INTERIM SURVEY REPORT:

RECOMMENDATIONS FOR ERGONOMICS ENGINEERING

INTERVENTIONS FOR SHIP CONSTRUCTION PROCESSES

at

JEFFBOAT LLC
Jeffersonville, Indiana

REPORT WRITTEN BY
Stephen D. Hudock, Safety Engineer
Steven J. Wurzelbacher, Industrial Hygienist
Ova E. Johnston, Engineering Technician

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Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health
Division of Applied Research and Technology
Engineering and Physical Hazards Branch
4676 Columbia Parkway, Mailstop R-5
Cincinnati, Ohio 45226

PLANT SURVEYED:

Jeffboat LLC,
A unit of American Commercial Lines Holdings LLC,
1030 East Market Street
Jeffersonville, Indiana 47130-4330

SIC CODE:

3731

SURVEY DATE:

November 9-10, 1999

SURVEY CONDUCTED BY:

Stephen D Hudock, Safety Engineer
Steven J Wurzelbacher, Industrial Hygienist
Ova E Johnston, Engineering Technician
Karl V Siegfried, MEMIC Safety Services,
Portland, Maine

EMPLOYER REPRESENTATIVES CONTACTED:

Stephen R Morris, CSE, CSM, ASP,
Director of Safety - Shore Facilities
David Temple, NREMTB, Safety Assistant
Gary Neese, Structural Shop Supervisor

EMPLOYEE REPRESENTATIVES CONTACTED

Michael Everhart, Chief Union Steward, Teamsters
Local Union 89

DISCLAIMER

Mention of company names and/or products does not constitute endorsement by the Centers for Disease Control and Prevention (CDC)

ABSTRACT

A pre-intervention quantitative risk factor analysis was performed at various shops and locations within Jeffboat LLC, a builder of river barges in Indiana, as a method to identify and quantify risk factors that workers may be exposed to in the course of their normal work duties. Four locations were identified the rake frame subassembly process, the unloading of angle irons in the steelyard, the honeycomb confined space welding process for double hull barges, and the shear press operation in the plate shop. Possible engineering interventions to address the risk factors associated with these processes are discussed

I.   INTRODUCTION

IA.   BACKGROUND FOR CONTROL TECHNOLOGY STUDIES

The National Institute for Occupational Safety and Health (NIOSH) is the primary Federal agency in occupational safety and health research   Located in the Department of Health and Human Services, it was established by the Occupational Safety and Health Act of 1970   This legislation mandated NIOSH to conduct research and education programs separate from the standard setting and enforcement functions carried out by the Occupational Safety and Health Administration (OSHA) in the Department of Labor   An important area of NIOSH research deals with methods for controlling occupational exposures to potential chemical and physical hazards   The Engineering and Physical Hazards Branch (EPHB) of the Division of Applied Research and Technology has been given the lead within NIOSH to study the engineering aspects of health hazard prevention and control

Since 1976, NIOSH has conducted a number of assessments of health hazard control technology on the basis of industry, common industrial process, or specific control techniques   The objective of each of these studies has been to document and evaluate effective control techniques for potential health hazards in the industry or process of interest, and to create a more general awareness of the need for or availability of an effective system of hazard control measures

These studies involve a number of steps or phases   Initially, a series of walk-through surveys is conducted to select plants or processes with effective and potentially transferable control concepts or techniques   Next, in-depth surveys are conducted to determine both the control parameters and the effectiveness of these controls   The reports from these in-depth surveys are then used as a basis for preparing technical reports and journal articles on effective hazard control measures   Ultimately, the information from these research activities builds the data base of publicly available information on hazard control techniques for use by health professionals who are responsible for preventing occupational illness and injury

IB.   BACKGROUND FOR THIS STUDY

The background for this study may be found in the previous report EPHB 229-11a, "Preliminary Survey Report Pre-Intervention Quantitative Risk Factor Analysis for Ship Construction Processes at Jeffboat LLC, Jeffersonville, Indiana "

IC.   BACKGROUND FOR THIS SURVEY

Jeffboat LLC is a private shipyard located in Jeffersonville, Indiana that performs primarily new vessel construction   This yard is considered to be a medium-to- small-size yard   The primary product of the yard is river barges of various configurations   Approximately 350 barges are completed each year   Jeffboat is a member of the Shipbuilders Council of America

Looking at Jeffboat production employees, for the period 1995 to 1998, there were 503 injuries and illnesses. From 1995 to 1998, there was a decline in both the total incidence rate (33 % reduction) and the days away from work incident rate (24 per cent reduction). Among production workers, musculoskeletal disorders represented 27 per cent of the total cases and 35 per cent of the days away from work cases. Departments within Jeffboat with the highest rates and numbers of musculoskeletal disorders include the Structural Shop, Towboats, Hatch Covers, Line 4 Sub-Assembly, Line One Hull, Line One Sides, Line 4 Hull and the Plate Shop. These same departments had the highest rates and number of musculoskeletal disorders that resulted in days away from work. Occupations with the highest number of musculoskeletal disorders include welders and shipfitters. Musculoskeletal disorders, including those resulting in days away from work, most commonly involved the lower back.

II   PLANT AND PROCESS DESCRIPTION

IIA.   INTRODUCTION

Plant Description. Jeffboat LLC calls themselves "America's Largest Inland Shipbuilder." Jeffboat's primary products are river barges and towboats. The shipyard facilities include over a mile of waterfront property, 4 drydocks and approximately 50 acres of property.

Corporate Ties. A unit of American Commercial Lines Holdings LLC.

Products. Jeffboat produces approximately 350 barges per year in a variety of configurations based on client needs including open hopper barges, double-hull liquid and chemical tankers, covered rake barges, and self-unloading cement barges. Occasionally towboats and paddlewheelers for the gaming and excursion industries have been built.

Age of Plant. The site of Jeffboat has been functioning as a shipyard since 1939. Most of the facility has been updated or rebuilt since that time.

Number of Employees, etc. Approximately 975 production employees, of which 169 are new hires with less than 90 days experience with the company. Approximately 45 per cent of the production workers are classified as welders. Annual turnover has historically been near 40 percent.

