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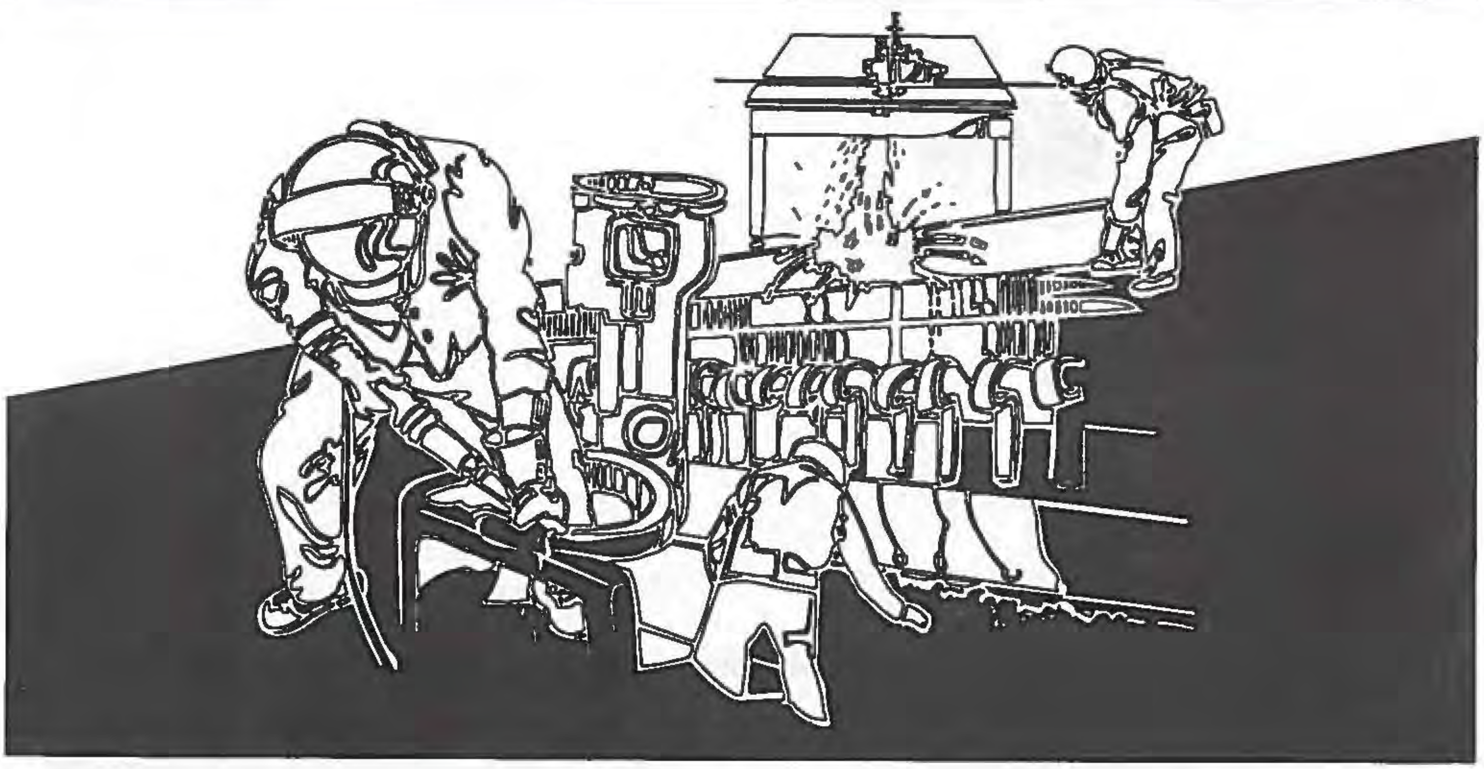
NIOSH HEALTH HAZARD EVALUATION REPORT

HETA 95-0109-2520
KAISER ALUMINUM
OXNARD, CALIFORNIA



U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer and 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.

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I. SUMMARY

On April 5-7, 1995, researchers from the National Institute for Occupational Safety and Health (NIOSH) conducted an evaluation of musculoskeletal disorders of the upper limbs and back at an aluminum forging plant. 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 these jobs; and 3) provide proactive recommendations for establishing an ergonomics program to reduce musculoskeletal disorders for this company.

NIOSH researchers reviewed Occupational Safety and Health Administration (OSHA) Log and Summary of Occupational Injuries and Illnesses (Form 200) from 1992 to 1994. Musculo-skeletal strain injuries accounted for 38 percent of total reported injuries in 1992. In 1994, similar types of injuries accounted for over 50 percent of total injuries in the forging area (one injury occurred in the administrative offices and was not included as part of the forging area). An initial walk-through survey and discussion with plant representatives indicated that areas of most concern were the pressing areas. Ergonomic evaluations were targeted for these jobs.

Job analyses of five press operations showed potential risk for musculoskeletal injury. The workers in these areas were at risk for back injury due to a combination of repetitive and sometimes awkward postures required to manually handle aluminum pieces throughout the entire pressing process. The task of retrieving aluminum pieces from the pre-heat oven presents risks of back and upper extremity musculoskeletal strain to the worker from pulling and handling pieces while in an awkward position. The tasks involving piece handling and lubrication of the die press area present risks of lower and upper extremity musculoskeletal strain from repeated awkward postures. Also, the use of the tongs presents risks of strain to workers' wrists due the orientation of the handle which places the wrist in a deviated posture during many tasks. Lifting devices, improved conveyor delivery system, adjustable height and positioning palletizers, equipment repositioning, and tong handle reorientation should reduce the risk of injuries among workers.

On the basis of the information collected during this evaluation, NIOSH researchers determined that potential for overexertion injuries to the back and upper extremity exists among press machine workers. Highly repetitive work cycles and extended reaches during manual material handling of aluminum pieces are the primary risk factors for these jobs. The potential for hand and wrist injuries also exists with these workers due to prolonged static postures during the lubrication task. Recommendations to reduce risk for musculoskeletal injury and disease in problem jobs, along with guidelines for establishing an ergonomics program are in Sections V, VI, and VII of this report.

Keywords: SIC 3463 (Aluminum Forging), Musculoskeletal Disorders, Manual Materials Handling, Cumulative Trauma Disorders, Nonferrous Metal Milling, Aluminum, Ergonomics, Workstation Design, Engineering Controls.

II. INTRODUCTION

On December 27, 1994, NIOSH researchers received a joint management and labor Health Hazard Evaluation request from Kaiser Aluminum, an aluminum forging plant located in Oxnard, California. The request was for an ergonomic assessment of various jobs within the plant. 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 150,000 square feet of operating space. The plant has 120 employees, with 95 in the hourly ranks and three work shifts. It produces aluminum forging for the aerospace, transportation, medical, and various other fields of industry. According to a 1994 production assessment, the plant produced 650 to 700 thousand aluminum forgings per month. The forging work force is divided into the following product focused work teams.

Aerospace Team
Ground Transportation Team
Hand Forging Team
Air Bag Team
Production Support Team (Heat Treat, Metallurgical Lab)
Manufacturing Support Team (Die Repair and Storage and Layout)
Manufacturing Support Team

Each team has a Team Leader and is responsible for the manufacture of a product. Each team determines the best method to produce their product.

