Risk assessment of jobs through job analysis,
- Medical surveillance to identify problem jobs,
- Intervention or prevention applications to reduce or eliminate musculoskeletal disorders, and
- Follow-up on the effectiveness of the intervention or prevention applications.

In a recently published NIOSH technical report entitled Participatory Ergonomic Interventions in Meatpacking Plant[32] the key findings included:

- *"Sustained participatory efforts in ergonomics problem solving will require strong in-house direction and support plus significant staff expertise in both team building and ergonomics.*
- *Training in both team building and ergonomics can create the in-house knowledge and team activities reflecting an orderly approach to problem solving and lays a strong foundation for a program.*
- *Team size should be kept minimal, but should include production workers engaged in the jobs to be studied, area supervisors, and maintenance and engineering staff who can effect proposed job improvements. Higher level management or labor representatives may also facilitate decision-making, but their presence on teams may intimidate front-line workers and limit their input. These people may best serve on second level groups, providing oversight to the team activities and approvals of actions as may be needed.*
- *Effective team problem solving requires member access to, and sharing of, information bearing on the issues under study. In addition, reports on the team's objectives, progress, and accomplishments need to be circulated to the*

plant workforce to keep all parties informed about the program. Goals for the program need to be realistic and take account of the fact that solutions to some problems may not be immediately forthcoming. Opportunities to address and solve simpler problems can build confidence in newly formed teams and provide positive motivations about undertaking the tasks involved.

! *Means for evaluating team efforts and results need to be written into the overall plan for participatory ergonomic program. Varied techniques exist for measuring aspects of team building and team function, the perceived level of effectiveness, and performance in both subjective and objective terms. Such data will enable the teams to appraise their progress, provide feedback to affected or interested parties, and make suitable corrections where necessary to improve the overall effort."*

These findings were based on reports describing the observations and experiences of three different investigative groups at three different meat packing plants. The findings from these researchers are not exclusive to meat packing plants and can be applied to any plant or industry that requires manually intensive labor.

In addition to the findings of the participatory ergonomic interventions report, it is important to establish an ergonomics program that matches the philosophy, corporate culture, and goals of the company and its labor force. Earlier studies of such programs were begun because the company recognized it had a problem with musculoskeletal disorders and needed to do something about them. Such efforts had limited success. In order to succeed, management needs to commit its time and resources to this problem, and labor needs to be involved by having its workers help solve problem jobs.[33,34,35,36]

VI. RESULTS AND DISCUSSION

A. *Epidemiologic Assessment*

1. OSHA 200 Logs

Review of OSHA 200 logs from 1992 through April 1994 revealed the following percentage of musculoskeletal disorders per year: piston sleeve machinists 18% (15/85), piston machinists 8% (11.5/150), aluminum foundry molders 9% (4/45). None of these departments showed any significant change in rates between the three years. The maintenance workers, inspection workers, and cast iron workers all had incidence rates of less than 7 percent per year.

2. Questionnaire Results (from questionnaire in Appendix A)

The demographic characteristics of the three departments surveyed are shown in Table 4. The workers in the three departments were all male, had an average age of over 30, and greater than ten years of work at this company.

The results of the workers' report of musculoskeletal pain (question 13) are shown in Table 5. In all three work areas, the back and hand/arm were the parts of the musculoskeletal system where workers most commonly reported discomfort.

The average level of physical exertion reported by the workers varied by department (question 12). Piston sleeve machining workers reported their work as "hard," piston machining reported "somewhat hard" and the aluminum foundry workers reported their work as "fairly light."

B. *Ergonomic Evaluation*

1. Piston Sleeve Machining

Table 6 shows the job stresses and recommended changes to decrease these stressors. The major stressors are during the initial lift of the 28 lb piston sleeve from the wire cart and lifting the piston sleeves over the metal barrier which encloses the Barnes drill platform. Like the repetitive handling for milling pistons, as discussed below, the possibility of musculoskeletal fatigue is much higher for the piston sleeves because of the total weight handled per day by this operator. Based on the cycle time observed during the NIOSH evaluation, it was determined that it took approximately 118 seconds to mill a piston sleeve. At this pace, it was calculated that approximately 213 piston sleeves could be milled per day. Video analysis showed that the piston sleeve was manually handled 14 times from the beginning to the end of the work cycle. Therefore, the total amount of weight handled per 8-hour shift was estimated to be 66,885 lb (e.g., 210 pistons x 22.8 lb x 14 times handled). Potential for injury from handling this amount of weight is increased because of extended reaches required to remove the piston sleeves from the cart and from the need to lift the piston sleeve over the metal barrier of the Barnes drill.

Biomechanical analyses of the extended reach to remove the piston sleeve from the cart shows potentially hazardous biomechanical loading conditions for the worker. The initial weight of the piston sleeve (28 lb) and the weight of the worker's torso as a result of his extended reach makes this a slightly hazardous lifting condition (NIOSH Lifting Index of 1.3, see Table 7). Reducing the reach distance and adjusting the height of the cart will significantly reduce the biomechanical load on the back. If the wire basket is adjusted to knuckle height and the reach distance is reduced, the biomechanical demands on the worker's body can be significantly reduced.