IIB. PROCESS DESCRIPTION

Figure 1   Rake Frame Subassembly Area

IIB1.   Rake Frame Subassemblies within Structural Shop

Subassemblies such as rake frames, or the skeletal framework for the curved bows of tanker, chemical, and cargo barges are created in this area Three stations exist for each type of rake frame, at approximately 21 5 feet x 36 feet each Jigs are set-up at ground-level being welded in place on the steel deck floor The overall rake frame process is as follows

    1)   Delivery of angle irons, ranging in size and shape, by overhead crane to stacks parallel to the jig set-up

    2)   Place angle irons manually into the jig, usually done by one shipfitter, sometimes in tandem lifts This placement requires worker to bend at the waist and to lift loads up to about 125 pounds Workers who do this job are very skilled and tend to slide and pivot the larger angle irons into place rather than lift the entire load Smaller angle irons (ranging in size from 45 to 90 pounds) are still often lifted entirely by hand

Figure 2   Shipfitter moving angle iron from stockpile to jig

3)   Angle irons are adjusted into place by the shipfitter using their hands and gator pry bar
      to grip the angle irons   Wedges are then hammered into place to hold the angle irons in
      place in the jig
4)   Horizontal plates at the corners of the rake frame are manually lifted, positioned on the
      frame and held in place by the use of C-clamps, as are the smaller angle irons

Figure 3   Shipfitter holding angle irons together with C-clamps

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5)   A team of 2 welders stick weld the joints of the rake frame that face up Postures
        assumed during welding are typically bent at the waist, kneeling, or sitting on the
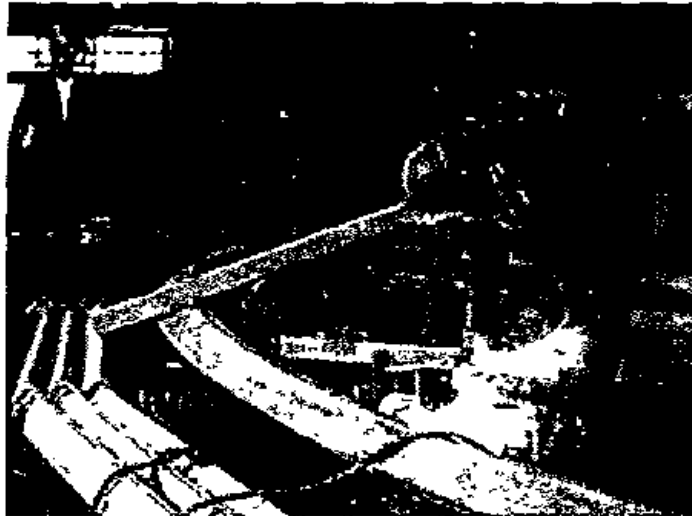   rake frame

Figure 4   Welding rake frame angle irons while standing
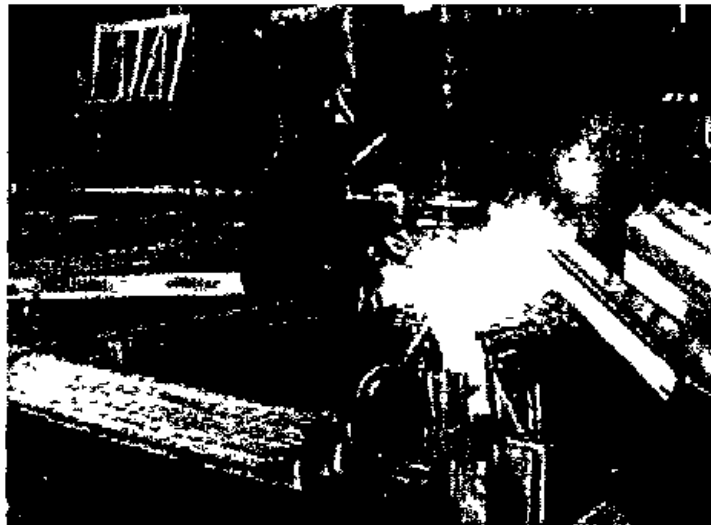

Figure 5   Welding rake frame angle irons while squatting

6)   The rake frame subassembly is released by the shipfitter knocking out the wedges with
        a hammer   The rake frame subassembly is then picked up, flipped over, and moved to
        an area adjacent to the jig by the overhead crane   Frames are stacked in piles of 6-7
        frames

7)   The welders move to the stack of frames and weld the joints that are now facing up
During this process, the shipfitter and the welders are working at the same time so that
one frame is being set up as the other is being finished welded together   Approximately
18-21 of these frames are done a day

The most common trades employed within the Structural Shop are welders and shipfitters

During rake frame subassembly, shipfitters undergo awkward postures including extreme lumbar flexion
and excessive loads to low back Welders undertake awkward postures such as extreme lumbar
flexion, shoulder abduction, wrist flexion, both ulnar and radial deviation, and kneeling on hard surfaces
The ergonomic analyses of all processes under consideration at this shipyard may be found in the
previously cited report by Hudock et al, 2000
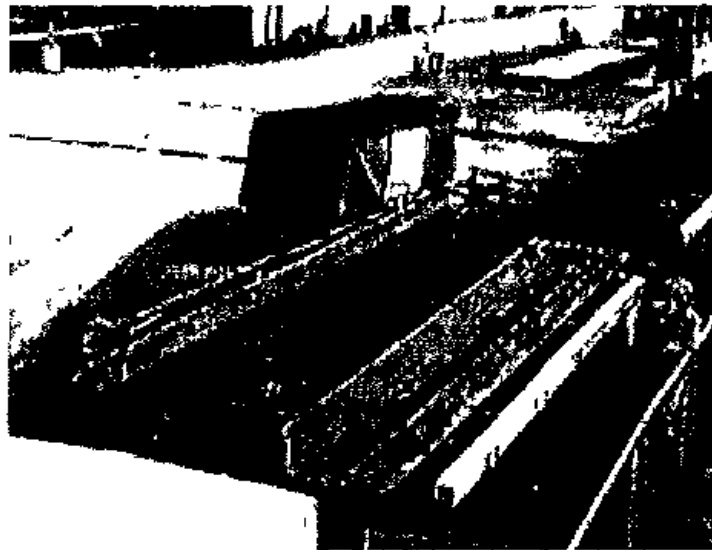
IIB2.   Angle Iron Unload in Steelyard

Figure 6   Steelyard conveyor system

Raw material, primarily steel plate and angle irons, is brought to the shipyard by truck, train or barge
Material is placed within the steelyard by the use of an A-frame crane and stored outside until needed
by the various production departments   Task under consideration is the separation of angle iron from
batch loads The type of angle iron used within the shipyard varies greatly in size, length and weight
Common angle irons are 5 inches by 3 inches by forty feet in length and 5/16 inch thick A general
description of angle iron separation process follows
1)   Large A-frame crane picks up batch load of angle irons from steelyard and transports it
to an unloading station