The forging process includes the use of eight major production presses. There are two hydraulic presses, a 5000-ton press and a 1500-ton press. Mechanical presses are rated at 4000 tons, 3000 tons, 1300 tons (two) and an 800-ton and 300-ton long stroke (used to produce air bag components).

III. PROCESS DESCRIPTION

The NIOSH evaluation focused on the following operations (see Design and Methods section); one hydraulic press (5000 tons), three mechanical presses (4000, 3000, and 1300 tons), and one air bag component press (800 tons). The forging processes from the 5000 to the 1300 are similar, while the forging process for the air bag component is slightly different. Detailed descriptions of the work activities for these jobs are presented in the Results and Discussion section of this report.

A. Hydraulic and Mechanical Presses.

Each of these operations involves two to four employees, and requires six basic steps to complete. A worker manually places aluminum pieces on a conveyor that feeds into a preheat oven. A piece is then removed from the oven and placed in the proper position in the press die area. The press cycle is then activated and the forged piece is subsequently removed from the press die area after pressing. Once the piece is removed, the die area is sprayed with a lubricant to prevent the next piece from becoming stuck. The basic elements to perform these jobs are shown in Tables 1-3.

B. Air Bag Component Press.

There are two employees working in this area. This job also consists of six basic steps. Aluminum pieces are manually placed on a stand. Once a sufficient number of pieces have been placed on the stand the die area is sprayed with air for removal of dirt and metal particles. An aluminum piece is then retrieved from the stand and placed in the die area and the pressing cycle is activated. The forged piece is then removed from the die area and placed in a bin. The basic elements to perform this job are shown in Table 4.

IV. DESIGN AND METHODS

NIOSH researchers conducted an on-site evaluation on April 5-7, 1995. The evaluation consisted of a review of Occupational Safety and Health Administration (OSHA) Log and Summary of Occupational Injuries and Illnesses (Form 200), and a detailed ergonomic evaluation of jobs in five press operations. These operations were the 5000-ton, 4000-ton, 3000-ton, 1300-ton, and air bag component (800-ton) presses. These jobs were selected for evaluation based on an initial job survey and conversations with management and labor about the jobs having the potential for an increased rate of musculoskeletal disorders as the workforce ages. OSHA 200 logs from 1992 to 1994 were reviewed to determine incident rates of musculoskeletal disorders.

Ergonomic Evaluation

Videotapes of workers performing the 5000-ton, 4000-ton, 3000-ton, 1300-ton, and air bag component press 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.[1] *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.[2] In addition, biomechanical evaluation of forces which are exerted on the back while performing the task also was performed (see Appendix A for evaluation criteria).[3] 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 controls aimed at reducing the risk for musculoskeletal stress and injury.

V. WORK-RELATED MUSCULOSKELETAL DISORDERS

A. Epidemiologic Studies

Several case reports have suggested certain occupational risk factors for musculoskeletal disorders.[4,5,6,7] 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.[8,9,10,11,12,13] 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 hand-held vibrating tools. Because repetitive movements are required in many service and industrial occupations, occupational groups at risk for developing WRMDs of the upper limbs continue to be identified.

Engineering controls are the preferred method to reduce WRMDs. Examples include selecting the right tool for the job, using non-vibratory 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.[14]

C. Low Back Injuries

Occupational risk factors for low back injuries include manual handling tasks,[15] twisting,[16] bending,[16] falling,[17] reaching,[18] lifting excessive weights,[16,19,20] prolonged sitting,[17] and vibration.[16,21] Some nonoccupational risk factors other than physical stress for low back injury include obesity,[22] genetic factors,[23] and lack of job satisfaction.[24,25]

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.[26]

D. Ergonomic Control Programs

There are seven basic elements needed to establish an effective ergonomics program:[27]

- 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 Plants[28] 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 the 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 studies are not limited to meat packing plants and can be applied to any plant or industry that requires manually intensive labor.

VI. RESULTS AND DISCUSSION

A. Epidemiologic assessment

The OSHA 200 logs revealed the following information on musculoskeletal disorders per year: In 1992, 38 percent of the reported injuries were listed as strains (5 of 13 reported injuries). In 1993, two out of the three reported injuries were listed as strains, one of which was in the accounting department. In 1994, 66 percent of the reported injuries were listed as either strains or tendinitis (6 of 9 reported injuries), where one occurred in the administrative office area. There does not appear to be a clear pattern of musculoskeletal disorders over time or by team.

B. Ergonomic Evaluation

1. 5000-Ton Press

a) Loading pre-heat oven conveyor

Table 5 shows the job stresses and recommended changes to decrease these stressors. Manually handling pre-pressed pieces of aluminum from the bin to the conveyor is the primary source of musculoskeletal stress on the worker. The repetitiveness of the task and the amount of exertion needed to lift each piece may significantly contribute to musculoskeletal fatigue and strain of the lower back and upper extremity. The task rate is approximately 2 seconds per piece, with the worker placing them on the conveyor in a row of 14-16 adjacent pieces. With a piece weight of 44 lb and a handling rate of 1 every 2 seconds, the amount of weight handled in just 30 seconds equates to 660 lb (15 x 44 lb).

Table 6 is an analysis of the lifting task. The analyses illustrate that although each piece weight is below the cut-off of 51 lb, the job does pose a risk due to a combination of frequency of lifts, body posture, and weight. The recommended weight limit (RWL) and lifting index (LI, i.e., weight lifted divided by RWL) calculations in Table 6 were done using equations and tables shown in Appendices A and B. Considering piece weight and handling rate, the calculated RWL's at origin and destination are 5.3 lb and 4.7 lb respectively. These numbers along with the calculated lifting indices (origin: 8.3 [44/5.3], destination: 9.4 [44/4.7]) indicate that this loading task poses a high risk of strain to the worker. However, understanding that the worker may not perform this task for an hour, another set of calculations were done with an adjustment in handling frequency to 1 every 10 seconds. Loading the conveyor at this slower pace raised the RWL's (origin: 14.1 lb, destination: 12.7 lb) and lowered the lifting indices to approximately 3. Although loading at a slower pace allows for more weight before a risk of strain occurs, the calculated allowable weight remains below the current piece weight of 44 lb.

The potential for strain to the back and upper extremities can be reduced by providing a "feeder bin," which is operated by either a push-button, a foot pedal, or a hand crank. The bin would approximately be the width of the conveyor and have pieces already situated in rows. Pieces could be fed onto the conveyor by hydraulics, rollers, etc. Figure 1 illustrates a possible concept for this process. Another modification to the loading area may consist of locating a "feeder bin" on one side of the conveyor. The "feeding" outlet point of the bin should be level with the conveyor, such that aluminum pieces can be fed or rolled directly onto the conveyor.

b) Piece retrieval from pre-heat oven

The major stresses occur during the initial retrieval of the pre-pressed piece of aluminum from the pre-heat oven conveyor belt, and while the piece is lifted into another position after one press cycle. The repetitive nature and the amount of exertion necessary to handle the piece may increase musculoskeletal fatigue due to the amount of weight handled per shift by a worker performing this task. Based on the cycle time observed during the NIOSH evaluation, the entire pressing operation took approximately 50 seconds. At this pace, approximately 504 aluminum pieces could be pressed per shift (a one- hour break is included in the calculation). Video analysis showed that for this task the piece was manually handled 2 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 44,352 lb (e.g., 504 pieces x 44 lb x 2 times handled). Potential for musculoskeletal injury from handling this amount of weight is increased because of extended reaches required to remove the piece from the pre-heat oven and from the need to lift and maneuver the piece into the second press stage position after one press cycle.

