

# Ladle Relining Lift Equipment – Ergonomic and Technical Design Considerations

Key words: ladle relining, rebricking, lift, ergonomics, safety, injury prevention

## INTRODUCTION

For millennia, bricklayers have been suffering from the physically demanding and repetitive nature of their work. In fact, of all the construction trades, “masonry is one of the highest risk groups for non-traumatic MSDs (musculoskeletal disorders) of the back, shoulders, arms and legs.”<sup>1</sup> Refractory masons who specialize in rebricking the interior of ladles in the steel industry face many of the same ergonomic challenges as their colleagues in the construction industry. This paper seeks to explore the ergonomic reasons driving the recent surge of interest in powered ladle relining lifts and to provide technical guidance and considerations for specifying and recommending the purchase of such equipment.

## TYPICAL MASONRY ACTIVITIES THAT CAUSE LOWER BACK MSDS

Since the majority of work-related injuries in the masonry trade are in the lower back<sup>2</sup>, a review of the NIOSH literature related to such injuries indicates the following risk factors:

1. Heavy physical work
2. Lifting and forceful movements
3. Bending and twisting (awkward postures)
4. Whole body vibration
5. Static work postures<sup>3</sup>

Although any one of these factors can cause injury on its own, the risk increases when multiple factors exist simultaneously in the same occupation.

Based on a report by Rob Strickland which provides an ergonomic evaluation of ladle rebricking activities at Cascade Steel<sup>4</sup>, it is clear that 4 of the 5 risk factors apply to ladle rebricking activities:

### Heavy Physical Work

NIOSH Definition: heavy tiring tasks, manual materials handling tasks, and heavy, dynamic, or intense work.<sup>3</sup> This definition applies to ladle rebricking since it involves the repetitive lifting, moving and placement of refractory bricks which can weigh anywhere from 10-28 lbs. each. The placement of as many as 3 bricks per minute<sup>4</sup> over the course of an 8 hour shift requires considerable physical strength and energy.

### Lifting and Forceful Movements

NIOSH Definition: Lifting is defined as moving or bringing something from a lower level to a higher one. Forceful movements include movement of objects in other ways, such as pulling, pushing, or other efforts.<sup>3</sup> Repetitive lifting of bricks and mortar to the brick face is a key activity in bricklaying as described under the Heavy Physical Work risk factor above.

### **Bending and Twisting (awkward postures)**

NIOSH Definition: Bending is defined as flexion of the trunk, usually in the forward or lateral direction. Twisting refers to trunk rotation or torsion. Awkward postures include non-neutral trunk postures (related to bending and twisting) in extreme positions or at extreme angles.<sup>3</sup> Strickland, in his ergonomic evaluation of ladle rebricking at Cascade Steel, noted considerable trunk bending, twisting, squatting and kneeling coupled with reaching above shoulder height or below knee height during the rebricking process.<sup>4</sup>

### **Whole Body Vibration (WBV)**

NIOSH Definition: WBV refers to mechanical energy oscillations which are transferred to the body as a whole (in contrast to specific body regions), usually through a supporting system such as a seat or platform.<sup>3</sup> Whole body vibration was not noted as a primary ergonomic risk factor in ladle rebricking activities at Cascade Steel.<sup>4</sup> However, it should be noted that some vibrations were encountered during the use of powered tamping tools.<sup>4</sup>

### **Static Work Postures**

NIOSH definition: Static work postures include isometric positions where very little movement occurs, along with cramped or inactive postures that cause static loading on the muscles.<sup>3</sup> Strickland noted static postures as a primary ergonomic risk factor at Cascade Steel due to prolonged periods of standing in a bent over position or kneeling during ladle rebricking.<sup>4</sup>

## **WORK PLATFORM OPTIONS**

Since the position of the mason relative to both his bricks and to the wall he is building has a direct impact on the amount of bending and lifting required, consideration should be made of the work platform options available. There are currently two basic work platform options for ladle rebricking: stackable stationary platforms and powered lifting devices.