Lifting the piston sleeve over the Barnes drill barrier also creates a biomechanical hazard (NIOSH Lifting Index of 1.5) for the worker's shoulders when lifting above heart level, and for the back when extending the reach to place the piston sleeve on the drill platform (see Table 8). Removal of the barrier, reducing the height of the barrier, or installation of a rubberized flexible barrier, so that the piston sleeve does not have to be lifted as high, will reduce the stress to the worker's shoulders and back.

Of the three department jobs evaluated during the NIOSH visit, the piston sleeve machinist's job appeared to have the greatest risk for causing back injury. This is supported by the OSHA 200 log reports. Lift devices may reduce the risk of back injury, especially when reaching into milling machines. However, the lift devices may not be used on a regular basis because it usually takes longer to use them compared to manual handling. Systematic evaluation of where extended reaches occur during the milling process, and employing methods to shorten these reaches, will help reduce biomechanical stress to the back. For example, shortening the metal barrier on the Barnes drill will allow easier access to this machine and reduce the reach distance.

2. <u>Piston Machining</u>

Table 9 shows the job stressors observed for piston machining and recommended changes to decrease these stressors. The major musculoskeletal stressors to the upper limbs and back are: the initial lift of the piston from the wire cart, the hand pinch used to move the piston from one workstation to another, and placement of the piston into the finished wire cart. The possibility of musculoskeletal fatigue is due to the total amount of weight handled per day by this operator. Based on the cycle time observed during the NIOSH evaluation, it was determined that it took approximately 46 seconds to mill a 10.4 lb piston. At this pace, it was calculated that 545 pistons could be milled per day. Video analysis showed that the piston was manually handled ten times from the beginning to the end of the work cycle. Therefore the total amount of weight handled per 8-hour shift was estimated to be 56,600 lbs (e.g., 545 pistons x 10.4 lbs x 10 times handled). Even if half the number of pistons were milled per day (273), this would amount to 28,300 lb. Potential fatigue from handling this amount of weight (range 28,300 to 56,600 lb) may be exacerbated with extended reaches from reaching and placing the piston in the wire cart.

Biomechanical analyses of the extended reach to get the piston from the cart, and to place the milled piston in a finished cart did not show potentially hazardous biomechanical loading conditions for the worker. However, while the weight of the piston (10.4 lb) is not a major risk factor, the weight of the worker's torso as a result of his extended reach combined with the weight of the piston could make this a potentially hazardous lifting (see Table 10). Reducing the reach distance and adjusting the height of the cart will reduce the bio-mechanical load on the back. Similar conditions exist for removing the piston from the finish lathe and placing it in the finish wire basket (see Table 11).

While the weight of the pistons does not appear to be a problem at this workstation, the repetitive and awkward reach for the pistons may over time strain the worker's back. Back strain can be reduced with an adjustable palletizer that can bring the pistons to the worker's waist level. If the palletizer has a swivel top, the worker can rotate the skid to get the pistons as needed.

3. Aluminum Foundry Molders

Table 12 shows the job stressors and the recommended changes to decrease these stressors. The major stressor during this job is from static awkward posture of the hands, wrists, and arms during the pouring of aluminum from the ladle into the mold. The weight of the ladle and molten aluminum is approx-imately 22.5 lb when it is held over the mold. Most of the weight of the filled ladle is in the worker's left hand as it supports the 1/2" diameter handle connected to the ladle. The right hand turns the handle to pour the liquid aluminum into the mold. The time required to pour the aluminum into the mold is approximately 40 seconds, or 26 percent of the total work time of 155 seconds. The amount of weight handled per day is approximately 6,300 lbs (e.g., 163 pistons at 22.5 lb + 16 lb for ladle only x 163 lb from skimming crust from aluminum bath).

Biomechanical analysis of this job showed that the most stressful elements for the back were reaching, scooping, and lifting the ladle of molten aluminum from the tub. A NIOSH Lifting Index of 1.3 was calculated mostly because of the extended reach to scoop the aluminum from the tub (see Table 13). Stress on the wrists and hands were caused by the static posture and strength required to slowly and carefully pour the aluminum from the ladle into the mold. The third stressful element was manually shaking the excess molten aluminum from the piston rings with slip-joint pliers. The fourth stressful element was removing the aluminum piston from the mold with the slip pliers and placing the piston on an inclined conveyor.

Possible solutions to these stressors include a zero-balancer hoist with a quick connect/disconnect device to hold the ladle handle while the aluminum is being poured into the mold. Another suggestion is to use a slightly larger ladle and rest the edge of the ladle on the mold while pouring the aluminum. This will temporarily relieve the worker's forearm, wrist, and hand muscles from holding the ladle over the mold while pouring. The excess aluminum can be removed from the piston rings by gently tapping them on the inside edge of the aluminum bath tub, rather than "flicking" the wrists. The piston can be removed from the mold by using a zero-balance lifting device. Moving the conveyor next to the mold machines would reduce the transport distance.

C. *Ergonomic Control Program Guidance*

The first step in forming an ergonomics team is to make sure all personnel resources in the plant are represented including: management, labor, engineering, medical, and safety personnel. The team establishes a training schedule in which an outside expert, familiar with the plant operations, teaches ergonomics principles to the management and labor workforce.