Biomechanical analyses of the extended reach from the conveyor to remove the piece from the pre-heat oven shows potentially hazardous biomechanical loading conditions for the worker. The weight of the piece (44 lb) and the required pulling action with an extended reach makes this a potentially hazardous condition. Reducing the reach distance and having the pieces emerge from the oven directly onto a stand in an upright position will reduce the biomechanical stress on the arms, shoulders, and back. Also if the tong handles are modified to maintain wrist-neutral posture, the stress to the worker's wrists and forearms will be reduced. Figures 2 and 3 are conceptual examples of a stand and tool handle design.

Lifting and situating the piece into the second-stage position also creates a biomechanical hazard for the worker's arms, shoulders, and for the back when workers reach to place the piece on a stand slightly above the first-stage position (see Table 5). Redesign of the stand so that the piece can be slid directly from the conveyor instead of lifted will reduce the stress to the worker's shoulders and back.

c) Press activation and lubrication:

The musculoskeletal stressors to the neck and back are from repeated neck extension, bending, and reaching to apply lubrication to the die press area from a hand-held lubrication gun (lube gun) with a wand of approximately 3 ft in length. The possibility of musculoskeletal fatigue is due to the total amount of bending activities per shift required for this task. With a work cycle time of approximately 50 seconds, a worker performing this task is required to bend and reach over 500 times over an 8-hour shift. This number of neck extensions and bending in combination with a static standing posture will provide stress to the neck and lower back.

Also, maintaining a grip on the "lube gun" between cycles will cause stress to the hand and wrist. Providing a place to hang the "lube gun" should relieve stress to the worker's hands and wrists between press cycles.

d) Third stage placement and removal from press

The musculoskeletal stresses to the neck, shoulders, arms, and wrists are from transferring the piece from the second to the third stage and subsequently removing it from the press and sliding it along a stand. The potential for musculoskeletal fatigue is due to the repetitive nature of the task and the amount of weight handled over an 8-hour shift. The NIOSH evaluation determined that the handling frequency is similar to that of the removal of the piece from the pre-heat oven at twice every 50 seconds. In combination with a piece rate of 504, the amount of weight handled per 8-hour shift was calculated to be 44,352 lb. The possibility for injury to the worker is increased from the awkward postures and exertion necessary to lift and transfer the piece.

Biomechanical analyses of the transfer activity indicates a potential hazard from biomechanical loading of the shoulders, arms, and wrists. In attempting to pry or "pop" up the piece from the die press area the worker's wrists are deviated with the shoulders and arms elevated. The weight of the piece (44 lb), along with a long moment arm (i.e., high torque on the wrists) created by the tongs and subsequently awkward postures, presents a slightly hazardous condition. Redesigning the die press area so that the piece can slide will alleviate the musculoskeletal stress on the worker from having to lift the piece during transfer. Also, providing tongs with a flexible head and reoriented handles to maintain the worker's wrists in a neutral posture when prying the piece will reduce stress to the wrist areas.

2. 4000-Ton and 3000-Ton Presses

The ergonomic assessments for the piece retrieval and lubrication tasks are discussed together due to the basic similarities with these two processes. Any pertinent distinctions between the two will be highlighted.

a) Piece Retrieval

Table 7 shows the stressors observed for piece retrieval and the recommended changes to decrease these stressors. The main musculoskeletal stressors to the upper limbs and back are retrieving pieces emerging from the pre-heat oven with the tongs, and placing the piece on the stand for sliding into the die press area. The possibility of musculoskeletal fatigue is due to the total amount of wrist deviations and shoulders/arms elevation due to tong handle orientation and height of the stand. The NIOSH evaluators observed approximate cycle times of 10 seconds for the 4000-ton press and 20 seconds for the 3000-ton press. At this pace the number of pieces that can be handled over an 8-hour shift (an hour break is included in each calculation) is 2520 for the 4000-ton press, and 1260 for the 3000-ton press. Although the piece weight for either process (1.5 to 2.5 lb) may not impose a significant external load, in combination with the tong length and weight (30 in, 2.4 lb) it may exacerbate potential wrist stress and fatigue. Also, having to elevate the arms and shoulders to place the piece on the stand repeatedly for either press may increase the potential for musculoskeletal stress and fatigue.

Biomechanical analyses of the tong handle orientation showed that the workers must maintain ulnar wrist deviations with intermittent amounts of wrist flexion and extension. Biomechanical stress on the wrist area can be reduced by placing a stand at the end of the pre-heat oven conveyor to "catch" the pieces in an upright position, and adjusting tong handle orientation to maintain the wrist in a neutral position. Figures 2 and 3 are conceptual examples of a stand and tool handle design.

While piece weight does not appear to be a problem when elevating to the stand, the repetitive nature of this task may, over time, strain the worker's shoulders and arms. Such strain can be reduced with an adjustable stand that can alter the access point position for workers of varying heights.

b) Presser (4000-ton press)

The mechanical stresses associated with this task occur during situating the piece into the die area and piece removal. For this particular process, the point of operation was farthest from the worker, requiring the worker to adopt an extended reach. Once a press cycle was completed, the pressed piece was placed into a bin directly behind this area. The bin location required the worker to turn approximately 180 degrees. This task, with a handling rate of approximately 2520 pieces per 8-hour shift, may pose biomechanical stress to the worker. Although the tongs are not heavy (2.5 lb), the extended reaching creates an extended moment arm that requires more upper extremity exertion then would be necessary if the point of operation was closer to the worker. Also the repetitious use of the tongs, with deviated wrists and repeated turning to access the bin, may pose a risk of injury to the worker's wrist and lower back area.

Biomechanical stresses to the worker's upper extremity can be reduced by rotating the die area 90 degrees, which should bring the point of operation closer. Additional stress to the wrists can be reduced by reorientation of the tong handles. Figure 3 illustrates a possible handle modification to maintain the wrists in a neutral posture. To reduce the amount of turning and twisting during removal of pieces from the press area, the bin could be placed in a location to directly receive output from the press. A ramp could be retrofitted to the press, so that after a press cycle, the piece is slid directly into the bin. Figure 4 is a conceptual example of a ramp, attached to the press, that directly feeds a bin for piece placement.

c) Presser (3000-ton press)

The mechanical stressors associated with this task are similar to those of the presser at the 4000-ton press. Although the piece handling rate per shift is shorter (1260), the 3-stage process increases handling time and may result in increased exposure time to stressors. This task requires reaching at least twice as many times while accessing the point of operation for certain stages. Other similarities with the 4000-ton press operation include the type of tongs used, as well as the location of the bin for placing pieces after pressing.

