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Ergonomic Evaluation
Cascade Steel, McMinnville, Oregon
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By Rob Strickland, OTR

A work site visit was conducted in the Ladle Bricking area at the request of Pat Kraft, Manufacturing Consultant and Project Director. Videotaping and digital photos of the work in progress were performed and are available for review. Employee discomfort surveys were completed.

Purpose/Background: The purpose of this evaluation is to provide an initial assessment of the Musculoskeletal Disorder (MSD) risk factors associated with this activity. This is done as part of the Oregon OSHA Worksite Redesign Program Grant which has been awarded to Cascade Steel. The intended goal of this project is to make engineering improvements to reduce the identified MSD risk factors in order to prevent work injury.

General description: The following description was provided by Cascade Steel and Mr. Kraft: As part of our manufacturing process, we use large melting pots, known as "ladles", for melting materials. These ladles are lined with a fireproof brick material, which is sealed with a cement-like compound, which holds the bricks in place. These bricks are chipped out and replaced every 100 heat cycles of the ladle. It is an ongoing process to rotate used ladles in for refurbishment. The ladles average 10 feet in inside diameter, by 10 feet in inside depth. It is a very labor intensive process and compares closely with building a round brick room 10 feet in diameter, by 10 feet deep over and over again. It currently requires an excessive amount of repetitive lifting, from ground level height, through six feet in elevation, of the 20-25 pound bricks. There are over 1,300 bricks used in each ladle.

Job Steps

Ladle is put in place with overhead crane
Pallet of bricks is lowered into ladle with overhead crane
Worker descends 6 ft. step ladder into ladle
Place/set bricks on floor of Ladle
Remove leftover pallets with overhead crane
Lower pallet of bricks for walls into ladle with overhead crane
Place starter set of bricks for walls
Build walls with bricks setting one layer at a time
Back fill behind bricks with "macrovibe" (course sand like) material using overhead hose (generally every two rows)
Tamp macrovibe material in place with trowel
At approximately 6 feet height of wall, remove pallets and lower "table" in place to form a new standing platform at approximately 5 feet up from floor
Continue building brick wall to top of ladle
Place ramming material (pliable clay-like substance) around top rim and tamp in place with air powered ramming tool (similar to a small jack hammer)

Work Environment and Equipment: Relevant dimensions

Floor brick- 6" x 9" x 4" high (rectangle)

Small pallet of floor bricks contains 120 bricks (6 layers of 20)

Typical wall brick- 6" x 8" x 4" high (rectangle with concavity on one end, convexity on other end)

Large pallet of wall bricks contains 216 bricks (6 layers of 36), dimension of load= 36" x 48" x 24" h

A pallet of bricks is placed in the ladle on a stack of empty pallets (4 -7 high) resulting in the top layer of bricks on the load starting as high as 54", to as low as 18" (last layer of bricks on pallet)

With pallet placed near the center of the ladle floor, there is approximately 17" to 24" of clearance at each corner from the brick wall.

Each layer of bricks in the wall contains approximately 44 bricks.

Key physical demands: The physical stressors in this task vary somewhat depending on the stage of completion of the project, generally described as follows:

Phase 1- Floor: The worker is primarily working in a kneeling position, twisting at the trunk, reaching up to grasp a brick with one hand from the load on the pallet (anywhere from waist high to shoulder high) turning back and placing the brick on the floor, setting it into position while bending forward at the trunk.

Phase 2- Wall: Approximately 1320 bricks (30 layers consisting of approximately 44 bricks per layer)

Stage 1- First 25% of wall (up to 30" high): The worker is primarily in a kneeling position again, twisting at the trunk, reaching up to grasp a brick with one hand from the load on the pallet (anywhere from waist high to shoulder high) turning back and placing the brick to continue building a row around the perimeter of the ladle. The last 2 rows of this stage may be accomplished by standing but then involves frequent bending and twisting at the trunk to pick up a brick from the pallet load and again while placing it in the row on the wall.