### **Stationary work platform / scaffolding / pies**

Stationary work platforms are placed by crane within the ladle one atop another throughout the rebricking process to periodically raise the level of the refractory mason(s). These stackable platforms are also commonly referred to as scaffolding or pies. Time must be spent removing all materials and allowing personnel to exit via ladder each time an additional platform is added to the stack.



Figure 1 Photo of stacks of stationary “pies” in foreground and stationary brick pallet tables in background

### **Powered lift devices**

Once the floor and bottom rows of bricks have been placed within the ladle, a powered lift device can be lowered into the ladle by overhead crane. The ladle relining lift can be quickly repositioned by the worker at any time to maintain an optimal ergonomic working position. Ladder use, and therefore the potential for falls, is greatly reduced since the lift can be easily raised to allow personnel to exit or enter the working area. A secondary pallet lift can also be loaded onto the primary lift to adjust the pallet of refractory brick so that it too remains at an ergonomically desirable height.



Figure 2 Example of collapsed ladle lift with secondary lift in raised position on top

### SUPPORT FOR POWERED LIFT DEVICES

A key recommendation by both OSHA<sup>5</sup> and by the Construction Safety Association of Ontario<sup>2</sup> to help combat lower back MSDs is the use engineering controls such as lifts or automated materials handling equipment. A powered lifting platform can help to keep the work area of the mason positioned roughly waist level where minimal movements in both the back and arms are required.

In a study of bricklaying ergonomics in the construction industry, the “wrist/hands to elbows” zone was identified as being the one where bricklayers were at their most comfortable and productive.<sup>6</sup> The study included the use of both questionnaires and an experiment to measure actual productivity at different working heights. The study found that maximum bricklaying productivity occurred from a height of 1’4” above the work platform to 4’0”. The following negative effects on productivity were found at levels above and below the recommended working zone:

Height above work platform	Effect on Productivity
From 0’ to 1’4”	19% to 23% drop
From 4’0” to 5’4”	29% to 33% drop
From 5’4” to 6’8”	48% to 53% drop

Table I Summary of productivity findings in article “Productivity & Ergonomics: Effect of Spatial Variables on Bricklaying” by Rasha Stino<sup>6</sup>

The primary conclusion drawn from this study is that the zone of highest productivity matched the zone where masons are most comfortable working. Interestingly, Stino goes on to remark that although there is a lack of published scientific studies on the benefits of adjustable scaffolding, her findings “present evidence to substantiate and quantify the advantages of adjustable scaffolding.”<sup>6</sup>

In several government sponsored studies, powered lift devices have been found to be beneficial for bricklayers in both the construction and steel industries. An ergonomic demonstration project was undertaken by Spilker Masonry in Spokane, Washington in 2001 to find ways to prevent MSDs in construction masons. One control that they researched was a comparison of hydraulic powered scaffolding vs. standard scaffolding. Spilker found that powered hydraulic tower scaffolding not only kept bricklayers at optimal ergonomic laying height but also increased productivity by 20%.<sup>7</sup>

In the steel industry, a follow-up ergonomics evaluation following the implementation of ladle relining lifts at Cascade Steel in Oregon found that a comparison between pre and post project employee discomfort surveys indicated a 32% decrease in overall refractory bricklayer discomfort levels and slightly increased production efficiencies.<sup>8</sup>

To substantiate this finding among additional purchasers of ladle lift equipment, a small, informal survey of ladle lift purchasers was undertaken by the authors of this paper (please see Appendix I for complete survey results). The answers indicate that the primary benefits of using such lifts were reduced ladderwork and risk of injuries. Employee morale among brickers was also noted as being “somewhat increased” to “greatly increased” in all plants where ladle lifts had been introduced.

Additionally, a small powered lift table placed on top of the platform lift may be helpful in keeping the mason’s supply of bricks at an optimal ergonomic height. In a study of masons in the construction industry in Ontario, the recommendation was that the minimum height for platforms of brick should be knee-level to reduce the amount of forward bending. The same study found that bricklayers (working without the benefit of a brick lift) often bend forward more than 1,000 times per shift.<sup>2</sup>

## LADLE LIFT DESIGN CONSIDERATIONS

The following section is provided for steel mill personnel as a layman's guide to the various powered ladle lift design specifications and options that should be considered when working with a lift supplier.