Similar strategies to reduce biomechanical stress to the worker are recommended: rotate the die press area 90 degrees to bring the point of operation closer to the worker; modify the tong handles, to maintain neutral wrist postures (Figure 3); and move the location of the bin so it can directly receive pieces from a ramp attached to the press to alleviate the amount of twisting and turning (Figure 4).

d) Lubrication (4000-ton and 3000-ton press)

The mechanical stressors associated with this task include constantly holding the "lube gun," and working with a static standing posture. They affect the hands/wrists and the lower extremity. Potential reduction of these stresses can be accomplished by providing a J-hook for the "lube gun" when not in use, and providing soft pliable mats to stand on.

3. <u>1300-Ton press</u>

a) Piece retrieval and press

Table 8 shows the stressors affecting this job and the recommended changes to decrease the stresses. The major stress during this task is from awkward posture of the neck and wrists during retrieval of pieces from the pre-heat oven and subsequent operation of the press. The repetitive nature of the task is of more concern than the weight of pieces handled. The work cycle time was determined as the worker handling a piece approximately every 12 seconds, which equates to handling 2100 pieces in an 8-hour shift (this calculation takes an hour break into consideration). This is also the number of times the worker adopts an awkward posture. The height of the pre-heat oven conveyor and die press area are low, requiring the worker to maintain a flexed neck posture when retrieving and pressing. As with the other press operations, the tong handle design deviates the worker's wrists. Also, the bin for pressed pieces is located behind the presser, requiring twisting/turning for piece placement once a cycle has completed.

Possible solutions to these stressors include adjusting the height of either the conveyor, die area, or the floor to accommodate taller and shorter workers. Another suggestion is, once again, to modify the design of the tong handle to maintain the wrists in a neutral posture. This area could also benefit from moving the location of the bin to directly receive press output, as described previously. Relocating the bin will not only reduce the amount of twisting, but will also provide more space in that area for the workers to maneuver.

b) Lubrication

This task has stressors similar to those described for the other press operations. However the worker performing this task was using a J-hook on the presser to rest the "lube gun" between cycles.

4. Air bag component press

a) Piece retrieval and press

Table 9 shows the stressors affecting this job and the recommended changes to decrease the stress. The major stresses during this task are reaching to place the piece into the die press area and handling the "lube gun." The repetitive nature of the task is of more concern than piece weight. The work cycle time was determined as the worker handled a piece approximately every 10 seconds, which equates to handling 2520 pieces in an 8-hour shift (this calculation takes an hour break into consideration). This is also the number of times the worker reaches into the press area. Although reaching to access the point of operation may not seem excessive, doing it approximately 2520 times a day may lead to upper extremity, low back, and lower extremity musculoskeletal fatigue. Also, the high grip force necessary to maintain hold of the "lube gun" creates a risk of musculoskeletal fatigue to the worker's hand and wrist. Since this "lube gun" is used to clear the die area with powerful blasts of air, the worker must handle the subsequent kickback from the high velocity of the emanating air.

The amount of reaching can be reduced by providing a chute or ramp that feeds directly to the die press area. The chute/ramp will allow the worker to slide the pieces into the press instead of having to repeatedly reach. Also, providing a device that will absorb or dampen the amount of kickback force resulting from "lube gun" activation can reduce stress to the worker's hand and wrist.

b) Piece removal

This task has stressors similar to those described for the other press operations. The stress and potential for musculoskeletal fatigue is from tong use. As with the other tongs, these tongs deviate the worker's wrists. A potential piece rate of 2520 per 8-hour shift may result in fatigue and injury. A redesign of the tong handles will reduce wrist deviation, stress, and the potential for injury.

VII. RECOMMENDATIONS

A. Engineering Controls

1. 5000-Ton press operation

a) Consider the use of a piece container handling stand which will mechanically lift and place pieces on the pre-heat oven conveyor a row at a time (Figure 1). This will reduce the amount of manual lifting necessary to load the conveyor. The stand can contain a number of rows, or it can be just one row that is fed by an adjacent bin. Although the stand should be as close to the conveyor as feasible, it should be made portable so that it can be moved, slid, or carried, to allow for maintenance on the conveyor or the oven. The design of the stand should include a mechanism that will still allow operation to continue manually if equipment malfunction occurs.

Consider the use of a container located adjacent to the conveyor that feeds pieces directly onto the conveyor. The container bottom should be raised such that it is virtually level with the conveyor. Also, one side of the container bottom should be spring-loaded or fitted with hydraulic lifts to tilt the pieces toward the conveyor. An outlet door should be located at the lower section of the container, allowing the pieces to be rolled onto the conveyor as the container bottom tilts. The outlet door size should allow only one piece to roll out at a time.

b) Provide another stand at the end of the conveyor where the pieces emerge from the pre-heat. The stand should be designed to accept the conveyor feed by row and position the pieces vertically (Figure 2). The pieces can slide down onto the stand or they can slide onto a platform and rotate down into a vertical (upright) position. The stand, should be flush with the press conveyor for piece retrieval and transfer.

c) Modify the tong handles to form a right-angle grip; the angle can be held angle up or down (Figure 3). The tongs modified in this manner should be offered as an option allowing the worker the final decision on tong handle configuration preference. For the initial retrieval aspect of this operation, an additional grip can be retrofitted close to the tong head, similar to the existing tong design. Also, consider designing and developing a tong type of tool with a flexible head having two degrees of freedom. Tong head flexibility can be in the form of flexion and extension, similar to that of the human wrist. Flexion and/or extension can be activated from a pistol grip handle. This type of tool capability should reduce awkward upper extremity and back postures that occurs when workers attempt to pry the piece loose.

d) Consider re-engineering the die press area such that the forming facet will simultaneously rise as the overhead press descends and return at the completion of a pressing cycle. This should allow the pieces to be slid from stage to stage instead of being lifted, making for easier handling.

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

2. 4000-Ton, 3000-Ton, and 1300-Ton press operations

a) Consider the use of a ramp, conveyor, or vacuum system that feeds pieces to the press area directly from the pre-heater oven.

b) Consider locating the finished piece bin on the side of the press and constructing a ramp from the die area to the bin. At the completion of a press cycle, either the die area should tilt or the worker can manually slide the piece down the ramp into the bin (Figure 4).

c) For the 3000-ton and 1300-ton presses, consider rotating the die area 90 degrees. Also, consider making the stages more sequential.

3. Air bag component press

a) Consider a ramp system that will enable pieces to be fed directly from the container to the die press area. The ramp should be situated such that, without compromising safety, the protective barrier fits over it while the press descends. If the barrier cannot fit over the ramp, then the ramp can be designed to be retractable for every press cycle.

b) Attach a counterbalance to the "lube gun" that will absorb and/or transfer the resulting air kickback force away from the hand and wrist.