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2) After the crane releases the load on a large stand, the steel bands holding the batch together are cut using a set of shears and one worker begins separating the load with a gator bar, which is about 3 feet long, and weighs 12 2 pounds

Figure 7   Separating angle irons with gator bar

3) The worker grabs hold of each individual iron with the gator bar and lets it fall onto a sorting table below

4) Two workers then pull the angle across the table either by hand or with large, long hooks and spread the angle irons across the roller conveyor

Figure 8   Workers positioning angle iron on roller conveyor

5)   Once the angle irons are placed on the roller conveyor, the angle irons are transferred to a mobile conveyor section that places the angle irons into the surfpreparation process

The gator bar worker experiences awkward postures including extreme lumbar flexion and excessive shoulder loads in separating the angle irons apart   The unload helpers also experience awkward postures including moderate lumbar flexion and moderate shoulder loads in pulling the angle irons across the roller conveyor

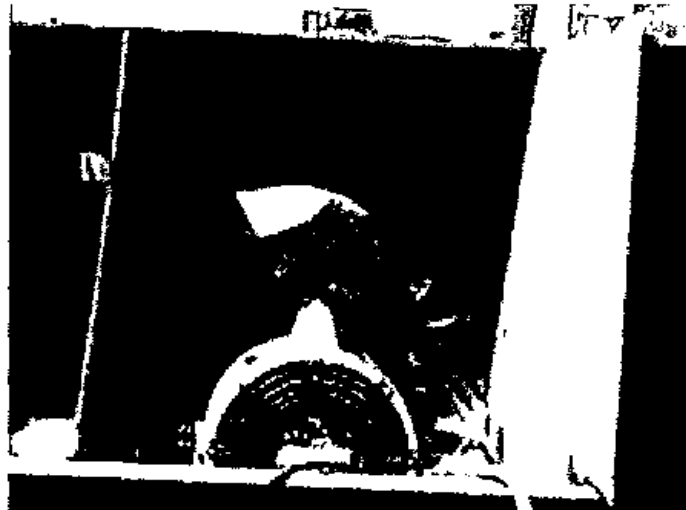## IIB3. Honeycomb Welding in Line Four Hull Area

Figure 9   Honeycomb confined space welding at Line Four Hull area

The Line Four Hull area is responsible for welding the double hulls for chemical and liquid tankers   This involves welding in spaces known as honeycombs which are two feet by two feet by sixteen feet long   The bottom plate is welded to the vertical supports on both sides of the honeycomb   Currently, a stick welding process is used   Typically 8-10 honeycombs can be completed in a shift by each welder   Ventilation is primarily by blower fan forcing outside air into the honeycomb   A detailed report on ventilation interventions for this process can be found in Wurzelbacher et al, 2000

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Figure 10   Constrained posture of confined space honeycomb welder

The welders must assume constrained postures in order to crawl to the far end of the honeycomb to begin welding This task also includes extreme lumbar flexion in confined spaces, contact stress on the knees and elbows, pulling and lifting weld leads into and out of the honeycomb, positioning the blower fan and moving it from one honeycomb to the next, and extreme environmental temperatures in summer and winter

IIB4.   Shear Operation in Plate Shop

Figure 11   Shear operation in plate shop

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The primary processes within the plate shop are to cut, size, and shape steel plate required for hulls and subassemblies using shear machines, automated plasma cutters, and manual cutting torches. The particular process flow for the shear is as follows

    1)   raw plates are moved to pallets next to shear by jib crane that sits between stations

    2)   plates are moved manually from pallet to shear, and

    3)   cut plates are sorted at the back of the shear at ground level and lifted into carts

Figure 12   Shear operator lifting plate from back of shear

Shear operators often lift awkward loads from the ground-level shear chutes and material supply pallets   Contact stresses experienced by the shear operator include kneeling on the floor to get material and contact with the sharp edges of the raw or cut material

III.   ERGONOMIC INTERVENTION COST JUSTIFICATION

The following section has been adapted from the article by Alexander, 1998

The effectiveness of any ergonomic intervention does not necessarily correlate with the cost of implementing that intervention   The possibility exists for a very effective intervention to be found at a low implementation cost, as well as, the possibility of the opposite   The preferred intervention strategy from a business sense is to implement those interventions with the lowest costs and the highest effectiveness   This point can be illustrated by the value/cost matrix as illustrated in Figure 13
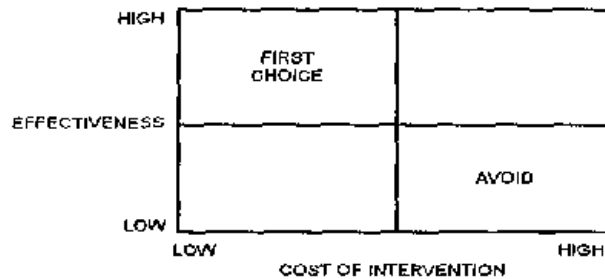
Figure 13   Value Cost Matrix

There are a number of benefits that can be credited to the application of ergonomic interventions in general   These benefits include

      – avoidance of current expenses and ongoing losses from 1) reducing workers compensation costs, 2) overtime for replacement workers, 3) lost productivity, quality or yields from less skilled workers, and 4) increased training and supervisory time,

      – enhanced existing performance from 1) increased productivity including fewer bottlenecks in production, higher output, fewer missed delivery dates, less overtime, labor reductions, and better line balancing, 2) improved quality including fewer critical operations, more tasks with every operator's control and capacity, and fewer assembly errors, 3) increased operating uptime including faster setups, fewer operating malfunctions, and less operator lag time, and 4) faster maintenance including increased access, faster part replacement, fewer tools needed, more appropriate tools, more power and faster tool speeds,

      – enhanced quality of worklife from 1) less turnover, and 2) less employee dissatisfaction,

      – fewer traumatic injuries,

      – fewer human errors resulting in lost product or operating incidents, and

      – reduced design and acquisition costs

In addition to the direct medical costs associated with worker injuries, one must also consider the indirect or hidden costs associated with the primary worker being away from their job   These indirect costs include

      – costs of replacement workers from 1) hiring costs for permanent replacements plus training and other costs, and 2) additional costs for temporary workers who may also have lower work skills

