THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS
601 Pavonia Avenue, Jersey City, NJ 07306
Tel. (201) 798-4800 Fax. (201) 798-4975
Paper presented at the 2001 Ship Production Symposium, June 13 - 15, 2001
Ypsilanti, Michigan

PAPER 17

Implementation of Shipyard Ergonomic Interventions

Stephen D. Hudock[1](M), Steven J. Wurzelbacher[2]( ) Laurence D. Reed[2]( ), Thomas R. Hales[2]( ), Karl V. Siegfried[3]( )

ABSTRACT

Researchers at the National Institute for Occupational Safety and Health (NIOSH), in conjunction with the Facilities and Tooling initiative of the MARITECH Advanced Shipbuilding Enterprise, conducted a series of ergonomic interventions at eight shipbuilding, ship repair and ship breaking yards across the United States. These interventions were targeted to address those processes within the shipyards that resulted in the highest number, most severe, or costliest work-related musculoskeletal injuries. Examples of problem processes included confined space welding tasks, overhead insulation installation or removal, electric cable pulling, and exposure to vibrating powered hand tools. Pre-intervention risk factor analyses were conducted using various exposure assessment techniques to develop baseline information for each process considered. Following the intervention implementation, the same exposure assessments were applied in order to quantify the effectiveness of each intervention. Productivity, quality and health metrics are discussed, as are technology transfer techniques.

INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH), one of the Centers for Disease Control and Prevention (CDC), is conducting a project concerned with the implementation of ergonomic interventions for targeted work processes within the domestic maritime industries. Historically, the domestic shipbuilding, repair and recycling industries have had much higher incidence rates that those of general industry, manufacturing, or construction. For 1999, the last year available, the U.S. Bureau of Labor Statistics reported that the shipbuilding and repair sector (SIC 3731) had a recordable injury rate of 20.2 per 100 full-time employees (FTE). By contrast, in 1999 the manufacturing sector reported a rate of 9.2 per 100 FTE, construction reported a rate of 8.6 per 100 FTE, and general industry reported a rate of 6.3 injuries per 100 FTE (Figure 1).

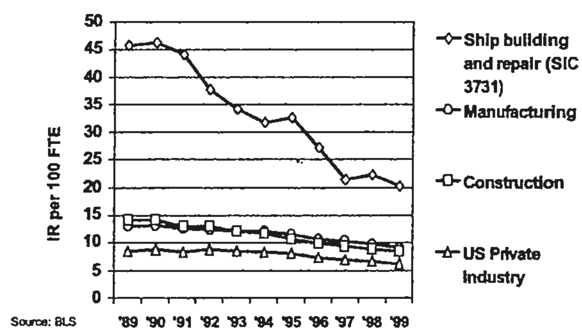

Figure 1 - Recordable Injury Rate by Industry, 1989 - 1999

[1] Centers for Disease Control and Prevention (CDC), National Institute for Occupational Safety and Health (NIOSH), DART
[2] Centers for Disease Control and Prevention (CDC), National Institute for Occupational Safety and Health (NIOSH)
[3] MEMIC Safety Services

When considering lost workday cases, for 1999 shipbuilding and repair had an incidence rate of 10.7 per 100 FTE, compared to manufacturing at 4.6, construction at 4.2, and general industry at 3.0 lost workday cases per 100 FTE (Figure 2).

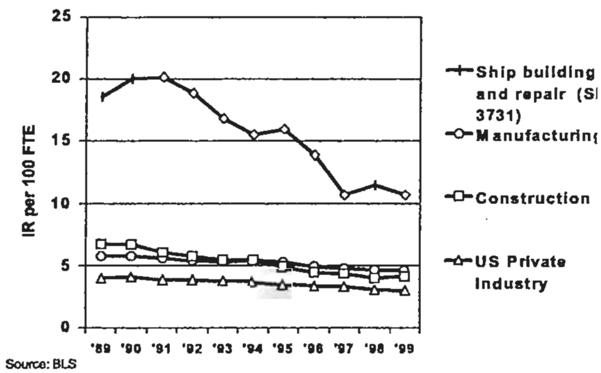

Figure 2 - Lost Workday Case Rate by Industry 1989 - 1999

When one considers which part of the worker's body is being injured and the injury also resulted in lost workdays, shipbuilding and repair was significantly different than the manufacturing sector. For injuries to the upper extremity, in 1998 shipbuilding and repair had an injury incidence rate of 80.1 per 10,000 FTE compared to 70 per 10,000 FTE for the manufacturing sector (Figure 3).