4. General

a) Provide a pistol grip "lube gun" that is suspended from a trolley or tram and can be placed in or out of the point of operation at will. This type of setup should allow the "lube gun" to be placed to the side and out of the way between press cycles. Another suggestion is to provide a hook for which to rest the "lube gun" between press cycles.

b) Provide cushioned, heat resistant floor mats for those having to stand by the press a significant part of their shifts. The floor mats should provide good traction despite having lubricant spilled on them.

c) Provide bottom-spring-loaded bins for those operations which require obtaining pieces from a bin as part of the work cycle. A spring-loaded bin will bring the remaining pieces closer to the worker as the top pieces are removed. This should relieve the worker from having to reach excessively into the bin as the bin load decreases.

B. Work Practices - All press operations

1. When loading the pre-heat oven conveyor, the pieces should be close to the body before lifting.

2. As the pieces emerge from the oven, bring them as close to the conveyor edge as possible. This should reduce the amount of reaching during piece retrieval.

3. If possible, alternate between the left and right foot when using the foot pedal to activate the press cycle.

C. Organizational - All press operations

1. Continue periodic job rotation within or between press operations. Job rotation and job enlargement should be so that the worker can use different muscle groups. Automation should be considered when it makes the job safer or it frees up the worker to accomplish other more important tasks.

2. 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 teach job performance techniques that optimize movement and function. For example, experienced workers could discuss the proper techniques for setting pieces in the die press area efficiently and effectively.

D. Administrative considerations

It is important to establish an ergonomics program that matches the philosophy, corporate culture, and goals of the company and its labor force. This particular plant has begun a program to reduce worker injury by job observation and effective communication on behavior modifications from specifically trained workers. As with other similar types of plants attempting to augment an injury reduction program, management and labor have decided to be proactive in their approach to control injuries.[29,30,31,32] 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 ergonomic principles to the management and labor workforce.

This would be an opportunity to augment the existing Zero Accident Prevention Process (ZAPP) team program. Such augmentation may just require modification and/or expansion of certain elements within the ZAPP team procedure to encompass ergonomic considerations. For example, consider expanding the ZAPP job hazard checklist from activities that cause injuries to those that may cause musculoskeletal disease.

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. Use the ZAPP teams after ergonomic training to discuss hazardous jobs and solutions using ergonomic controls. Develop a budget for purchasing control equipment, and compose a time line for implementing controls. To document hazards, and the effectiveness of controls, the workers' jobs may be videotaped before and after ergonomic changes are implemented. The videotape can be used for retraining experienced employees and as part of orientation for new employees. Evaluating medical surveillance records for changes in the incidence and severity rates is one mechanism from which to evaluate the success of ergonomic interventions. Injury and illness rates should be standardized with production rates, time of year, and age and gender of workforce.

The two most important lessons learned from ergonomics programs are: (1) The program 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.

E. Medical Surveillance

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. In many instances worker awareness of work-related musculoskeletal diseases and injuries will show an increase in incidence rates (due to better reporting) early in the ergonomics program. However, as the program matures, both musculoskeletal disorder incidence and severity rates usually decrease.[31,32] 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 2 - 3 years before "real" effects are seen.[29,30]

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 200 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.

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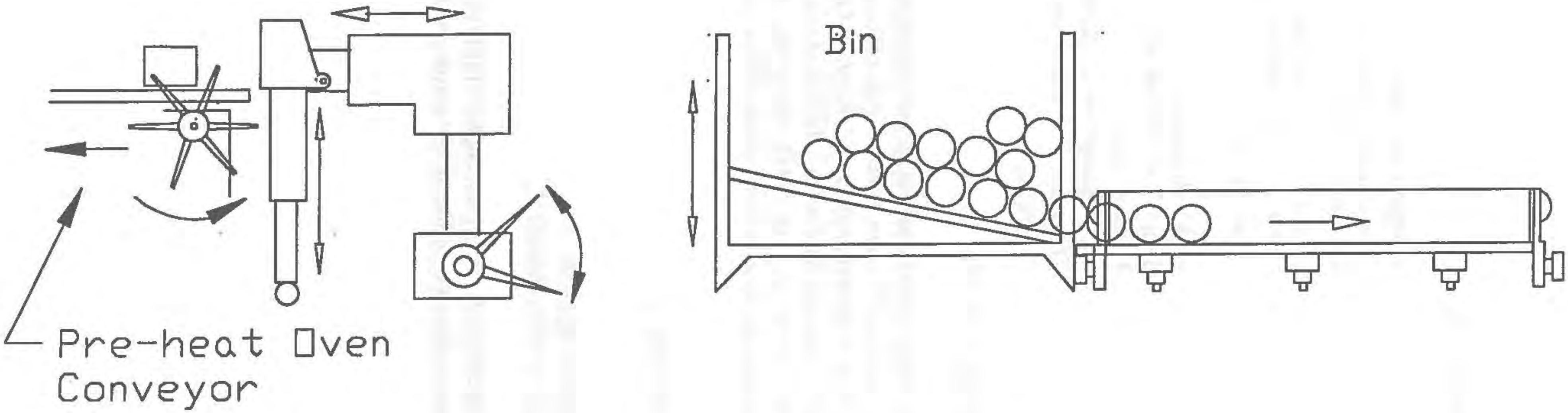