Over time, medical surveillance is used to determine the effectiveness of the ergonomic interventions. Medical surveillance can be active or passive. Active surveillance is usually conducted by administering standardized questionnaires to workers in problem and non-problem jobs. Passive surveillance is conducted by examining medical injury or illness records, such as OSHA 2000 logs, workers compensation reports, and attendance records for absenteeism. Analysis is done on both approaches to determine patterns of injury and changes in these patterns, either by increases or decreases, over time.

Decreases in the incidence and severity rate for musculoskeletal disease and injury serve is one measure of success. Incidences in productivity and product quality serve as another. In many instances worker awareness of their musculoskeletal disease and injuries will show an increase in incidence rates early in the ergonomics program. However, as the program matures, both incidence and severity rates usually decrease.[35,36] The length of time required to observe such effects can be a function of the company resources, worker participation, company size, corporate culture, and type of product produced. On average, it takes two to three years before "real" effects are seen.[33,34] The two most important lessons learned from ergonomics programs are:
1) It should not be created as an entity separate from the mission of the plant. Rather it should be woven into existing programs such as safety and medical programs.
2) The ergonomics programs must be sustained, as it is an iterative process that incorporates the philosophy of continuous improvement, transfer of technologies from one department to another, and documentation of ergonomic success and failures.

VII. RECOMMENDATIONS

A. *Engineering Controls*

Piston Sleeve Machinists

1. Consider the use of container handling turntables which will pneumatically lift and rotate the container so that the piston sleeves are always closest to the body when lifting. This will reduce the reach distance required to obtain the premilled piston sleeves. The height of the "working row" of piston sleeves in the container should be approximately 30" from the ground, and the piston sleeves should be no more that 10" or less from body when standing erect. Design specifications for the container lift device should allow for toe room so the operator can stand as close to the container as possible.

2. Remove the metal barrier from the front of the Barnes drill platform and replace it with a 2" barrier or flexible rubber barrier so the operator does not have to lift the piston sleeves over this barrier.

3. Use a vacuum rather than an air hose to remove metal debris from the work tables and the piston sleeves.

4. Keep the work area as clear as possible. All worktables in the piston sleeve milling area should have purpose and be positioned so they help with throughput. The worktable corners should be rounded to avoid sharp contact points between the worker's hands and the piston sleeves.

5. Keep the rubber matting for the worktables and floor in good repair, and replace it periodically to maintain good cushion and support for the worker.

Piston Machinists

1. Consider the use of container handling turntables which will pneumatically lift and rotate the container so that the pistons are always closest to the body when lifting. This will reduce the reach distance required to obtain the premilled pistons. The height of the "working row" of pistons in the container should be approximately 30" from the ground, and the pistons should be no more that 10" or less from body when standing erect. Design specifications for the container lift device should allow for toe room so the operator can stand as close to the container as possible.

2. Consider reducing material handling of the pistons by constructing a gravity feed conveyor to move the pistons from one milling station to another.

Aluminum Foundry Molders

1. Install an overhead zero-balance lifting device with a quick connect/disconnect hook to support the ladle when pouring aluminum into the molds.

B. *Work Practices*

Piston Sleeve Machinists

1. Slide piston sleeves from the center of the container to the edge before lifting. The piston sleeves should be close to the body before lifting them. The reverse procedure should be done when placing the piston sleeves on the container when finished.

Piston Machinists

1. Slide the pistons from the center of the container to the edge before lifting. When reaching or moving pistons to or from the center of the container, the pistons should be slid into position, rather than reaching and placing them in or from the center.

2. Use two hands when handling pistons from the beginning to end of work cycle.

3. Avoid hand pinch posture when transporting pistons from one workstation to another.

Aluminum Foundry Molders

1. Use the lighter-weight skimmer tool provided to skim off aluminum crust rather than the aluminum ladle.

C. *Organizational*

Piston Sleeve Machinists

1. Consider worker rotations, job enlargement, or automation of the milling piston job. If worker rotation is used, the rotation from one job to another should be done approximately every two hours. Job rotation and job enlargement should be so that the worker can use different muscle groups.

Aluminum Foundry Molders

1. Train workers about ergonomic principles to reduce work hazards in their area. Experienced workers can demonstrate work practice techniques to reduce musculoskeletal strain on the body, and how to perform their job to optimize movement and function. For example, using larger ladles to pour aluminum into molds will allow workers to rest the ladles on the edge of the molds while pouring.

2. Consider sit/stand chairs to offer temporary relief from standing between work cycles when milling machines are performing work.

D. *Organizational*

1. Develop a written ergonomics program that includes medical surveillance, risk assessment of hazardous jobs, training and education of workers and management, implementation of controls, and feedback from the workforce on the effectiveness of controls. Consider using self directed work teams in each department after ergonomic training to discuss hazardous jobs and to discuss solutions using ergonomic controls. Develop a budget for purchasing controls, and compose a timeline for when the controls will be implemented. To document hazards and the effectiveness of controls, the worker's jobs may be videotaped before and after ergonomic changes are implemented. The videotape can be used as an orientation for new employees and for other departments as a place to begin their own program. Evaluating medical surveillance records for changes in the incidence and severity rates in various departments is one mechanism in which to evaluate the success of ergonomic interventions. Injury and illness rates should be standardized with production rates, time of year, age, and gender of workforce.