Stage 2- Second 25% of wall (up to 60" high): The worker generally stands and retrieves bricks from the pallet load (height varying from 18" to 54") and begins this stage by forward bending slightly and twisting to place the brick on the wall, gradually building it up to shoulder level, involving reaching outward and upward.

Stage 3- Third 25 % of wall (up to 90" high): The worker stands, picking up bricks from the pallet load as in stage 2, beginning by placing the bricks from shoulder level to approximately 72" high. At this point the pallets are remove and the table platform is inserted by the overhead crane, forming a floor at the 60" level above the original floor. From this point the activity resembles that described in stage 1.

Stage 4- Final 25% of wall (up to 120" high): The activity in this stage very much resembles the work in stage 2 to the point of finishing the wall. The concluding work involves hammering or prying away excess brick and cement from the old wall followed by placement of ramming material into the top rim and behind the bricks to seal the wall. This material is then tamped into place with an air powered ramming tool resembling a small jackhammer.

Results & Discussion

Frequent, awkward postures are observed with workers performing these job tasks. Most prominent are forward bending of the trunk up to 90 degrees, trunk twisting and side bending, long periods of kneeling (with knee pads) and frequent shoulder flexion and abduction while handling the bricks. Optimal postures with good body mechanics for these tasks would be defined as:

1. Work in standing rather than kneeling positions
2. Work with no or minimal bending or twisting of the trunk
3. Handling bricks with both hands
4. Handling bricks between knuckle height and chest height keeping elbows close to trunk
5. Minimizing reach distances

Examining the observed body mechanics and work postures employed by the workers indicates that optimal positioning as described above occurs only 20% to 25% of the time during wall building (i.e. when bricks on the pallet and wall are located between 30" and 45" vertical height. During the phase 1 while laying the floor bricks, optimal positioning is rarely possible (due to kneeling and bending positions required).

Primary Ergonomic/ MSD risk factors

1. Repetition- involving trunk bending, twisting, squatting or kneeling, and upper extremity movements of reaching down, forward and above shoulder, while lifting and handling bricks at the rate of approximately 3 per minute resulting in significant generalized fatigue and localized muscle fatigue.

2. Forces and Loads- 20 to 25 lb. bricks, individually may not be excessive except for the significant repetition involved with possible lack of muscle recovery time. The Revised NIOSH lifting Equation Composite Recommended Weight Limit***** (see appendices) was 9.3 lb. with a Composite Lifting Index of 2.16. This means that the actual task is exceeds the recommended weight limit defined by NIOSH by two times.

3. Awkward postures- trunk forward bending may be combined with twisting and side bending, shoulder flexion reaching above shoulder level and kneeling while handling the load.

4. Static postures- remaining in kneeling and forward bent postures for prolonged periods while building brick layers.

5. Contact stress- grasping bricks with gloved hands.

Preliminary Recommendations:
Engineering controls

1. Design and build an adjustable floor platform that can be inserted with the overhead crane into the ladle and adjusted upward as brick layers are built up, maintaining the working height of the brick wall being laid, for the most part, at waist to chest height (controlled by worker).

2. Design and build a pallet lift table that can be inserted with the overhead crane to the brick floor of the ladle and then later removed and re-inserted to the adjustable floor platform, to adjust the height of the brick supply on the platform to maintain a knuckle height to waist height location as the bricks are removed from a stack to build the layers.

The following guidelines are offered as suggested criterion for adjustment range of these devices based on the selected group of employees being the 5^{th} to 95^{th} percentile male population used as the design goal (or target population) assuming that these criteria are feasible from an engineering perspective:

A. The floor platform should be adjustable from a low position of 15" vertically to a height of 75"
B. It should have the ability to rotate or index around 360 degrees (an advantage when only one worker is on duty)
C. The pallet lift table should be adjustable from a low position of 8" high (preferably as low as possible) to a high position of at least 32" (preferably as high as 36")
D. An indexing option should be considered as a means of rotating the load of bricks and thus reduce reach distances and trunk twisting (an advantage when only one worker is on duty)
E. The device should be efficient, safe, simple to operate and not create additional MSD risk factors.