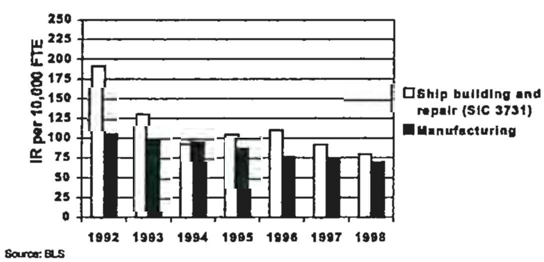

Figure 3 - Upper Extremity Incidence Rate, 1992-1998

For back injuries in the same year, shipbuilding and repair had an injury incidence rate of 93.6 per10,000 FTE, nearly twice the manufacturing rate at 49.4 per 10,000 FTE (Figure 4).

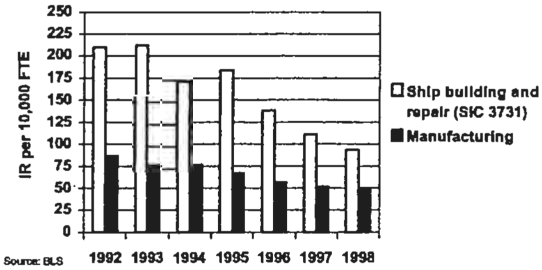

Figure 4 - Back Incidence Rate, 1992-1998

For injuries to the lower extremity, shipbuilding and repair had an injury incidence rate of 126 injuries per 10,000 FTE, compared to 40.7 injuries per 10,000 FTE for the manufacturing sector, over three times higher (Figure 5).

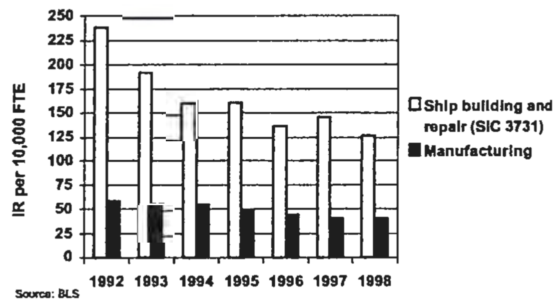

Figure 5 - Lower Extremity Incidence rate, 1992-1998

In 1999, MARITECH Advanced Shipbuilding Enterprise announced the availability of funding, through the U.S. Navy, to develop projects focused on the improvement of shipbuilding and repair work practices and processes. Researchers at NIOSH successfully competed for the external funding and were able to expand the scope of their initial project.

METHODOLOGY

In order to obtain a representative sample of shipyard processes, it was decided to sample by yard size, primary function and location. The American Shipbuilding Association, representing the six largest ship construction companies and about 90 percent of shipyard production workers, was contacted and three yards agreed to participate:

1) Bath Iron Works in Maine, a new construction yard building guided missile destroyers for the U.S. Navy;
2) Litton Ingalls Shipbuilding in Mississippi, also primarily a new construction yard, building identical guided missile destroyers as Bath Iron Works; and
3) Continental Maritime, a West Coast subsidiary of Newport News Shipbuilding performing repairs work.

Many smaller new construction and repair yards are represented by the Shipbuilders Council of America, and this association provided four shipyards for the project:

1) Jeffboat, on the Ohio River in Indiana, building river barges and associated vessels;
2) Halter Marine (now part of Freide Goldman Halter), primarily a builder of small commercial and Navy vessels on the Gulf Coast;
3) Marinette Marine in Wisconsin, building coastal and oceangoing buoy tenders for the U.S. Coast Guard; and
4) Todd Pacific Shipyards in Washington, now primarily a repair facility. The U.S. Navy provided access to Puget Sound Naval Shipyard, a public yard scrapping and recycling nuclear submarines, also located in Washington.