E. *Medical Surveillance*

1. Develop a medical surveillance program for musculoskeletal disorders. Training of plant personnel will raise awareness of job hazards, and more reporting of musculoskeletal discomfort may occur. Because of the dynamic nature of manufacturing in this plant, job hazards may vary depending on production demands, quality of parts, and maintenance of machines and tools. Early detection of problems will complete the communication cycle between workers and management to avoid more serious musculoskeletal disorders. An indication that the program may be working is an initial increase in the incidence of musculoskeletal disorders, but over time a decrease in the severity of such disorders should occur.

F. *Other*
Foundry

Ventilation

1. Establish an environmental control department to maintain ventilation equipment (fans and collectors) and monitor flows/pressure drops.

2. Train plant engineers in ventilation design. Consider the American Conference of Governmental Industrial Hygienists Ventilation Manual and study guide for plant engineers to use.

3. Establish a respirator program. Use air supplied helmets for grinders. The helmets will help with eye protection as well. Nuisance dust masks are not recommended because they are not protective enough.

4. Bring fresh air ventilation ducts down to worker level, and discharge at low level and low velocity. Fresh air should be delivered to crane (air track); be cautious with large fans as they may stir up dusts.

5. Enclose and ventilate the mold (sand) pouring and cooling area. Eliminate roof exhaust. Improve the PEPSET exhaust. During the NIOSH evaluation, it was observed that there was a damaged duct connected to the sand hopper. This may have added to the dust cloud in the worker's breathing zone at molder area when sand and resin were poured into the mold. The operator may need to wear a respirator while performing this job.

Noise

1. Consider: 1) muffling compressed air exhausts; 2) lining enclosures for centrifugal casting machines; 3) lining hoppers/conveyors with plastic; and 4) enclosing tumbler.

Smoking

1. Smoking on the job should be prohibited. Contaminants from the foundry process such as lead and silica may be inhaled or ingested while smoking and cause long-term health problems. Good hygiene practices such as washing of hands should be followed when workers take breaks to avoid contamination of cigarettes or food. Additional information about the hazards of smoking in the workplace and recommendations to eliminate involuntary exposure to environmental tobacco smoke may be found in the NIOSH Current Intelligence Bulletin #54, 1991.[37]

Machine Shop

Cutting Fluids

1. Several employees commented on skin problems that they attributed to being exposed to cutting fluids. To ensure fluid cleanliness, check cutting fluids regularly to make sure bacterial levels are low, pH levels are relatively neutral, and cutting fluid concentrations are maintained at recommended levels. Also, educate employees on the importance of wearing gloves, and washing hands when working with or around cuttings fluids. Additional guidelines may be from the Society of Manufacturing Engineers, Independent Lubricant Manufacturers Association.

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3. OSHA, Region V

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Table 1

Description of Job Elements for Piston Sleeve Machining

Basic Job Elements	Description of Job Elements for Work Cycle for Piston Sleeves
1	Get piston sleeve from wire basket.
2	Position piston sleeve on first worktable next to prep lathe.
3	Remove piston sleeve from prep lathe and position on second worktable.
4	Get piston sleeve from first worktable, position in prep lathe, then activate controls.
5	Use air hose to remove metal debris from piston sleeve on second worktable.
6	Get piston sleeve and position it on penturn worktable.
7	Removes piston sleeve from penturn lathe, cleans metal debris with air hose, and position it on worktable.
8	Get piston sleeve from worktable, position it in penturn lathe, and activate lathe controls.
9	Get piston sleeve from penturn worktable and position it on finish turn lathe.
10.	Get piston sleeve from finish turn lathe, clean off metal debris with air hose, and position it on table.
11.	Get piston sleeve from finish turntable and position it in finish turn lathe.
12.	Get piston sleeve from finish turntable and position it inside Barnes drill work platform.
13	Remove piston sleeve from Barnes drill and position a second piston sleeve in Barnes drill; activate controls.
14.	Get piston sleeve from Barnes drill platform and position it in calibration unit; check calibration.
15.	Get piston from calibration unit and position it in stamp machine worktable.
16.	Position piston in stamp machine and mark piston.
17.	Get piston from stamp machine and position it in receiving basket.
	Repeat work cycle.
	Initial weight of piston sleeve is 28 lbs, final weight is 17.5 lbs, average weight is 22.8 lbs. The piston sleeve is handled 14 times, averaging 319 lbs per work cycle. The average work cycle time is 1:58 minutes (118 seconds). Approximately 210 piston sleeves are milled per 8-hour day x 22.8 lbs x 14 = 66,885 lbs/8-hr day handled.

Table 2

Description of Job Elements for Piston Machining

Basic Job Elements	Description of Job Elements for Work Cycle for Piston Milling
1.	Get piston from back of wire basket and position piston on work table next to Skirter lathe.
2.	Get piston from Skirter lathe and position on worktable.
3.	Get piston from worktable and position in Skirter lathe and activate lathe controls.
4.	Get piston from Skirter lathe worktable and position on Roughing lathe worktable.
5.	Get piston from Roughing lathe and position on worktable.
6.	Get piston from roughing lathe table and position in Roughing lathe and activate lathe controls.
7.	Get piston from Roughing lathe table and position on Finishing lathe platform.
8.	Get piston from Finishing lathe and position on platform.
9.	Get piston from platform and position in Finishing lathe and activates controls.
10.	Get piston from platform and position near back of wire basket.
	Repeat work cycle. Average work cycle time was 46 seconds ± 4 seconds, production capable of 1.3 pistons milled per minute; 545 pistons per 8-hour work shift (420 minutes -- allowing for 30 minutes lunch, and 30 minutes for work breaks); each piston handled 10 per work cycle; average weight of piston is 10.4 lbs; therefore total weight handled during 8-hour day is: 10.4 lbs x 10 times handled x 545 pistons produced = 56,680 lbs.