### Ladle sizes suited to the use of powered lift devices

A two-stage scissor lift is a commonly used lift style for the ladle rebricking process. This type of lift features two sets of scissors one atop the other, and provides an ergonomic bricking range from approximately 5 feet above the refractory base to 13 feet or more. The low end of this range is based on an approximate collapsed lift height of 2 feet plus the roughly 3 feet required to reach the waist height of a typical worker standing on the lift. The upper range of the lift's vertical travel is determined by the diameter of the ladle at its base: the greater the diameter, the longer the scissors can be and the higher the lift can travel.

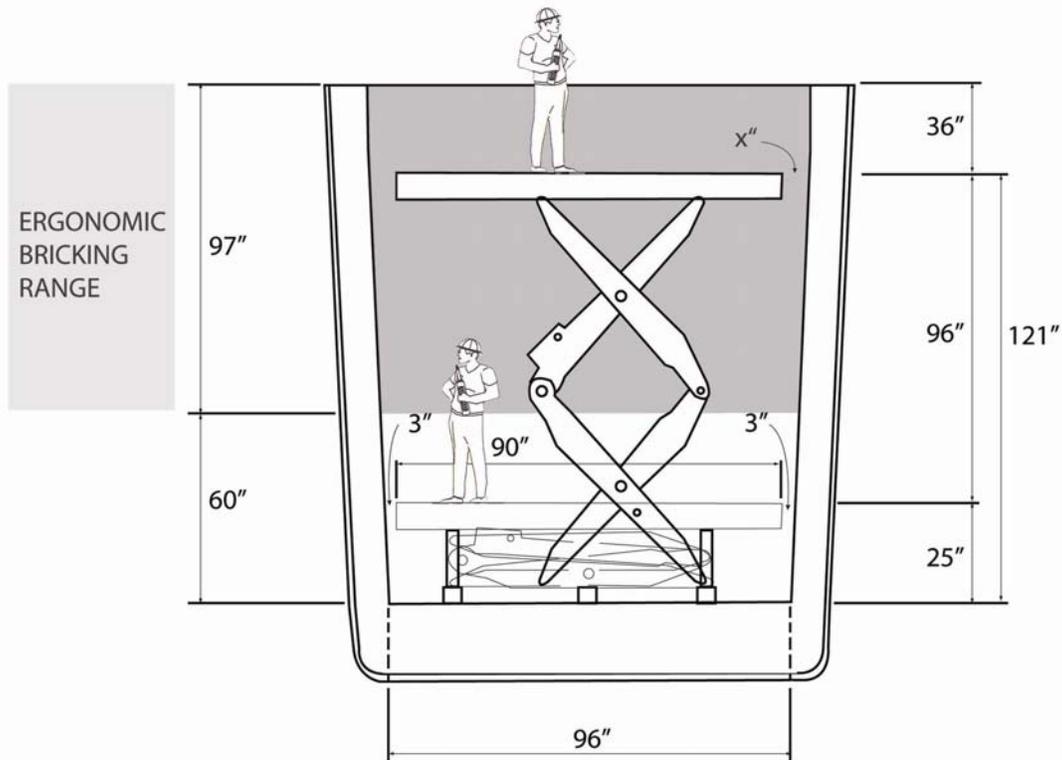


Figure 3 shows a typical two-stage lift inside a ladle in both the fully collapsed and fully raised positions.

The diameter of the ladle at the base in Figure 3, from brick face to brick face, is 96". An allowance of 3" between the lift's circumference and the wall face results in a maximum lift platform diameter of 90". At this diameter, the maximum vertical travel of the lift is 96" measured from the top of the collapsed lift to the top of the fully raised platform.

It should be noted that ladles smaller at the base than the example in Figure 3 may be suitable for a powered lift device however a different number of scissor stages may be required depending on the depth of the ladle. Your lift manufacturer should have the engineering expertise to advise you on the lifting device best suited for your particular ladle.

Ladles measuring 71" or less from the top of the ladle to the top of the refractory base are not suitable for powered lifting devices for practical reasons. The height of the collapsed lift is often enough of a boost to the worker that no additional elevating is required. Therefore, the use of a stationary "pie" would be a more cost effective solution for ladles of minimal depth.