      – lower productivity, such as 1) fewer units per hour, 2) lower yields, and 3) damage to material or equipment that would not occur with an experienced worker

      – lower quality, including 1) number of rejects, 2) amount of rework, and 3) timeliness of product delivery

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– increased supervision including cost to manage/train a less skilled worker

– training to develop and maintain job skills including 1) amount of lost work time and 2) time of trainer

Many of these indirect costs are difficult to estimate and can vary widely depending on the severity of the injury involved. The ratio of indirect costs to direct costs has also been found by a number of studies to vary between 5 1 to 1 5, depending on industry (Heinrich, 1931, 1959, Levitt et al, 1981, Andreoni, 1986, Leopold and Leonard, 1987, Klen, 1989, Hinze and Applegate, 1991, Oxenburgh, 1991, 1993) As a conservative estimate, the state of Washington recently decided upon indirect costs of 75 percent of direct workers' compensation incurred costs (WAC 296-62-051, 2000)

Another aspect of ergonomic interventions that must be considered is the cost benefit analysis. If total costs outweigh total benefits received from implementing the intervention, the intervention is not worth undertaking from a strictly financial viewpoint. From the public health perspective, any intervention that reduces the risk to workers is worthwhile. One has to determine the associated start-up costs, recurring costs, and salvage costs of the intervention as well as the time value of money (present worth versus future worth) and the company's Minimum Attractive Rate of Return, the interest rate the company is willing to accept for any project of financial undertaking

IV.   CONTROL TECHNOLOGY

IVA. Rake Frame Subassembly Possible Interventions

The primary concern with the rake frame subassembly process is the fact that both the shipfitter and welders must bend forward, or flex, at the waist to perform their work at toe height. This is due in part to the jig for the rake frame being welded directly to the steel floor. An adjustable jig (more accurately, a jig top placed on a lift table) may offer a solution, and it may be that one jig can be made to fit all three rake frames (See Figures 14-17) This would open more floor space and eliminate the need for the welders and shipfitter to bend. Possible problems with this approach are that some of the workers prefer the low height of the jig because the angle irons can be pivoted and maneuvered into place easily. This can be addressed by lowering the lift table and jig as low as possible to allow the angle irons to be maneuvered in a similar manner as currently performed. Another concern is that the jig would be too high for the crane to offload, but this wouldn't be a problem if the jig table could be lowered back down to the floor when unloaded. Also, there are concerns that the welders would trip over the raised rake frame, although no welds actually require the welder to be inside of the frame while welding. The only reason that they currently stand inside of the frame while welding is because the angle irons are stacked up parallel to the jig about one foot away and impede getting around the outside of the frame. This means that the stacking of the material would have to be changed too if the jig is raised, unless the frame can be rotated as it is raised, which might be possible if engine stand type lifts were used. A rotatable jig would also eliminate the need for the crane to flip the frame and also eliminate the problem of welding the frames that are stacked on the ground first
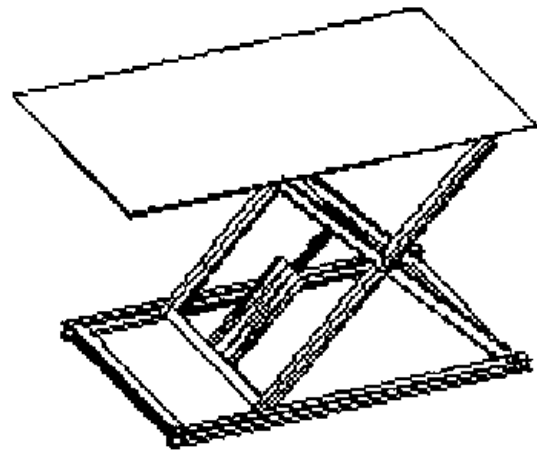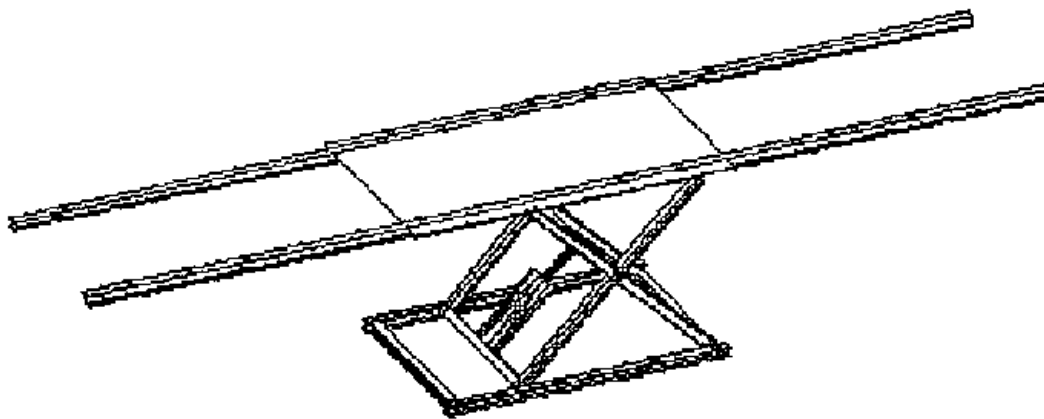
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Figure 14   Lift Table
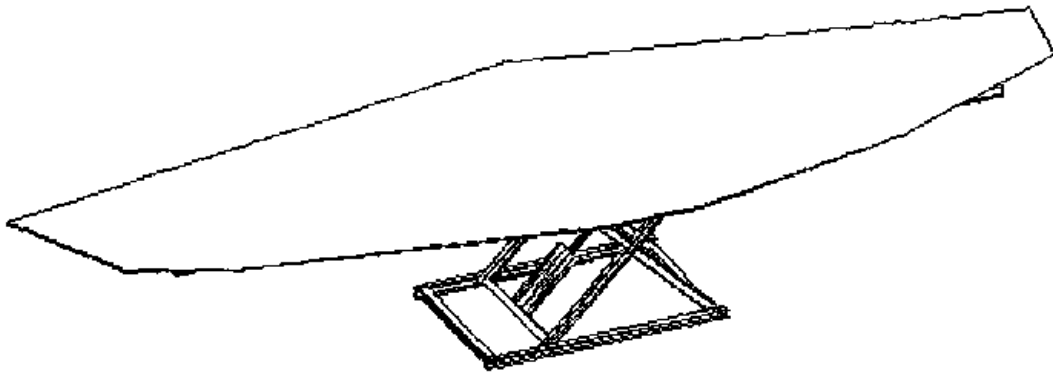
Figure 15   Lift Table with Jig Support Beams