Table 3

Description of Job Elements for Aluminum Foundry Molding

Basic Job Elements	Description of Job Elements for Work Cycle in Aluminum Foundry
1.	Get hook in aluminum bath containing aluminum coated piston ring.
2.	Get ring from hook with slip joint pliers.
3.	Add ring to hook and put it in aluminum bath.
4.	Use slip joint pliers to manually shake off excess aluminum from ring.
5.	Position ring in aluminum mold #1.
6.	Position mold wedges in mold core.
7.	Get aluminum ladle and scoop aluminum from bath.
8.	Pour aluminum from ladle into mold machine #1.
9.	Pour excess aluminum into bath.
10.	Skim off hardened aluminum crust with ladle from aluminum bath.
11.	Gets piston from mold machine #2 with pliers.
12.	Position piston on incline conveyor.
13 - 24.	Repeat steps 1 through 12 above for machine #2.
25.	Wait for machine #1 to open.
26.	Get piston from machine #1 with pliers and put on incline conveyor.
	Repeats work cycle (average work cycle time 2 minutes 35 seconds for work cycle $\pm$ 16 seconds).

Table 4

Demographics of Male Workers

Work Type	**Number**	**Mean Age, Years**	**Mean Employment, years**
Piston Sleeve Machining	21	39	12
Piston Machining	21	38	17
Aluminum Foundry Molders	6	33	15

Table 5

Percentage of Musculoskeletal Injury Among the Exposed Workers

Work Type	Right Neck-Shoulder	Back	Right Hand-Arm	Left Hand-Arm	Right Leg-Foot	Left Leg-Foot	Any Body Area
Piston Sleeve Machining	42%	85%	63%	53%	--	--	90%
Piston Machining	56%	66%	72%	61%	56%	56%	86%
Aluminum Foundry Molders	--	80%	80%	--	60%	--	80%

Table 6

Job Risk Factors and Recommendations for Piston Sleeve Machining

Basic Job Elements from Table 1	Job Stressors -- for piston sleeve machinists	Recommendations
1.	Potential for overexertion injury to shoulders and back while getting piston sleeves from wire basket.	Bring piston sleeve closer to operator before lifting. Suggest putting wire basket on lift table with 360 degree rotational platform. Worker can rotate table to bring piston sleeves close to operator before lifting.
2,5,6,9, 10.	Excess metal debris and worn and loose rubber matting on worktables for lathes and drills. Piston sleeve may fall from work table due to loose matting causing foot or leg injury.	Vacuum (rather than use air hose) metal debris every 3-4 work cycles. Replace rubber matting as the material becomes worn, and secure it to the worktable during the work cycles.
12.	Worker must lift piston sleeve over metal barrier (approximately 48 inches high) which encloses the Barnes drill platform. Lifting piston sleeve over platform cause an overexertion injury to shoulders.	Remove metal barrier from the front of Barnes drill platform, or reduce the height of the barrier to 2 inches above the platform base.

Table 7

Calculations Using 1991 NIOSH Lifting Formula for Calculating the Recommended Weight Limit and Lifting Index for Lifting a Piston Sleeve from Wire Basket for Machining

Job Analysis Worksheet
Department: Piston Sleeve Machine Shop
Job Title: Piston Sleeve Machinist
Job Description: Lift Piston Sleeve from wire basket and put in prep lathe — Date: April 29, 1994

Step 1. Measure and record task variables

Object Weight (lbs)		Hand Location (in)				Vertical Distance (in)	Asymmetric Angle (degrees)		Freq. Rate	Duration	Object Coupling
		Origin		Dest.			Origin	Dest.	lifts /min	Hours	
L(avg)	L(Max.)	H	V	H	V	D	A	A	FM		CM
28.0	28.0	18	36	15	40	4	0	30	.40	8	Fair

Step 2. Determine the multipliers and compute the Recommended Weight Limits (RWL's)

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

ORIGIN RWL = 51 x .56 x .96 x 1.0 x 1.0 x .82 x 1.0 = 22.5 lbs

DESTINATION RWL = 51 x .67 x .93 x 1.0 x .9 x .82 x 1.0 = 23.5 lbs

Step 3. Compute the LIFTING INDEX

ORIGIN Lifting index = Object Weight / RWL = 28.0/22.5 = 1.3

DESTINATION Lifting index = Object Weight / RWL = 28.0/23.5 = 1.2

Formulas for calculating Recommended Weight Limit: Load Constant = 51 lb; Horizontal Multiplier (HZ) = (10/H); Vertical Multiplier (VM) = 1-(.0075)|V-30|); Distance Multiplier (DM) = .82 + (1.8/D); Asymmetric Multiplier (AM) = 1-(0032A); Frequency Multiplier (FM) = from Appendix B, Table 1B; Coupling Multiplier (CM) = from Appendix B, Table 2B.