To maintain optimal work postures and body mechanics, the newly designed work flow process would roughly follow the procedures outlined below:

1. Lay bricks on floor (no change- no engineering solution has yet been identified to improve this process)
2. Place pallet lift device in ladle on brick floor
3. Build brick wall up to approximately 45" high, maintaining pallet of bricks between knuckle height and waist height.
4. Remove pallet lift device and place adjustable floor platform into ladle at 15" high (or as low as possible)
5. Re-place adjustable pallet lift and continue building brick wall, maintaining pallet of bricks between knuckle height and waist height.
6. Raise adjustable floor platform to maintain working height of wall between waist height and chest height.

For further assistance or questions regarding this report please contact Rob Strickland, OTR at 503-667-3564.

Respectfully,

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Photos

Figure 1

Height of brick supply on pallet is not adjustable, causing worker to bend frequently while picking up bricks

Figure 2

Worker bends down to place the brick on the wall, building the layers up

Figure 3

Worker raises the ramming tool overhead to tamp down the ramming material

Appendices

NIOSH Work Practices Guide for Manual Lifting- 1991 Revised Equation

The NIOSH WPG revised equation is based on a combination of biomechanical, epidemiological, psychophysical, and physiological data. It establishes acceptable lifting limits based on selected task parameters and specifies recommended engineering controls. Proper application of the equation requires an appreciation of assumptions/limitations that underlie the equation and that characterize the job being evaluated. They can be categorized as:

A. Equation related assumptions-

1. Phychophysical laboratory studies provide the basis of much of the equation. These studies are based on perceived lifting stress as opposed to the potential for low back injury.
2. Physiological guidelines focus on preventing whole body fatigue.

B. Job related assumptions

1. Lifting and lowering tasks have the same level of risk for low back injuries. This assumption is invalid if the worker actually drops the load instead of lowering it all the way to the destination.
2. Activities other than lifting are minimal and do not require significant energy expenditure. These include holding, pushing, pulling, walking climbing. etc.
3. There are no unpredictable conditions such as an unexpected heavy load.
4. Lifting and lowering is performed with two hands.
5. Lifting and lowering is limited to no more than eight hours.
6. The worker is standing while performing the lifting/lowering.
7. The lifting/lowering occurs at a moderate pace, characterized by slow and smooth movements with constant velocity.
8. The load is stable (center of mass does not shift).
9. Equation does not apply to one handed lifting, lifting while seated or kneeling, lifting wheelbarrows or shoveling.
10. The workers are physically fit and accustomed to physical labor.
11. Favorable environmental conditions exist involving temperature (66-79 deg. Fahrenheit) and humidity (35 to 50%).
12. The floor surface is even.
13. The surface between the shoe sole and the floor has a .4 static coefficient of friction.
14. The work space is not restricted.

Recommended Weight Limit (RWL) and Lifting Index (LI)

The NIOSH equation computes the RWL which is assumed to be safe for 99% of the male population and 75% of the female population for the given task being evaluated. The lifting index (LI) is computed by dividing the actual weight being handled (numerator) by the RWL (denominator). If this resulting number is less than one (1) the task is considered safe. If the LI is greater than one it exceeds the recommended weight limit and results in increased risk of injury to employees

Ergonomics and Musculoskeletal Disorders

BACKGROUND (Adapted from Federal Register, Nov. 23,1999, Department of Labor, OSHA, Ergonomics Program; Proposed Rule)

Ergonomics is the science of fitting the workplace conditions and job demands to the capabilities of the working population. It is an applied science, incorporating engineering, anatomy, physiology, psychology, anthropology and medical sciences. Effective "fits" assure high productivity, avoidance of illness and injury risks, with increased comfort and satisfaction among the work force. A primary goal of occupational ergonomics is the prevention of work-related musculoskeletal disorders (MSDs).