### Customizing the top platform of the lift to the size and shape of the ladle

To keep the amount of stretching and reaching by the refractory masons minimized as much as possible during the ladle rebricking process, it is important to keep the lift as close to the brick face as possible. For this reason, the top platform of the lift should be customized to fit the exact shape and size of the ladles being serviced. When the collapsed lift is placed via overhead crane into the ladle, the top of the collapsed lift platform should be within 3" of the refractory face around the full circumference of the lift.

Since most refractory ladles are tapered with the narrowest diameter at the base of the ladle, the distance from the edge of the lift to the brick face increases as the workers travel upwards (see measurement “x” in Figure 3). Platform extensions of various types have been tried in the field to help narrow the gap between the lift platform and the brick face in the upper work zones of the ladle with mixed results. A frank discussion with your lift manufacturer of the extension options available - including sliders, fold-downs, clip-ons, etc. - is recommended.

Other safety recommendations for the design of the top platform include a toe plate around the edge of the platform and anti-slip provisions. The toe plate is recommended so that the refractory masons have a tactile warning of where the edge of the platform is and to prevent tools and debris from being brushed or kicked off the platform. An anti-slip surface such as checker or diamond plate on the platform is also strongly recommended to prevent accidental slips and falls.

### **Lift actuation – why hydraulic scissor lifts are recommended**

Hydraulically actuated scissor lifts are the recommended lift solution for ladle rebricking applications for several reasons. In terms of lift style, scissors are the optimal design for this application (as opposed to a single or multi-post design) for the simple reason that a lift actuated from below the platform provides unobstructed 360° access to the bricking area. Post lifts would by nature have one or more posts sticking above the platform during most of the lift’s travel that would partially obstruct access to the work area.

In terms of lift actuation, hydraulic is superior to both mechanical (usually screw) and pneumatic (compressed air) actuation options for ladle rebricking. The two most important considerations for a ladle rebricking lift are lift low / collapsed height and cost. Secondary considerations include the potential for actuator contamination and ease of maintenance.

### **Lift low height**

When comparing lifts with the same platform size, a hydraulically actuated lift offers a lower collapsed lift height than a mechanically or pneumatically actuated device. This is primarily because the power source for a hydraulic actuator need not be attached directly to the actuator: it can be placed at a distance within the lift base frame at a point that allows the lowest collapsed lift height possible. A mechanical actuator requires the power source to be directly attached thereby increasing the collapsed height of the same lift. A pneumatic lift’s low height is not affected by the physical presence of a power source but by its operating pressure. Since the operating pressure (psi) of compressed air is approximately 20 times lower than that of a hydraulic actuator, a cylinder with a bore 4.5 times larger than the one required for a hydraulic lift of the same capacity must be used. This increase in cylinder size translates into an increased lift low height. Minimizing lift low height is important for maximizing the useful bricking range of the lift.

### **Cost**

At the lifting capacity typically required for a ladle rebricking operation (roughly 8,000 to 12,000 lbs.), hydraulic actuation is the most cost effective of the three actuation options. Pneumatic actuation would be second due to increased costs associated with the larger cylinders required. Mechanical actuation would be the most expensive option due in large part to the cost of the drive-line.

### **Potential for Contamination of Actuator**

Both hydraulic and pneumatic actuators are by design better sealed against contamination from dust and debris than mechanical devices. Essentially the rod is cleaned of debris each time it moves into and back out of the tightly sealed cylinder used in both hydraulic and pneumatic applications. Mechanical actuators are typically protected from debris by bellows boots. The problem with bellows is that they require air movement into and out of the actuator area each time the bellow is stretched and then compressed with the motion of the lift. Although air filters are typically incorporated in the bellows to prevent contamination, the filters may frequently become blocked with debris and require manual cleaning. In some cases, workers will remove the filters completely due to frustration with the regular cleaning required in particularly contaminated work environments. Unfortunately, this leads to contamination of the actuator which reduces its lifespan and increases the costs associated with spare parts, downtime, and maintenance over the life of the lift. With the significant amount of dry and wet mortar being dripped onto the lifts, complications from contamination should be a consideration.