Figure 1 5000 Press Pre-Heat Oven Conveyor Loader

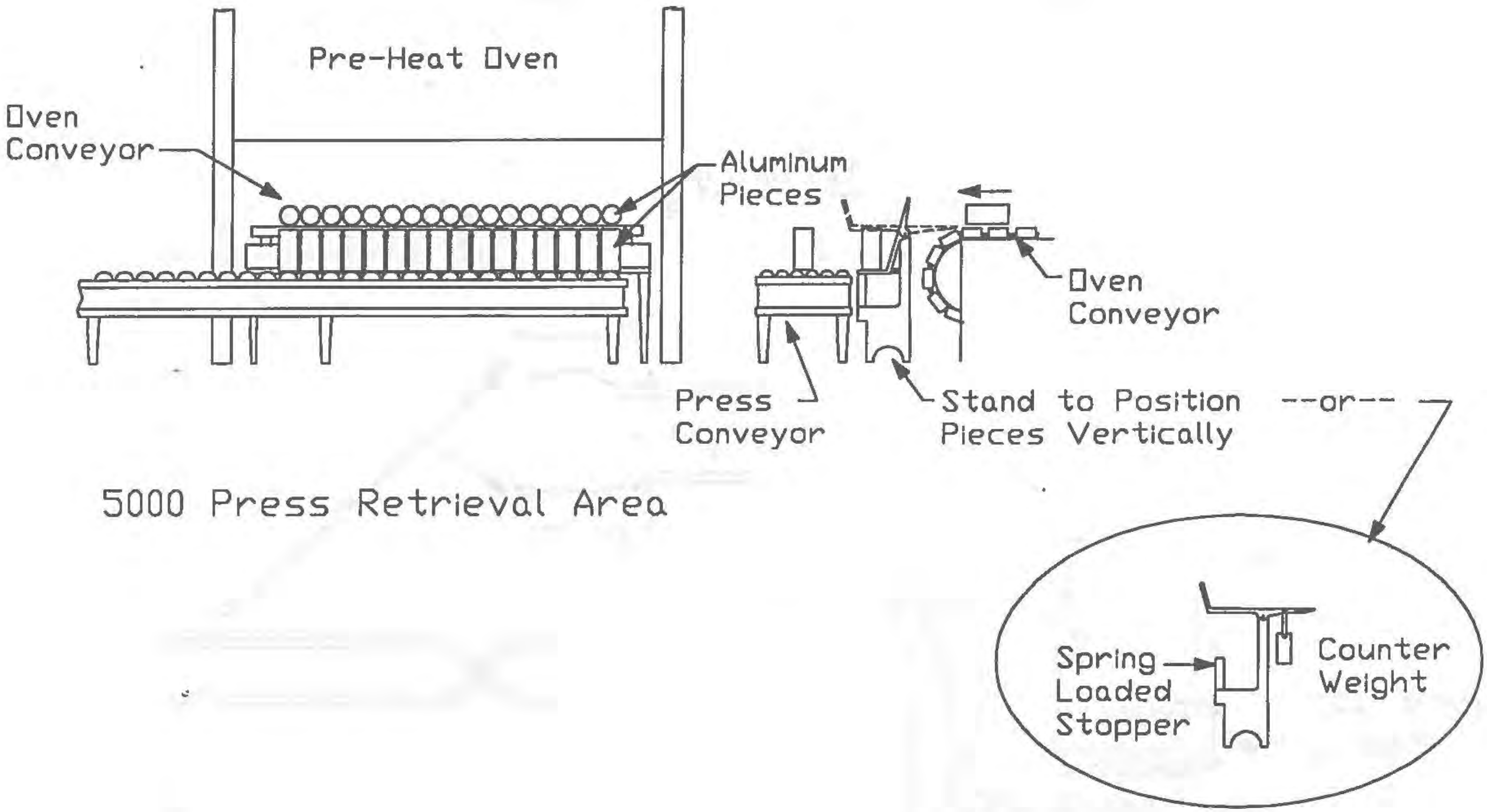
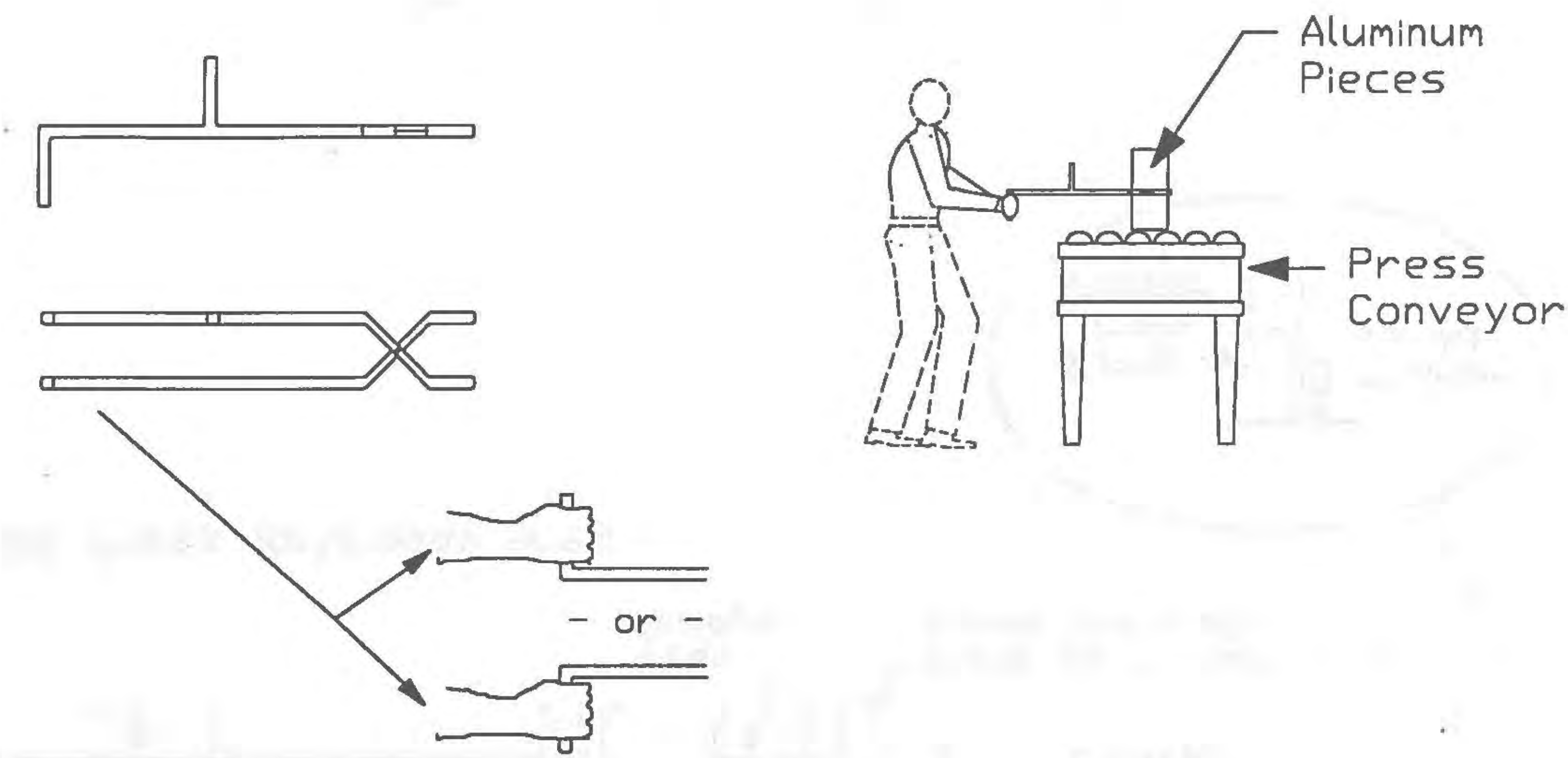

Pre-Heat Oven
Oven Conveyor
Aluminum Pieces
Oven Conveyor
Press Conveyor
Stand to Position Pieces Vertically
--or--
5000 Press Retrieval Area
Spring Loaded Stopper
Counter Weight