What are work-related musculoskeletal disorders?

MSDs are injuries or disorders of the muscles, tendons, joints, spinal discs, nerves, ligaments or cartilage. MSDs develop as a result of repeated exposure to ergonomic risk factors. Work related MSD's are those disorders to which the work environment and the performance of work contribute significantly. Another familiar and related term is cumulative trauma disorders, (CTDs). Common examples of MSDs include carpal tunnel syndrome, tendonitis, epicondylitis, herniated spinal discs, sciatica, low back pain, trigger finger and DeQuervain's disease.

What are ergonomic risk factors?

Ergonomic risk factors are the aspects of a job or task that impose biomechanical stress on the worker. Ergonomic risk factors are the synergistic elements of MSD hazards. OSHA discusses a large body of evidence supporting the finding that exposure to ergonomic risk factors in the workplace can cause or contribute to the risk of developing an MSD. This evidence, which includes thousands of epidemiologic studies, laboratory studies, and extensive reviews of the existing scientific evidence by NIOSH and the National Academy of Science, shows that the following ergonomic risk factors are most likely to cause or contribute to and MSD:

1. Force (i.e., forceful exertions, including dynamic motions)
2. Repetition
3. Awkward postures
4. Static postures
5. Contact Stress
6. Vibration
7. Cold temperatures

These risk factors are described briefly below:

Force

Force refers to the amount of physical effort that is required to accomplish a task or motion. Tasks or motions that require application of higher force place higher mechanical loads on muscles, tendons, ligaments and joints. Tasks involving high forces may cause muscles to fatigue more quickly. High forces also may lead to irritation, inflammation, strains and tears of muscles, tendons and other tissues.Force can be internal, such as when tension develops within the muscles, ligaments and tendons during movement. Force can also be external, as when a force is applied to the body, either voluntarily or involuntarily. Forceful exertion is often associated with the movement of heavy loads, such as lifting heavy packages, pushing a heavy cart, or moving a pallet. Hand tools that involve pinch grips require more forceful exertions than those that allow other grips such as a power grip.

Repetition

Repetition refers to performing a task or series of motions over and over again with little variation. When motions are repeated frequently (e.g., every few seconds) for prolonged periods (e.g., several hours, a work shift), fatigue and strain of the muscle and tendons can occur because there may be inadequate time for recovery. Repetition often involves the use of only a few muscles and body parts, which can become extremely fatigued while the rest of the body is little used. As task cycles in jobs get shorter (and the number of repetitions per minute increases) employees are at greater risk of injury. Where tasks cycles are short, the same muscles are in constant use and the muscles get no rest from the force required to perform the task cycle.

Awkward postures

Award postures refer to positions of the body (e.g., limbs, joints, back) that deviate significantly from the neutral position while job tasks are being performed. Neutral posture is the position of a body joint that requires the least amount of muscle activity to maintain. For example, the wrist is neutral in a handshake position, the shoulder is neutral when the elbow is near the waist, the back is neutral when standing upright.

Examples of awkward postures include: bent wrists while typing, bending over to grasp or lift an object, twisting back and torso while moving heavy objects and squatting. Awkward postures often are significant contributors to MSDs because they increase the work and the muscle force that is required.

Static postures

Static postures (or “static loading”) refer to physical exertion in which the same posture or position is held throughout the exertion. These types of exertions put increase loads or forces on the muscles and tendons, which contributes to fatigue. This occurs because not moving impedes the flow of blood that is needed to bring nutrients to the muscles and to carry away the wasted products of muscle metabolism. Examples of static postures include gripping tools that cannot be put down, holding the arms out or up to perform tasks, or standing in one place for prolonged periods.

Vibration

Vibration is the oscillatory motion of a physical body. Localized vibration, such as vibration of the hand and arm, occurs when a specific part of the body comes into contact with vibration objects such as powered hand tools (e.g., chain saw, electric drill, chipping hammer) or equipment (e.g., wood planer, punch press, packaging machine). Whole-body vibration occurs when standing or sitting in vibrating environments (e.g., driving a truck over bumpy roads) or when using heavy vibrating equipment that requires whole-body involvement (e.g., jackhammers).