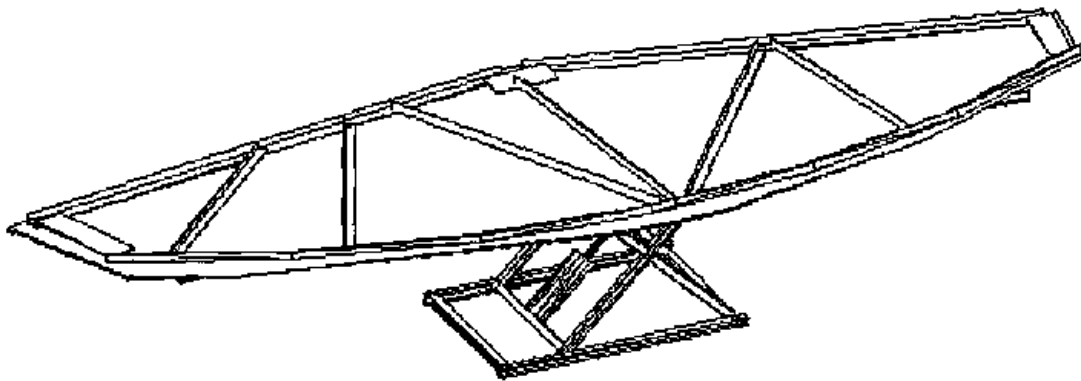13

Figure 16   Lift Table with Jig Pattern Top on Supports

Figure 17   Lift Table with Rake Frame Assembly

Table 1 Jig Table Materials

Material	Dimension	Weight	Cost
2 Jig Table Support Beams	24' x 3 5" x 3 5" x 5/16" each	172 8 lbs per beam 345 6 lbs total	$100
24 Assorted Jig Supports	6" x 3 5" x 3 5" x 5/16" each	3 6 lbs per support 86 4 lbs total	$50
Jig Table Top	28' x 10' narrowing to 3' at far ends x 1/4" = 182 ft^2	182 ft^2 x 10 2 lbs /ft^2 = 1,856 4 lbs	$500

Considering that the approximate weight of the rake frame subassembly is 1000 pounds and the weight of the jig table top is about 2300 pounds, it is suggested that a 2-ton lift table be utilized for this process to work well within the capacity of the lift table

Table 2   Approximate Lift Table Parameters

Type of Table	Low Profile Lift Table
Capacity	4,400 pounds
Lowered Height	4 0 inches
Raised Height	39 0 inches
Table Dimensions	45 inches x 61 inches
Voltage	230 Volt, 3-phase
Shipping Weight	1,150 pounds
Price	$4,550

One must consider the cost justification of implementing the intervention to determine whether the implementation makes economic sense   Assuming that the assembly of the jig table takes 20 worker hours at $20 per hour, the labor costs associated with the jig table assembly would be $400 Intervention costs are summarized in Table 3

Table 3 Cost Summary of Jig Table Intervention

Cost of Raw Materials	$650
Cost of Lift Table	$4,550
Cost of Labor	$400
Total Cost	$5,600

One must also identify the benefits associated with the implementation of any intervention as well One method of identifying benefits received from an intervention is to estimate the costs associated with injuries that may not have occurred because the intervention was in place Based on current shipyard Workers' Compensation data received to date from a number of different shipyards, it is possible to determine average medical and indemnity costs associated with musculoskeletal injuries by body part, as summarized in Table 4 From 1994 through 1998, this particular shipyard experienced seven musculoskeletal injuries within their structural shop as a result of moving angle irons or working on the rake frames, resulting in a direct total estimated medical and indemnity cost of $35,624, based upon part of body injured An average annual estimate direct cost (over the last five years) for musculoskeletal injuries for this process is $7,125 If indirect costs are conservatively assumed to be 75% of the direct costs, the total cost of these injuries is $12,468 per year It is this amount that can be considered an "avoided cost" and, therefore, a benefit due to the implementation of the intervention, if in fact the intervention eliminates all such future musculoskeletal injuries A simple benefit-cost ratio for the first year would be $12,468/$5,600 or 2 23 Since the benefit to cost ratio is greater than one, it is advantageous to implement the proposed intervention, given the parameters cited above

[1] Based on analysis of available participating shipyard compensation data from 1996 - 1998
[2] Does not include contusions or fractures

Ankle	$2,390
Arm, unspecified	$7,725
Back	$6,996
Elbow	$4,691
Finger	$735
Hand	$6,857
Knee	$7,472
Leg, unspecified	$849
Neck	$5,961
Shoulder	$4,960
Wrist	$3,925

However, possibly, only half the estimated annual injury cost is saved each year It is also possible that the jig lift table lasts at least two years Assuming that the shipyard has a minimum attractive rate of return of 20 percent for any project cash outlay, one can still calculate a benefit to cost ratio by utilizing the following equation to determine the present worth of an annual savings

$$\text{Equation 1} \qquad PW = AS \times \frac{\left[(1+i)^n - 1\right]}{i \times (1+i)^n}$$

where PW = present worth
       AS = annual savings
       i = interest rate (ex , 0 20 for 20 percent)
and n = number of years

Using an annual savings of just $6,234 at an interest rate of 20 percent over a two year period, the present worth of the proposed savings over a two year period is $9,524 Assuming initial costs of the lift table are $5,600 and negligible annual costs, the benefit to cost ratio of implementing this intervention is $9,524/$5,600 or 1 7, greater than one, and therefore still economically advantageous