Figure 2



Tongs

Figure 3

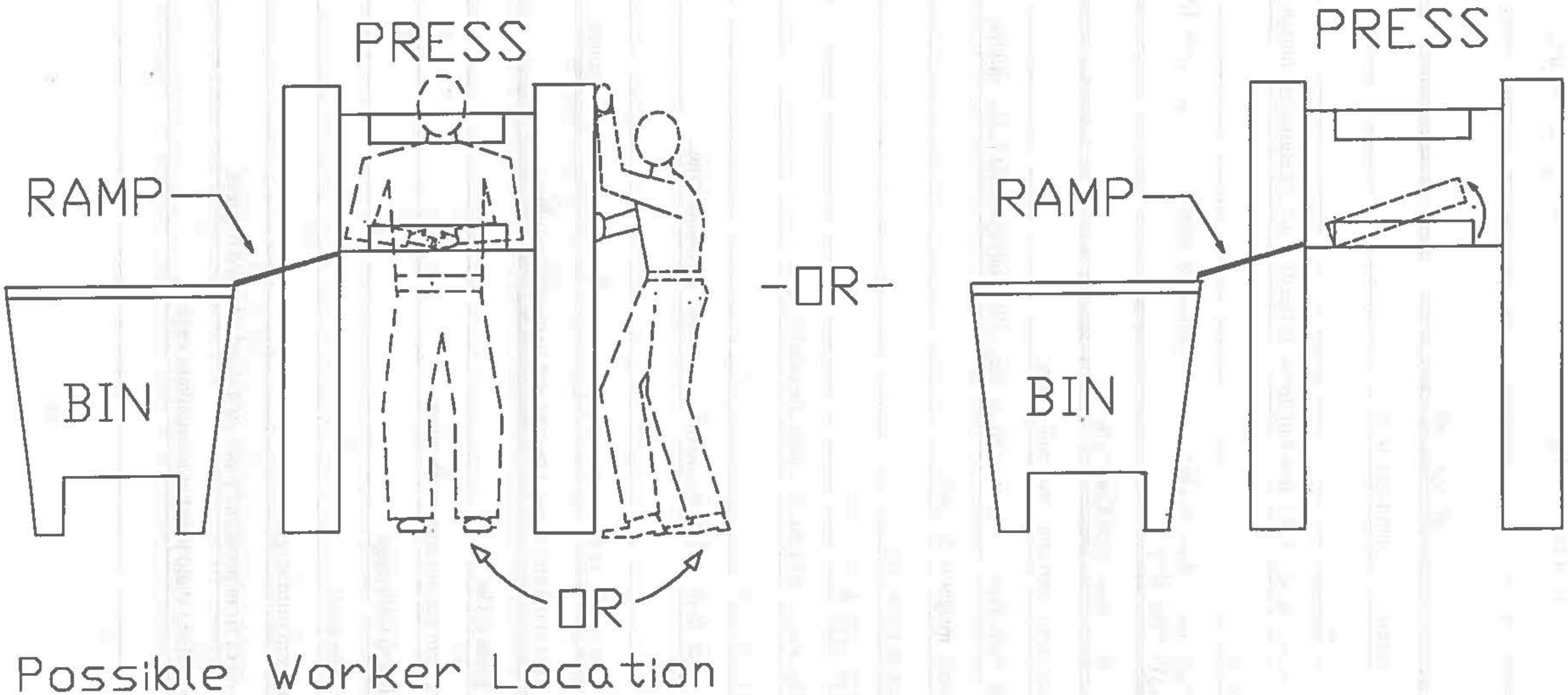


Figure 4 Piece Removal from Die Press Area

Table 1. Description of task elements for jobs in the 5000-ton press operation area.

Basic Job Elements	Loading Pre-heat Oven Conveyor Belt
1.	Grab pre-forged aluminum piece in bin.
2.	Lift piece from bin.
3.	Place piece on conveyor in a row lengthwise in the direction of conveyor motion.
4.	Return to bin.
	Piece weight: 44 lb, Work cycle time: 2-3 seconds, Number of pieces in a row: 14-16, Piece are in a cylindrical shape,
	Piece Retrieval from Oven Conveyor
1.	Grab piece from oven conveyor with tongs.
2.	Pull piece from oven conveyor on to another roller conveyor that feeds onto the press area.
3.	Rotate piece upright with tongs.
4.	Push piece to press area.
5.	Wait for press cycle.
6.	Push and place piece on to first stage die pressing area.
7.	Wait for press cycle.
8.	Remove piece from first stage and lift on to adjacent second stage.
9.	Return.
	Tong weight: 6.5 lb, Tong length: 38 in, Entire work cycle time: 30-40 seconds,
	Piece Second and Third Stage Transfer and Removal from Press
1.	Wait for press cycle.
2.	Pry piece from second stage with tongs.
3.	Move piece to third stage.
4.	Wait for press cycle.
5.	Pry piece from third stage.
6.	Remove piece from press and place on a stand attached to press.
7.	Slide piece along stand to robot manipulator cage.
8.	Return.

Table 1. (Continued)

	Entire work cycle time: 30-40 sec, Similar type tongs are used, Intermittent activities include: sliding pieces into robot manipulator cage, and occasionally applying additional lubricant to die press area,
	Press lubrication and activation
1.	Wait for positioning and/or removal of pieces.
2.	Spray lubricant into die press area with "lube gun."
3.	Step back and activate press cycle by using a "joy stick" on a portable console.
	Work cycle time: 5-8 seconds;

Table 2. Description of job elements for 4000-ton and 3000-ton press operations.

Basic Job Elements	Piece Retrieval from Oven
1.	Grab piece from pre-heat oven with tongs.
2.	Wait for press cycle.
3.	Slide piece into die press area.
4.	Return to oven conveyor.
	4000 tons press work cycle time: 10 seconds, 3000 tons press work cycle time: 20 seconds, Piece weight for the 4000 tons press operation: 2.5 lb, Piece weight for the 3000 tons press operation: 1.6 lb, Tong weight: 2.4 lb, height of conveyor required torso flexion from 15 to 20 degrees when grabbing pieces,
	Presser: 4000 tons press
1.	Grab piece, with tongs, that was slid into die press area.
2.	Place piece in proper position in the die area.
3.	Activate press cycle with right foot pedal.
4.	Wait for press cycle.
5.	Remove piece from die area.
6.	Place piece in bin.
7.	Return to press
	Work cycle time: 10 seconds; Oftentimes a piece may become stuck on the upper press, requiring torso flexion of approximately 60 degrees to see and pry piece loose;
	Presser: 3000 tons press
1.	Grab piece with tongs and place piece in first stage.
2.	Activate press with right foot pedal.
3.	Wait for press cycle.
4.	Grab piece with tongs and place in second stage
5.	Activate press.
6.	Wait for press cycle.
7.	Grab piece with tongs and place in third stage.
8.	Activate press.

Table 2. (Continued)

9.	Wait for press cycle.
10.	Remove piece from press.
11.	Place piece in bin.
12.	Return to press.
	Work cycle time: 20 seconds; Since this is a three stage press, it requires at least two additional times material handling while transferring from stage to stage,
	Lubrication
1.	Wait for press cycle.
2.	Wait for removal of piece from press
3.	Spray lubricant into die press area with "lube gun."
	Work cycle time: 5 seconds to lube,

Table 3. Description of job elements for 1300-ton press operation.

Basic Job Elements	Piece retrieval and press
1.	Grab piece from pre-heat oven conveyor with tongs.
2.	Carry piece to press area.
3.	Place piece on to first stage.
4.	Activate press with right foot pedal.
5.	Wait for press cycle.
6.	Grab and place piece on to second stage.
7.	Activate press cycle.
8.	Wait for press cycle.
9.	Grab/pry piece and remove from die press area.
10.	Place piece in bin.
11.	Return to press.
	Work cycle time: 12 seconds; The piece(s) being handled here are approximately 1 lb, therefore even with the additional load from the use of the tongs, the amount of weight being handled is probably not significant,
	Lubrication
1.	Wait for press cycle(s).
2.	Wait for removal of piece.
3.	Spray lubricant into press area with "lube gun."
	Work cycle time: 3 seconds to lube; This worker apparently did use a hook attached to the press to rest the "lube gun" while waiting between press cycles,

Table 4. Description of job elements for Air Bag Component Press operation.