Contact stress

Contact stress results from occasional, repeated or continuous contact between sensitive body tissue and a hard or sharp object. Contact stress commonly affects the soft tissue on the fingers, palms, forearms, thighs, shins and feet. This contact may create pressure over a single area of the body (e.g., wrist, forearm) that can inhibit blood flow, tendon and muscle movement and nerve function. Examples of contact stress include resting wrists on the sharp edge of a desk or workstation while performing tasks, pressing of tool handles into the palms, especially when they cannot be put down, tasks that require hand hammering, and sitting down without adequate space for the knees.

Cold temperatures

Cold temperatures refer to exposure to excessive cold while performing work tasks. Cold temperatures can reduce the dexterity and sensitivity of the hand. Cold temperatures, for example, cause the worker to apply more grip force to hold hand tools and objects. Also, prolonged contact with cold surfaces (e.g., handling cold meat) can impair dexterity and induce numbness. Cold is a problem when it is present with other risk factors and is especially problematic when it is present with vibration exposure.

Exposure to one ergonomic risk factor may be enough to cause or contribute to an MSD. For example, a job task may require exertion of so much physical force that, even though the task does not involve additional risk factors such as awkward postures or repetition, an MSD is likely to occur. However, most often ergonomic risk factors act in combination to create a hazard. Evidence shows that of these risk factors, the combination of force, repetition and awkward postures, especially when occurring at high levels are most often associated with the occurrence of MSDs. Jobs that have multiple risk factors have a greater likelihood of causing or contributing to MSDs, depending on the duration, frequency and magnitude of employee exposure to each risk factor or to a combination of them. Thus, it is important that ergonomic risk factors be considered in light of their combined effect in causing or contributing to an MSD.

Solving Ergonomic Problems

As stated above, a primary goal of ergonomics is the prevention of work-related musculoskeletal disorders (MSDs). Ideally, this is accomplished while simultaneously enhancing the productivity and job satisfaction of the employee work group. This is accomplished by identifying the ergonomic risk factors and systematically eliminating or reducing employee exposure to them. There are three approaches to this process described briefly below:

Engineering controls:

Engineering controls are physical changes to a job that eliminate or materially reduce the presence of MSD hazards. They are the primary and preferred method of improving job tasks to reduce exposure to MSD risk factors. Examples of engineering controls for MSD hazards include changing, modifying or redesigning the following:

1. Workstations
2. Tools
3. Facilities
4. Equipment
5. Materials
6. Processes

Work practice controls:

Work practice controls involve changes in the way an employee does the job. They are defined as changes in the way an employee performs the physical work activities of a job that reduce exposure to MSD hazards. Work practice controls involve procedures and methods for performing work safely. Examples of this type of control are training workers to: use good body mechanics and lifting techniques, to vary the tasks they perform throughout the day to minimize muscle fatigue and to use a new or modified tool properly. In the context of ergonomic programs, work practice controls are essential, both because they reduce ergonomic stressors in their own right and because they are critical if engineering controls are to work effectively.

Administrative controls:

Administrative controls are management-controlled work practices and policies designed to reduce exposures to MSD hazard by changing the way work is assigned or scheduled. Administrative controls reduce the frequency, magnitude, and/or duration of exposure and thus reduce the cumulative dose to any one worker. Examples of this type of control are employee rotation, job enlargement, and employer-authorized changes in the pace of work. Administrative controls should be used with caution and only after careful consideration of all reasonable engineering controls.

Ergonomic assessment tools:

- NIOSH Guide to Manual Lifting
- Postural assessments
- Risk factor check lists
- Task frequency and duration
- Force/weight measurements
- Dimension measurements
- Anthropometry data comparisons
- Energy demand
- Body mechanics assessment
- Environmental factors

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