### **Maintainability**

Of the three actuation types, hydraulic has the potential for requiring the least amount of maintenance. Hydraulic lifts can be designed using sealed for life bearings or bushings resulting in a lubrication free device. The frequency of lubrication for pneumatic lifts is determined by the quality of the compressed air being used to actuate the lift. Finally, mechanical lifts have parts which require periodic lubrication making them the lift type requiring the most maintenance.

Having made the case for hydraulic actuation, it is further recommended that a discussion occur between the lift purchaser and his supplier regarding the type of hydraulic fluid to be used in the lift. Often times it is possible (and desirable from a practical standpoint) to design the hydraulic lift to utilize a fluid already cleared for use within the purchaser’s steel mill.

## Capacity

The capacities of both the personnel lift and the brick lift are an important consideration when specifying a powered lifting device for ladle rebricking. The capacity of the primary lift should account for:

1. the combined weight of the maximum number of brick pallet(s) piled simultaneously on the lift *plus*
2. the combined weight of the maximum number of personnel working on the lift at any one time *plus*
3. the weight of the brick lift (if used) *plus*
4. the weight of mortar and tools used onboard the lift.

Depending on your lift manufacturer, they may build to suit your exact capacity requirement or they may recommend one of several standard ladle lift designs with a capacity adequate to cover your needs.

To calculate the capacity requirement for your brick lift, determine the weight of the largest brick load to be used on the lift at any time during a typical rebricking process including the pallet(s). Add to that weight any other tools or supplies typically stored on top of the brick pallet(s).

It is recommended that when making any lift capacity calculations, any potential capacity changes in the future should be taken into careful consideration in order to extend the useful life of your lift equipment.

## Durability of design

The harsh working conditions of the average steel mill require that equipment built for such an environment be durable and rugged. A powered lift must be designed to endure not only the jarring and bumping encountered while being moved into and out of ladles via overhead devices but also the impact that occurs when pallets of bricks are being loaded onto the lift. Such a lift must also be able to operate dependably in an environment where wet and dry mortar is routinely being dripped or chipped onto the equipment.

Of primary importance is how the main platform on the lift is engineered. Platforms may come as a plate or as an engineered platform. A plate is described as a flat disc of metal. An engineered platform is best described as a plate with tubular steel supports welded to the underside. This extra structural support can handle the impact and concentrated point loading of brick pallets better than a plate which may deform under the repetitive stress of such loading.

The use of metal piping for hydraulic fluids are important for avoiding punctures, breaks and the resulting hydraulic fluid leaks which can lead to lift failure, downtime and repairs.

## Leveling Capability

Depending on the requirements in each steel mill, leveling devices may or may not be required. If, for example, the powered lift is to be used during slag relines, where the base of the ladle may be uneven due to previous pours, a leveling feature may be very desirable. In mills using precast bottoms in their ladles, leveling may not be an issue. However, a lack of leveling devices may limit the future usefulness of the powered lift. Consideration of long term needs is again recommended when steel mills make the decision on whether or not to include leveling devices.

If leveling capability is requested of the lift manufacturer, leveling should occur at the base of the lift using a minimum of three but preferably four leveling devices. Four devices improve overall weight distribution and load handling stability. Furthermore, it is important that the leveling devices be accessible from the lift platform since leveling will occur once the collapsed lift has been placed within the ladle. Leveling devices will no longer be accessible from the side of the lift when this occurs.



Figure 4 Example of a leveling leg being manually adjusted from the top of the lifting platform via a special access cover.

The nature of the leveling device is limited only by budget considerations. Leveling devices may be automatically activated by push button or they may be manually adjusted via crank. Your lift manufacturer should be able to provide a variety of leveling options for you to choose from.

### **Lifting Shackles**

Like the leveling devices, lifting shackles should be attached to the base of the lift to ensure maximum stability and safe load handling via overhead device. These lifting shackles should also be accessible through the top platform of the lift when the lift is in the fully collapsed position. Ideally, such access should be via removable access covers on the lift platform to avoid creating trip hazards.