IVB. Angle Iron Unload in Steelyard Possible Interventions

The primary concern with the angle iron unload process in the steelyard is the movement of individual angle irons from the bundled stack table to the proper position on the roller conveyor As currently performed this is a three-person operation with one individual flipping the angle irons off the stack with a "gator" bar and two individuals positioning the angle irons onto the roller conveyor The worker using the "gator" bar must grasp each individual angle iron with the jaw end of the bar and, using primarily arm, chest and shoulder muscles, flip the angle irons onto the roller conveyor Individual angle irons can weigh up to about three hundred pounds depending on the length and thickness of the angle iron As currently delivered the angle irons within any given bundle are stacked with their ends nearly flush (Figure 18), forcing the worker to use the pry bar end of the tool to separate the irons By having the angle irons delivered in a staggered stack configuration (Figure 19), it should be easier to separate individual angle irons from the bundle
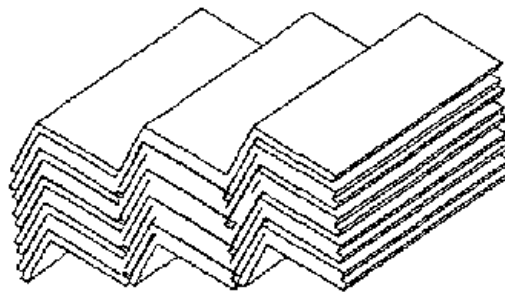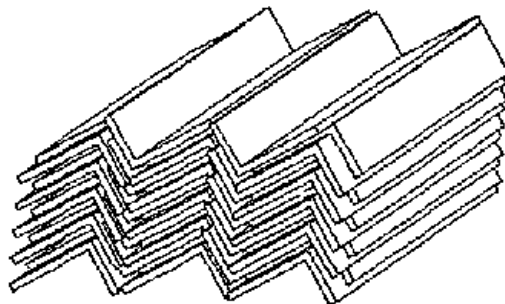
Figure 18 Even End Stacking of Angle Irons

Figure 19   Staggered End Stacking of Angle Irons

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A second possibility to aid in breaking up the bundle of angle irons is to install a pneumatic actuated breakup wedge system on the bundle support frame as illustrated in Figure 20. Once the bundle of angle irons is placed on the upper supply rack by the yard crane and the bundle ties are removed, the pneumatic cylinders can be activated to "bounce" the stack of angle irons (See Figure 21 and 22). This action should loosen the stack and make it easier to separate and then flip individual angle irons. The breakup mechanism can be installed so that the wedge extends about eight inches above the support rack surface when in the "up" position. When in the "down" position the point of the wedge should be below the bundle support frame. The dimensions of the wedge, which should be made from a minimum of ½" thick steel as shown in Figure 23. Approximate costs associated with the implementation of the pneumatic breakup wedge system are detailed in Table 5.
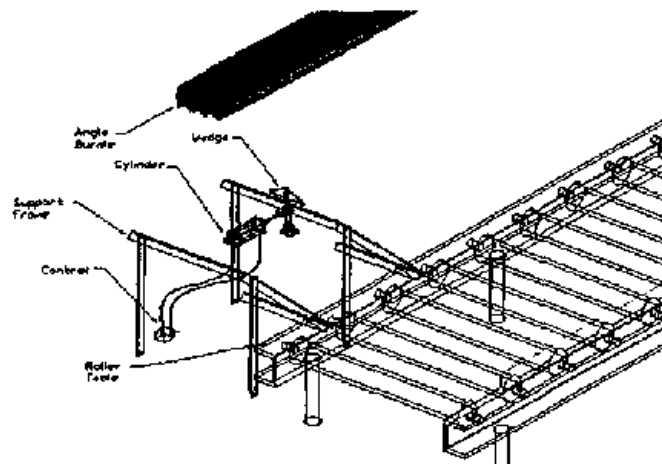

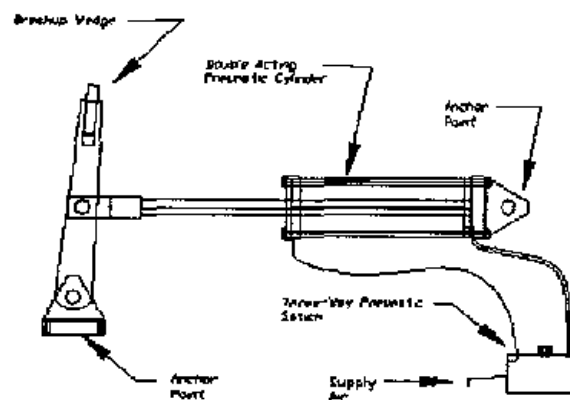Figure 20 Pneumatic Angle Wedge Breakup System

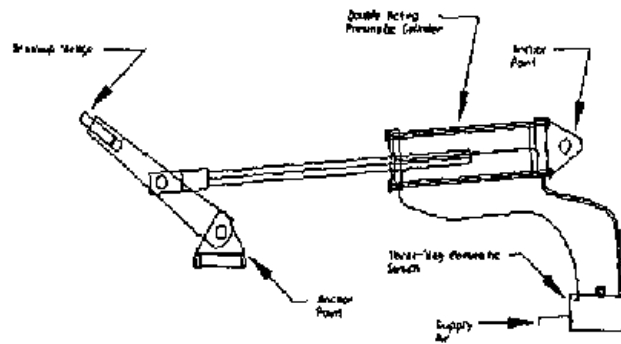Figure 21 Breakup Wedge in "Up" Position

Figure 22 Breakup Wedge in "Down" Position

(Blank Size = 1/2"x12"x18"

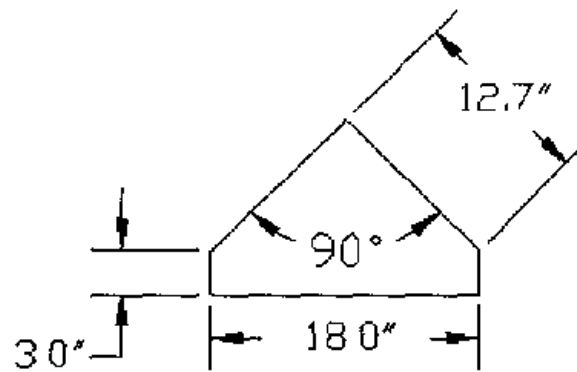Figure 23 Breakup Wedge Design

Table 5. Approximate Cost of Pneumatic Breakup Wedge System

Cost of 2 cylinder pneumatic system	$2,000
Labor, including installation (25 hours @ $20/hour)	$500
Total Costs	$2,500

From 1995 through 1998, this particular shipyard experienced six musculoskeletal injuries within their steelyard as a result of working with angle irons, resulting in a total direct estimated medical and indemnity cost of $38,905, based upon estimated costs associated with part of body injured An estimated yearly average total musculoskeletal injury direct cost for this specific process within the shipyard is $9,726 If indirect costs are conservatively assumed to be 75% of the direct costs, the total cost of these injuries is $17,021 per year It is this amount that can be considered an "avoided cost" and, therefore, a benefit due to the implementation of the intervention, if in fact the intervention eliminates all such future musculoskeletal injuries A simple benefit-cost ratio for the first year would be $17,021/$2,500 or 6 81 Since the benefit to cost ratio is greater than one, it is advantageous to implement the proposed intervention, given the parameters cited above