1. See Appendix B for Calculation for the NIOSH lifting formula.

Table 8

Calculations Using 1991 NIOSH Lifting Formula for Calculating the Recommended Weight Limit and Lifting Index for Getting Piston Sleeve from Finish Turn Lathe and Position in Barnes Drill

Job Analysis Worksheet
Department: Piston Sleeve Machine Shop
Job Title: Piston Sleeve Machinist
Job Description: Get piston sleeve from finish turn table and position in barnes drill.
Date: April 29, 1994

Step 1. Measure and record task variables

Object Weight (lbs)		Hand Location (in)				Vertical Distance (in)	Asymmetric Angle (degrees)		Freq. Rate	Duration	Object Coupling
		Origin		Dest.			Origin	Dest.	lifts /min	Hours	
L(avg)	L(Max.)	H	V	H	V	D	A	A	FM		CM
22.8	22.8	15	36	22	50	14	0	0	.4	8	Fair

Step 2. Determine the multipliers and compute the Recommended Weight Limits (RWL's)

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

ORIGIN RWL = 51 x .67 x .96 x .95 x 1.0 x .82 x 1.0 = 25.6 lbs

DESTINATION RWL = 51 x .46 x .85 x .95 x 1.0 x .82 x 1.0 = 15.5 lbs

Step 3. Compute the LIFTING INDEX

ORIGIN Lifting index = Object Weight / RWL = 22.8/25.6 = 0.9

DESTINATION Lifting index = Object Weight / RWL = 22.8/15.5 = 1.5

Formulas for calculating Recommended Weight Limit: Load Constant = 51 lb; Horizontal Multiplier (HZ) = (10/H); Vertical Multiplier (VM) = 1-(.0075)|V-30|); Distance Multiplier (DM) = .82 + (1.8/D); Asymmetric Multiplier (AM) = 1-(0032A); Frequency Multiplier (FM) = from Appendix B, Table 1B; Coupling Multiplier (CM) = from Appendix B, Table 2B.

1. See Appendix B for Calculation for the NIOSH lifting formula.

Table 9

Job Risk Factors and Recommendations for Piston Machining

Basic Job Elements from Table 2	Job Stressors -- for piston machinists	Recommendations
1.	Potential for overexertion injury to shoulders and back while getting pistons from back of wire basket.	Bring load closer to the operator at origin of lift. Suggest putting wire basket on lifting table with 360 degree rotational platform to move part closer to operator.
2-9.	Pinch grip used to get, move, and position piston in and out of lathes.	Use two hands to handle piston when getting and moving piston from lathes, or construct a gravity conveyer between Skirter, Roughing, and Finishing lathes to reduce material handling.
10.	Operator has to carry piston from Finishing lathe to wire basket.	Position wire basket closer to finishing lathe to decrease transport distance.
	Amount of weight handled per 8-hour day may be excessive (56,680 lbs), and should be reduced.	Worker rotation, job enlargement, or automation (i.e., piston is moved and positioned by an articulating device such as a robot arm) of this job.

Table 10

Calculations using 1991 NIOSH lifting Formula for Calculating the Recommended Weight Limit and Lifting Index for Lifting a Piston from Wire Basket for Machining

Job Analysis Worksheet
Department: Piston Machine Shop
Job Title: Piston Machinist
Job Description: Lift piston from wire basket and place in skirter lathe.
Date: April 29, 1994

Step 1. Measure and record task variables

Object Weight (lbs)		Hand Location (in)				Vertical Distance (in)	Asymmetric Angle (degrees)		Freq. Rate	Duration	Object Coupling
		Origin		Dest.			Origin	Dest.	lifts /min	Hours	
L(avg)	L(Max.)	H	V	H	V	D	A	A	FM		CM
11.5	11.5	25	24	14	45	21	45	0	.76	8	Fair

Step 2. Determine the multipliers and compute the Recommended Weight Limits (RWL's)

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

ORIGIN RWL = 51 x .40 x .95 x .9 x .85 x .78 x 1.0 = 11.5 lbs

DESTINATION RWL = 51 x .71 x .89 x 1.0 x 1.0 x .78 x 1.0 = 25.1 lbs

Step 3. Compute the LIFTING INDEX

ORIGIN Lifting index = Object Weight / RWL = 11.5/11.5 = 1.0

DESTINATION Lifting index = Object Weight / RWL = 11.5/25.1 = 0.4

Formulas for calculating Recommended Weight Limit: Load Constant = 51 lb; Horizontal Multiplier (HZ) = (10/H); Vertical Multiplier (VM) = 1-(.0075)|V-30|); Distance Multiplier (DM) = .82 + (1.8/D); Asymmetric Multiplier (AM) = 1-(0032A); Frequency Multiplier (FM) = from Appendix B, Table 1B; Coupling Multiplier (CM) = from Appendix B, Table 2B

1. See Appendix B for Calculation for the NIOSH lifting formula.

Table 11
Calculations Using 1991 NIOSH Lifting Formula for Calculating the Recommended Weight Limit and Lifting Index for Putting a Piston in a Wire Basket After Machining