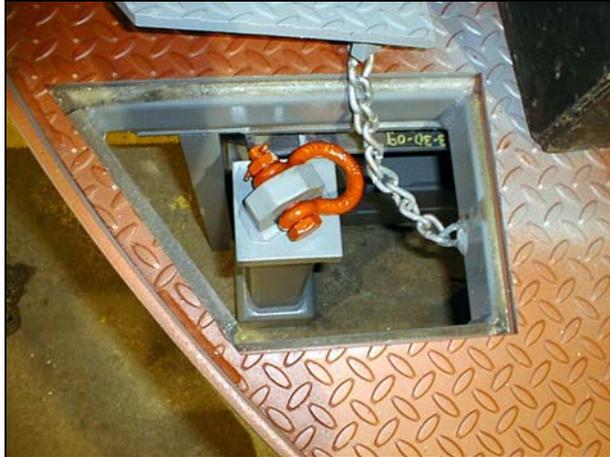


Figure 5 One of four lifting shackles accessible through the lift platform.

In the event that the lift must be lowered without the use of power, it is recommended that a manual lowering valve which is also accessible from the lift platform be incorporated in the lift.

### **Secondary table for positioning pallets of refractory bricks**

When considering the type of table best suited to the ergonomic positioning of pallets of refractory bricks, there are several options to consider: a stationary table, a spring-actuated table, or a powered scissor lift table.

#### **Stationary table**

A stationary table is the least expensive option of the three and is best suited for pallets of bricks that are of a height that does not require the mason to reach very far above or below wrist height. The study of bricklayer productivity and ergonomics by Rasha Stino found that “masons prefer brick supply stacked three to five rows high and material height at wrist/hand height.”<sup>6</sup>

#### **Spring-actuated table**

A spring-actuated pallet table is one that automatically rises as the load on the lift lightens. However, if any of the pallets used during the ladle relining process contain more than one size and weight of brick, this type of table is not recommended. The unloading of a pallet containing a variety of brick sizes may cause the table to react in unpredictable ways. These types of tables are best suited for unloading and positioning pallets containing uniform products.

#### **Powered scissor lift table**

A powered scissor lift table can be repositioned by the user as the need to raise or lower the load arises. The size of the lift platform should closely match the length and width of the brick pallet because a lift platform larger than the pallet will decrease the amount of space available between the lift and the brick face for the masons to work and move. Tipping of the load during movement and during loading/unloading of the lift can be prevented by ensuring that the lift platform is the same size as the pallet and by attaching the brick lift to the primary lift platform.

### **Control Options**

Lift functions should be controlled from the lifting platform for ease of use and to avoid unexpected motion. This can take the form of a hand-held pendant with push buttons or a guarded foot switch to control up and down motion. In either case, controls should be dead-man style – where buttons require constant pressure to operate the equipment. The use of one control of each type is recommended when a secondary brick lift is used onboard the primary lift (i.e. a foot switch on one lift and a pendant on the other) to prevent controls confusion and the unintentional movement of either lift.

Upper travel of the lift should be controlled via adjustable limit switch. Adjustability is recommended so that upper travel limits can be reset for use in ladles of various depths. It is further recommended that the limit switch be located beneath the lifting platform rather than at the baseframe as this offers the maximum protection for the switch.

### **Meeting ANSI MH29.1 – 2003 safety requirements for industrial scissor lifts**

All lift manufacturers in the United States should voluntarily adhere to the ANSI MH29.1 – 2003 safety standard.<sup>9</sup> Published by the Lift Manufacturers Product Section (LMPS) of the Material Handling Institute of America (MHIA), this document sets out in detail suggested safety practices regarding the design, manufacture, marking, installation and maintenance of industrial scissor lifts. It is recommended that purchasers require their industrial scissor lifts to be supplied in accordance with this safety standard. Purchasers should also be sure to install and maintain their industrial scissor lifts in accordance with the standard. To obtain a copy, please contact either the American National Standards Institute ([www.ansi.org](http://www.ansi.org)) or the Material Handling Industry of America ([www.mhia.org](http://www.mhia.org)).