However, possibly, only half the estimated annual injury cost is saved each year It is also possible that the pneumatic breakup wedge system lasts at least two years Assuming that the shipyard has a minimum attractive rate of return of 20 percent for any project cash outlay, one can still calculate a benefit to cost ratio, using Equation 1, to determine the present worth of an annual savings Using an annual savings of just $8,510 at an interest rate of 20 percent over a two year period, the present worth of the proposed savings over a two year period is $13,002 Assuming initial costs of the pneumatic breakup wedge system are $2,500 and negligible annual costs, the benefit to cost ratio of implementing this intervention is $13,002/$2,500 or 5 2, greater than one, and therefore still economically advantageous

A third possible intervention to address the handling of the angle irons in the steelyard is to develop a push ram system, as illustrated in Figure 24, to slide items across the roller conveyor This system would eliminate one worker position since that one worker will no longer be necessary to hook and pull angle irons or other material across the roller conveyor Approximate push ram system parameters are listed in Table 6 and estimated costs listed in Table 7
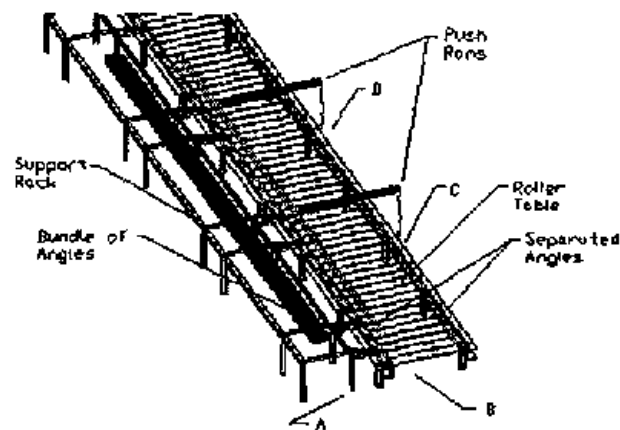

Figure 24 Push Ram System for Roller Conveyor

Table 6 Push Ram System Parameters

Push ram components	Two push rams, working simultaneously, controlled by one computer
Target size	6" x 6" x 9' (overall)
Maximum push distance	7 feet
Maximum push speed	105 feet per minute
Maximum push force	100 pounds per ram

Table 7 Approximate push ram system costs

Push rams with encoders	$2,500 each x 2 = $5,000
Computer	$3,500
Control software	$3,000
Miscellaneous (cabling, connectors, input/output devices)	$2,000
Installation labor	75 hours x $20 per hour = $1,500
Total initial costs	$15,000

Cost savings for this system can be reflected in the saved labor costs from eliminating one position to pull material across the roller conveyor Assuming labor costs at approximately $20 per hour x 2080 hours per year results in a savings of $41,600 The benefit cost ratio of this intervention would be $41,600/$15,000 or 2 77 In other words, this system should pay for itself in less than 5 months, just by eliminating the need for one steelyard worker

IVC. Confined Space Welding on Line Four Hull Possible Interventions

Possible interventions for the confined space welding process at this shipyard are detailed in the report by Wurzelbacher et al, 2000 In summary, the interventions include the change in weld process from stick to wire welding, the use of creeper carts to allow the worker to roll to the back of the honeycomb section, the installation of automatic welding systems, and improved ventilation systems

IVD. Shear Operation in Plate Shop Possible Interventions

The primary concern for the plate shop shear press operator or helper is the constant bending at the waist or kneeling to pick up material from the back of the shear press at floor level   One possible solution is to provide an adjustable lift table for the shear chute at the back of the machine, as seen in Figures 25 through 27   By placing the edge of the rear chute on top of the lift table, one can greatly improve the process   In this way the cut material would still fall onto the back chute of the shear press, however, when the worker needs to remove material from the chute, the lift table can be elevated, elevating the rear chute at the same time and allowing the worker to transfer cut material to the lift table at approximately waist height   This would eliminate the need for the worker to lift objects off the rear chute at near floor level   The rear chute plate weighs approximately 100 pounds and the weight of any material cut at any one time is under 300 pounds   It is suggested that a battery operated lift table be used to raise and lower material   Suggested approximate table characteristics are shown in Table 8   Approximate setup and training time with the table should be approximately 15 worker hours   At $20 per hour average wage, this amounts to an additional cost of $300
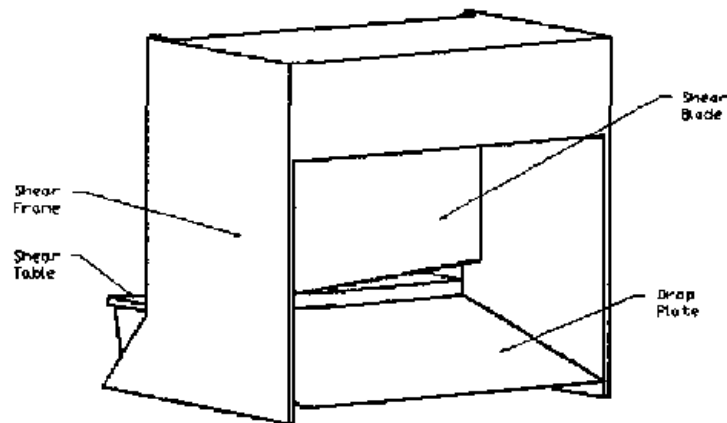