Job Analysis Worksheet
Department: Piston Machine Shop
Job Title: Piston Machinist
Job Description: Get piston from finishing lathe and position in finish wire basket.
Date: April 29, 1994

Step 1. Measure and record task variables

Object Weight (lbs)		Hand Location (in)				Vertical Distance (in)	Asymmetric Angle (degrees)		Freq. Rate	Duration	Object Coupling
		Origin		Dest.			Origin	Dest.	lifts /min	Hours	
L(avg)	L(Max.)	H	V	H	V	D	A	A	FM		CM
10.4	10.4	18	42	24	36	6	0	0	.76	8	Fair

Step 2. Determine the multipliers and compute the Recommended Weight Limits (RWL's)

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

ORIGIN RWL = 51 x .56 x .91 x 1.0 x 1.0 x .78 x 1.0 = 20.3 lbs

DESTINATION RWL = 51 x .42 x .96 x 1.0 x 1.0 x .78 x 1.0 = 16.0 lbs

Step 3. Compute the LIFTING INDEX

ORIGIN Lifting index = Object Weight / RWL = 10.4/20.3 = 0.5

DESTINATION Lifting index = Object Weight / RWL = 10.4/16.0 = 0.7

Formulas for calculating Recommended Weight Limit: Load Constant = 51 lb; Horizontal Multiplier (HZ) = (10/H); Vertical Multiplier (VM) = 1-(.0075)|V-30|); Distance Multiplier (DM) = .82 + (1.8/D); Asymmetric Multiplier (AM) = 1-(0032A); Frequency Multiplier (FM) = from Appendix B, Table 1B; Coupling Multiplier (CM) = from Appendix B, Table 2B.

1. See Appendix B for Calculation for the NIOSH lifting formula.

Table 12

Job Risk Factors and Recommendations for Aluminum Foundry Molders

Basic Job Elements from Table 3.	Job Stressors -- for Aluminum foundry molders	Recommendations
4,16.	Manually shaking off excess aluminum from ring with slip joint pliers causes ulnar deviation of the wrist resulting in excessive force to wrist and forearm.	Gently tap slip joint pliers against edge of bath counter to remove excess aluminum.
8,20.	Pours aluminum from ladle into mold machine #1, causing static stress to wrist and forearm (pouring aluminum into ladle comprises 26% of the work cycle).	Use larger ladle and rest ladle on edge of mold while pouring aluminum into mold. Option, use a zero-gravity counter balance device with a hook on the end to rest the ladle while pouring.
10,22.	Skim off hardened aluminum crust with ladle from aluminum bath.	Use lighter-weight tool provided to skim off aluminum crust. Consider shortening handle for maneuverability.
11,23,26.	Get piston from mold machine #2 with pliers.	Avoid using pliers to get piston from mold. Consider using lift hook to remove piston and position on conveyor.
12,24,26.	Position piston on incline conveyor.	Move conveyor behind or adjacent to mold machine.

Table 13
Calculations Using 1991 NIOSH Lifting Formula for Calculating the Recommended Weight Limit and Lifting Index for Aluminum Foundry Molder Scooping and Pouring Aluminum from Bath and into Mold

Job Analysis Worksheet
Department: Aluminum Foundry
Job Title: Aluminum Molder
Job Description: Scoop aluminum from tub and pour into mold.
Date: April 28, 1994

Step 1. Measure and record task variables

Object Weight (lbs)		Hand Location (in)				Vertical Distance (in)	Asymmetric Angle (degrees)		Freq. Rate	Duration	Object Coupling
		Origin		Dest.			Origin	Dest.	lifts /min	Hours	
L(avg)	L(Max.)	H	V	H	V	D	A	A	FM		CM
22.5	22.5	22	40	14	36	4	0	0	.52	8	Good

Step 2. Determine the multipliers and compute the Recommended Weight Limits (RWL's)

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

ORIGIN RWL = 51 x .46 x .93 x 1.0 x 1.0 x .81 x 1.0 = 17.7 lbs

DESTINATION RWL = 51 x .71 x .96 x 1.0 x 1.0 x .81 x 1.0 = 28.2 lbs

Step 3. Compute the LIFTING INDEX

ORIGIN Lifting index = Object Weight / RWL = 22.5/17.7 = 1.3

DESTINATION Lifting index = Object Weight / RWL = 22.5/28.2 = 0.8

Formulas for calculating Recommended Weight Limit: Load Constant = 51 lb; Horizontal Multiplier (HZ) = (10/H); Vertical Multiplier (VM) = 1-(.0075)|V-30|); Distance Multiplier (DM) = .82 + (1.8/D); Asymmetric Multiplier (AM) = 1-(0032A); Frequency Multiplier (FM) = from Appendix B, Table 1B; Coupling Multiplier (CM) = from Appendix B, Table 2B.