### **Ladle Lift Maintenance Considerations**

As with any piece of equipment, some consideration of future maintenance requirements should be undertaken prior to purchase. Powered ladle relining lifts are no exception.

#### **CSA / UL approved lift components**

The use of CSA / UL approved components in your ladle relining lift simplifies the process of obtaining and stocking spare parts.

#### **Armored HPU**

It is recommended that the hydraulic power unit (HPU) at the base of the lift be covered by a sturdy metal enclosure to prevent damage from regular usage and the accumulation of mortar (please see Figure 6). The better protected the HPU is, the longer it will run without requiring repair.



Figure 6 An example of an HPU whose cover was accidentally damaged during usage allowing mortar to accumulate inside. Had the HPU not been covered, the power unit may have required replacement instead of just a thorough cleaning.

#### **Wash-down**

Figure 6 also clearly demonstrates the need for periodic wash-down of the ladle relining lift to remove mortar accumulation. You may choose to perform this type of maintenance in-house or have your manufacturer to provide you with a scheduled maintenance program where the lift can be cleaned, inspected and repaired on a regular basis.

#### **Type of hydraulic fluid used**

As stated previously, it is desirable for the manufacturer to configure the hydraulic lift to operate using the same hydraulic fluid that is approved for use in your melt shop. This avoids compatibility issues and reduces purchasing / stocking requirements.

#### **Lubrication**

Where practical, sealed for life bearings or bushings should be incorporated into lift design to minimize or eliminate the need for lubrication.

### **Safety lock-up bars**

Per the ANSI MH29.1 – 2003 safety standard, safety lock-up devices should be incorporated into the design of your lift.<sup>9</sup> These devices are specifically for use when performing lift maintenance to prevent the accidental collapse of the lift.

### **Lift documentation**

Per the ANSI MH29.1 – 2003 safety standard, the owner’s manual provided with your powered ladle relining lift should include detailed instructions on installation / start-up, operation, maintenance, trouble-shooting , and replacement parts information.<sup>9</sup> Please be sure that you receive this manual with your lift and are familiar with the contents of the manual prior to installing and using your ladle relining lift.

## **LADLE LIFT DESIGN PROCESS CONSIDERATIONS**

Since it is recommended that the platform of a ladle relining lift be custom designed to match the size and shape of the ladles being serviced, a basic design and approval process should be followed by both the purchaser and the lift manufacturer. The first step in this process is for the client to supply drawings of both the empty ladles and the ladles with refractories to the lift manufacturer. The empty ladle drawings should be provided since they reveal the accurate location of all well blocks and slide gates in the ladle bottom. The lift should be designed to straddle these openings. The refractory drawing should be provided so that the lift manufacturer can provide approval drawings which show the ladle lift within the refractory lined ladle.

The manufacturer should then provide drawings back to the purchaser for final approval of the lift’s design. The drawing(s) should show lift within actual lined ladles to ensure accuracy of form, fit and function. The drawing(s) should indicate the tare weight of the lift to allow the client to verify that their overhead handling capabilities are adequate to the task. Purchasers at this point may wish to fabricate a mock-up of the lift platform in wood or another substance to physically place within their ladles prior to final approval of the design. Although this is an optional step, it helps to avoid the problem of ladle lifts being built to suit dimensions that may have been inaccurately recorded on the purchaser’s original ladle drawings.

## **CONCLUSION**

With increasing employee and industry pressures to implement ergonomic solutions for labor intensive tasks that are prone to generating lost time injuries, powered lift solutions for ladle relining activities in the steel industry have been gaining popularity. A review of the scientific and technical papers on the subject of bricklayer ergonomics supports the use of adjustable work platforms, specifically for keeping masons at an ergonomic working height during the bricking process. A layman’s guide to the design and process considerations for powered ladle relining lifts was provided to assist the steel industry in making an informed purchase for this specific bricking operation.

## **ACKNOWLEDGEMENTS**

The authors would like to thank Jacek Kaminski, P.Eng., Director of Engineering at Handling Specialty Manufacturing Ltd. for his technical input and review of the “Ladle Lift Design Considerations” section of this paper.

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