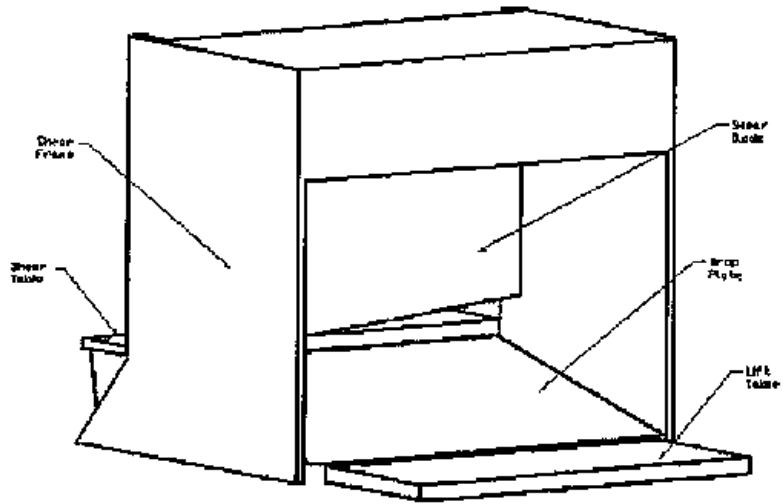Figure 25   Oblique Rear View of Shear
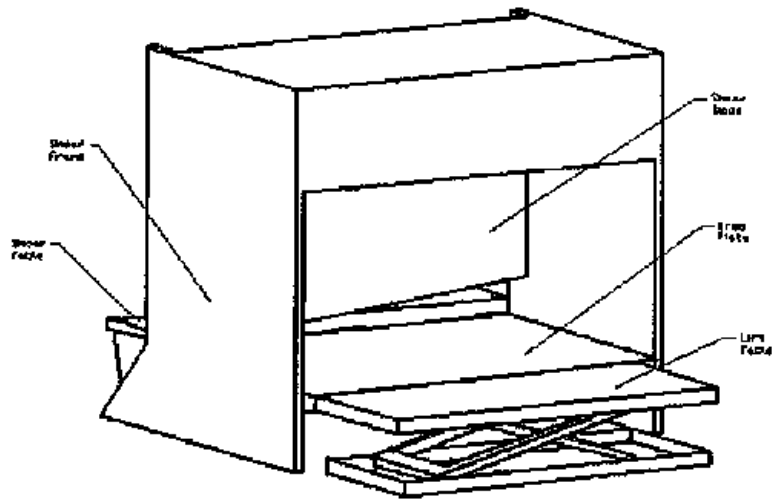
Figure 26   Shear with Lift Table in Down Position

Figure 27   Shear with Lift Table in Up Position

Table 8 Approximate Shear Press Lift Table Characteristics

Type of Table	Wheeled Battery Powered Lift Table with Hand Pendant
Capacity	1,500 pounds
Table Dimensions	24 inches x 48 inches
Vertical Travel	36 inches
Price	$1,700

Total cost for the lift table and the worker time is estimated to be $2,000

In identifying benefits of the intervention, one can use the medical and indemnity cost estimates as shown in Table 4 From 1994 to 1998, this particular shipyard experienced three musculoskeletal injuries to machine operators within the plate shop, resulting in a total estimated medical and indemnity cost of $17,917, based upon average costs by part of body injured The average annual estimate direct cost for musculoskeletal injuries for this process is $3,583 If indirect costs are conservatively assumed to be 75% of the direct costs, the total cost of these injuries is $6,271 per year It is this amount that can be considered an "avoided cost" and, therefore, a benefit due to the implementation of the intervention Assuming, the intervention fully eliminates such injuries, a simple benefit to cost ratio would be $6,271/$2,000 or 3 14 Since the benefit to cost ratio is greater than one, it is advantageous and cost-effective to implement the proposed intervention However it is possible that only half of the estimated annual injury cost is saved each year It is also possible that the lift table lasts at least two years Assuming that the shipyard has a minimum attractive rate of return of 20 percent for any project cash outlay, one can still calculate a benefit to cost ratio utilizing Equation 1 Using an annual savings of just $3,135 at an interest rate of 20 percent over a two year period, the present worth of the proposed savings would be $4,790 Assuming initial costs of the lift table are $2,000 and negligible annual costs, the benefit to cost ratio of implementing this intervention is $4,790/$2,000 or 2 4, greater than one, and therefore still economically advantageous

V.   CONCLUSIONS AND RECOMMENDATIONS

Four work processes within a barge building operation were surveyed to determine the presence of risk factors associated with musculoskeletal disorders and to arrive at possible interventions   The rake frame sub-assembly task requires workers, in the shipfitter trade, to maneuver long steel angle irons into position in a pattern laid out on the shop's steel floor These long angle irons can weigh up to approximately 240 pounds and are slid or bounced into position between jigs welded onto the floor Smaller angle irons and steel plates are manually placed to form cross members or corner supports The combination of manual materials handling and awkward posture of a bent torso to place the material near floor level results in a job the can be considered high in musculoskeletal disorder risk

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factors. Six separate exposure assessment techniques were used to quantify the risk factors associated with this shipfitter job. A possible intervention is raising the work surface by installing a lift table to hold the jig pattern for the rake frame, eliminating the bent torso for much of the task. Welders who join the individual pieces of steel also exhibit awkward postures while working near floor level. By raising the work surface, these awkward postures are minimized.

The unloading of angle iron in the steelyard was also analyzed with a number of exposure assessment techniques. The high amount of effort required to separate and flip individual pieces of long angle iron are some of the risk factors associated with this process. Possible interventions include staggering the end of the bundle of angle irons, installing a breakup wedge system to encourage the stack of angle irons to loosen when dropped by the yard crane, and automating some of the processes to eliminate the pulling of angle irons into position across the roller conveyor.

The honeycomb welder task in the manufacture of double hull sections requires the worker to enter a confined space and weld two seams between vertical supports and the bottom steel plate. This process can be improved from current conditions by changing ventilation set-ups, changing from stick to wire welding, or by automating the welding process. This last option may be most desirable to remove the worker from exposure to risk factors. Otherwise, the constrained postures, exposure to contact stresses to the knees and elbows, and exposure to some welding fumes would still be present. Creeper carts, as used in automobile repair garages, may allow the worker to travel to the back of the honeycomb section with less strain on their knees and back.

The shear operator in the plate shop often bends at the waist to pick up pieces of steel, either from a supply bin or from the tray at the back of the shear machine. Manually lifting the pieces of steel from near floor level results in undue stress on the back of the workers. By incorporating lift tables or tilting pallet jacks into areas both in front and behind the shear machine one can minimize the stress on the workers' backs.

Each of the interventions proposed in this document are to be considered preliminary concepts. Full engineering analyses by the participating shipyard are expected prior to the implementation of any particular suggested intervention concept to determine feasibility, both financially and engineering, as well as to identify potential safety considerations.

It is suggested that further action can be taken to mitigate the exposure to musculoskeletal risk factors within each of the identified tasks. The implementation of ergonomic interventions has been found to reduce the amount and severity of musculoskeletal disorders within the working population in various industries. It is suggested that ergonomic interventions be implemented at Jeffboat to minimize the hazards in the identified job tasks.

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