Basic Job Elements	Piece retrieval and press
	Prior to starting the worker stacks a number of pieces on to a pallet stand which is on a powered hand truck.
1.	Grab piece from stand with hands.
2.	Spray die press area with air using a air hose "lube gun."
3.	Drop piece into position.
4.	Activate press cycle with right foot pedal.
5.	Wait for press cycle.
6.	Return to pallet stand.
	Work cycle time: 10 seconds;
	Piece Removal
1.	Wait for press cycle(s).
2.	Grab piece with tongs.
3.	Check piece.
4.	Place piece in bin.
5.	Return to press.
	Work cycle time: 4 seconds;

Table 5. Job risk factors and recommendations for 5000-ton press operation.

Basic Job Elements from Table 1	Job Stressors -- for loading pre-heat oven conveyor	Recommendations
1-4	Potential for overexertion injury to shoulders and back while lifting aluminum pieces and placing them on the conveyor.	Use container handling stand which will mechanically (automatically, pneumatically, etc) lift and place pieces on the pre-heat oven conveyor a row at a time (Figure 1). The stand can contain a number of rows or it can be just one row that is fed by an adjacent bin.
	Piece retrieval	
1-9	Leaning and reaching over roller conveyor to grab pieces emerging from oven. Force necessary to pull and rotate piece on roller conveyor. Wrist deviations due to positioning piece and design of tong handles.	Have the oven conveyor deliver the pieces on to a stand that positions them vertically adjacent to the roller conveyor (Figure 2). Redesign the tong handles to a right angle pistol grip orientation. Keep an additional vertical handle on the tong stem to enable the worker to walk alongside the piece in a neutral posture (Figure 3).
	Piece second to third stage transferal and removal from press	
1-8	Wrist deviation and shoulder flexion/extension when having to pry and elevate piece to another stage or removing piece from press.	Redesign the die press, such that as the upper press descends the lower forming section raises. As the reciprocal occurs the lower section should flatten out , allowing the piece to be slid instead of elevated. Also redesign the tong handles to a right angle pistol grip orientation.
	Press lubrication and activation	
1-4	Constant grip on "lube gun." Also static standing posture between cycles.	Have the "lube gun" hang from a trolley or tram, which will allow it to be set aside when not in use. Attach a hook to the press or in the proximity, that will enable the worker to rest the "lube gun" when not in use. Provide thermal stress resistant and slip resistant soft pressure absorbing mats to reduce stress to lower extremity

Table 6. Calculations using 1991 NIOSH lifting formula for calculating the Recommended Weight Limit and Lifting Index for loading pre-heat oven conveyor belt for 5000-ton press operation.

Job Analysis Worksheet
Department: 5000 tons press
Job Title: Load pre-heat oven conveyor belt
Job Description: Lift piece from bin and place on to conveyor.
Date: April 5-7, 1995

Step 1. Measure and record task variables

Object Weight (lb)		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
44.0	44.0	18	36	18	16	20	75	75	.28	1	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 .95 x .91 x .76 x .28 x 1.0 = 5.3 lb

DESTINATION RWL = 51 x .56 x .90 x .91 x .76 x .28 x 1.0 = 4.7 lb

Step 3. Compute the LIFTING INDEX

ORIGIN Lifting index = $\frac{\text{Object Weight}}{\text{RWL}}$ = 44.0/5.3 = 8.3

DESTINATION Lifting index = $\frac{\text{Object Weight}}{\text{RWL}}$ = 44.0/4.7 = 9.4

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 A and Appendix B for Calculations for the NIOSH lifting formula.

Table 7. Job risk factors and recommendations for 4000-ton and 3000-ton press operations.

Basic Job Elements from Table 2.	Job Stressors -- for piece retrieval	Recommendations
1-5	Repetitive leaning and/or bending to grab pieces from oven conveyor.	Provide either a conveyor, ramp, or vacuum system that feeds pieces directly to press area from oven conveyor.
	Constant wrist deviation due to design of tong handles.	Redesign the tong handles to a right angle pistol grip orientation.
	Presser	
1-5 (4000) 1-12 (3000)	Repetitive extensive arm reaching when grabbing and positioning the piece in the die area.	Rotate die area 90 degrees to bring point of operation closer to worker.
	Repetitive twisting to place pieces in bin.	Place bin adjacent to press and attach a ramp from the press to the bin, enabling the worker to slide pieces down the ramp and into the bin (Figure 4).
	Constant wrist deviation due to design of tong handles.	Redesign the tong handles to a right angle pistol grip orientation.
	Lubrication	
1-3	Constant grip on "lube gun."	Have the "lube gun" hang from a trolley or tram, which will allow it to be set aside when not in use. Attach a hook to the press or in the proximity, that will enable the worker to rest the "lube gun" when not in use.
	Static standing posture.	Provide thermal stress resistant, slip resistant soft pressure absorbing mats to reduce stress to lower extremity. Position wire basket closer to finishing lathe to decrease transport distance.

Table 8. Job risk factors and recommendations for 1300-ton press operation.

Basic Job Elements from Table 3.	Job Stressors -- for piece retrieval and press	Recommendations
1-12	Constant neck flexion of height of die press area.	Modify the design of the press, to allow raising and lowering of point of operation.
	Repetitive twisting and turning to retrieve pieces from oven conveyor and place pieces in bin.	Provide ramp or vacuum system to directly feed pieces to the press from the conveyor. Place bin adjacent to press and attach a ramp from the press to the bin, enabling the worker to slide pieces down the ramp and into the bin.
	Constant wrist deviation due to tong handle design.	Redesign the tong handles to a right angle pistol grip orientation.
	Lubrication	
1-3	Static standing posture.	Provide thermal stress resistant, slip resistant soft pressure absorbing mats to reduce stress to lower extremity. Position wire basket closer to finishing lathe to decrease transport distance.

Table 9. Job risk factors and recommendations for Air bag component press operation.

Basic Job Elements from Table 3.	Job Stressors -- for piece retrieval and press	Recommendations
1-8	Repetitive high grip force exertions to maintain control of air hose "lube gun."	Redesign "lube gun" to include a counter balance or damper to absorb and transfer kickback force away from the hand and wrist.
	Repetitive leaning and reaching to drop piece into position.	Provide ramp or vacuum system to directly feed pieces to the press from the pallet stand.
	Piece retrieval	
1-4	Constant wrist deviation due to tong handle design.	Redesign the tong handles to a right angle pistol grip orientation.
	Static standing posture.	Provide thermal stress resistant, slip resistant soft pressure absorbing mats to reduce stress to lower extremity. Position wire basket closer to finishing lathe to decrease transport distance.

Appendix A
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 lb
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 ≥ 75 cm (30 in)
	Coupling Multipliers	
Good	1.00	1.00
Fair	0.95	1.00
Poor	0.90	0.90

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