1. See Appendix B for Calculation for the NIOSH lifting formula.

Appendix A

Standardized Questionnaire for Information About Worker Age, Gender, Job Function, and Symptoms Possibly Related to Musculoskeletal Disorders

National Institute for Occupational Safety and Health
A.E. Goetze Company, Lake City, MN
HETA 94-0040, April 26, 1994

1. What is your name: ____________ ____________
   Last First

2. What is your: age ____yrs
   height ____ft ____in,
   weight ____lbs

3. When did you start working at the A.E. Goetze Company?
   ____month 19____yr

4. Total years worked at the A.E. Goetze Company is: _____ yr(s)

5. Did you work at another foundry previously?____yes____no

6. If yes, how many years did you work at that other foundry?
   ____yrs____months

7. On average, how many hours do you work each week?
   _____ hours

8. During the past year (April 28, 1993--April 28, 1994), have you ever had an injury at work?
   ____yes____no

9. If yes, what part of your body did you injure?____________

10. During the past year, have you ever missed any workdays due to an injury at work?
___yes___no

11. If yes, how many days did you miss ?_________day

12. Using the rating scale shown below please rate the OVERALL physical effort level demanded by your job today. Please circle the most appropriate number on the following scale.

20
19 - Very, very hard
18
17 - Very hard
16
15 - Hard
14
13 - Somewhat hard
12
11 - Fairly light
10
9 - Very light
8
7 - Very, very light
6

13. Have you had any pain or discomfort during the last year? ____yes____no

If NO, skip to question 14.
If YES, continue with question 13.

If YES, put a number in each box to indicate your level of discomfort, using the following scale.

0=No discomfort
1=Uncomfortable
2=Very uncomfortable
3=Extremely uncomfortable

14. Please circle the relevant number next to the question.

How often:	Rarely	Occasionally	Sometimes	Fairly Often	Very Often
Does your job require you to work very fast?	1	2	3	4	5
Does your job require you to work very hard?	1	2	3	4	5
Does your job leave you with little time to get things done?	1	2	3	4	5
Is there a great deal to be done?	1	2	3	4	5

15. The next series of questions ask how much influence or control you have at work. Please circle the appropriate number corresponding to the question.

How much influence do you have over the:	Very Little	Little	Moderate	Much	Very Much
Variety of tasks you perform?	1	2	3	4	5
Amount of work you do?	1	2	3	4	5
Order in which you perform tasks at work?	1	2	3	4	5
Pace of your work, that is how fast or slow do you work?	1	2	3	4	5
Quality of the work that you do?	1	2	3	4	5

	Very Little	Little	Moderate	Much	Very Much
To what extent can you do your work ahead & take a short rest break during work hours?	1	2	3	4	5
In general, how much influence do you have over work & work-related factors?	1	2	3	4	5

Appendix B
NIOSH Lifting Equation Calculations

A. Calculation for Recommended Weight Limit

RWL = LC * HM * VM * DM * AM * FM * CM
(* indicates multiplication.)

Recommended Weight Limit

Component	METRIC	U.S. CUSTOMARY
LC = Load Constant	23 kg	51 lbs
HM = Horizontal Multiplier	(25/H)	(10/H)
VM = Vertical Multiplier	(1-(.003|V-75|))	(1-(.0075|V-30|))
DM = Distance Multiplier	(.82+(4.5/D))	(.82+(1.8/D))
AM = Asymmetric Multiplier	(1-(.0032A))	(1-(.0032A))
FM = Frequency Multiplier	(from Table 1B)	
CM = Coupling Multiplier	(from Table 2B)	

Where:

H = Horizontal location of hands from midpoint between the ankles. Measure at the origin and the destination of the lift (cm or in).

V = Vertical location of the hands from the floor. Measure at the origin and destination of the lift (cm or in).

D = Vertical travel distance between the origin and the destination of the lift (cm or in).

A = Angle of asymmetry - angular displacement of the load from the sagittal plane. Measure at the origin and destination of the lift (degrees).

F = Average frequency rate of lifting measured in lifts/min.
Duration is defined to be: $\leq$ 1 hour; $\leq$ 2 hours; or $\leq$ 8 hours assuming appropriate recovery allowances.

Appendix B
Table 1B
Frequency Multiplier (FM)
NIOSH Lifting Equation

Frequency Lifts/min	Work Duration					
	≤ 1 Hour		≤ 2 Hours		≤ 8 Hours	
	V < 75	V ≥ 75	V < 75	V ≥ 75	V < 75	V ≥ 75
0.2	1.00	1.00	.95	.95	.85	.85
0.5	.97	.97	.92	.92	.81	.81
1	.94	.94	.88	.88	.75	.75
2	.91	.91	.84	.84	.65	.65
3	.88	.88	.79	.79	.55	.55
4	.84	.84	.72	.72	.45	.45
5	.80	.80	.60	.60	.35	.35
6	.75	.75	.50	.50	.27	.27
7	.70	.70	.42	.42	.22	.22
8	.60	.60	.35	.35	.18	.18
9	.52	.52	.30	.30	.00	.15
10	.45	.45	.26	.26	.00	.13
11	.41	.41	.00	.23	.00	.00
12	.37	.37	.00	.21	.00	.00
13	.00	.34	.00	.00	.00	.00
14	.00	.31	.00	.00	.00	.00
15	.00	.28	.00	.00	.00	.00
>15	.00	.00	.00	.00	.00	.00

†Values of V are in cm; 75 cm = 30 in.

Appendix B
Table 2B
Coupling Multiplier
NIOSH Lifting Equation

Couplings	V< 75 cm (30 in)	V $\geq$ 75 cm (30 in)
	Coupling Multipliers	
Good	1.00	1.00
Fair	0.95	1.00
Poor	0.90	0.90