At each of the eight participating shipyards, an initial review of workplace injuries and musculoskeletal disorders was conducted. This process helped researchers to identify those work tasks resulting in the most frequent, severe, or costliest injuries and disorders. Once the specific tasks were identified, qualitative and quantitative risk factor surveys were performed for each of the job tasks.

Exposure Assessment Techniques

A variety of exposure assessment techniques were implemented where deemed appropriate to the job task being analyzed. The techniques used for analysis include:

1) the Rapid Upper Limb Assessment (RULA);
2) the Strain Index;
3) a University of Michigan Checklist for Upper Extremity Cumulative Trauma Disorders;
4) the OVAKO Work Analysis System (OWAS);
5) a Hazard Evaluation Checklist for Lifting, Carrying, Pushing, or Pulling;
6) the NIOSH Lifting Equation;
7) the University of Michigan 3D Static Strength Prediction Model; and 8) the PLIBEL method.

The RULA (McAtamney & Corlett 1993) is a survey method developed to assess the exposure of workers to risk factors associated with work-related upper limb disorders. On using RULA, the investigator identifies the posture of the upper and lower arm, neck, trunk, and legs. Considering muscle use and the force or load involved, the investigator identifies intermediate scores, which are cross-tabulated to determine the final RULA score. This final score identifies the level of action recommended to address the job task under consideration.

The Strain Index (Moore & Garg 1995) provides a semiquantitative job analysis methodology that appears to accurately identify jobs associated with distal upper extremity disorders versus other jobs. The Strain Index is based on ratings of intensity of exertion, duration of exertion, efforts per minute, hand and wrist posture, speed of work, and duration per day. Each of these ratings is translated into a multiplier. These multipliers are combined to create a single Strain Index score.

The University of Michigan Checklist for Upper Extremity Cumulative Trauma Disorders (Lifshitz & Armstrong 1986) allows the investigator to survey a job task with regard to the physical stress and the forces involved, the upper limb posture, the suitability of the workstation and tools used, and the repetitiveness of a job task. Negative answers are indicative of conditions that are associated with the development of cumulative trauma disorders.

The OWAS (Louhevaara & Suurnäkki 1992) was developed to assess the quality of postures taken in relation to manual materials handling tasks. Workers are observed repeatedly over the course of the day and postures and forces involved are documented. Work postures and forces involved are cross-tabulated to determine an action category that recommends if, or when, corrective measures should be taken.

The NIOSH Hazard Evaluation Checklist for Lifting, Carrying, Pushing, or Pulling (Waters & Putz-Anderson 1996) is an example of a simple checklist that can be used as a screening tool to provide a quick determination as to whether or not a particular job task is comprised of conditions that place the worker at risk of developing low back pain.

The NIOSH Lifting Equation (Waters et al. 1993) provides an empirical method to compute the recommended weight limit for manual lifting tasks. The revised equation provides methods for evaluating asymmetrical lifting tasks and less than optimal hand to object coupling. The equation allows the evaluation of a greater range of work durations and lifting frequencies. The equation also accommodates the analysis of multiple lifting tasks. The Lifting Index, the ratio of load lifted to the recommended weight limit, provides a simple means to compare different lifting tasks.

The University of Michigan 3D Static Strength Prediction Program (3DSSPP) is a useful job design and evaluation tool for the analysis of slow movements used in heavy materials handling tasks. Such tasks can best be analyzed by describing the activity as a sequence of static postures. The program provides graphical representation of the worker postures and the materials handling task. Program output includes the estimated compression on the L5/S1 vertebral disc and the percentage of population capable of the task with respect to limits at the elbow, shoulder, torso, hip, knee, and ankle.

The PLIBEL method (Kemmlert 1995) is a checklist method that links questions concerning awkward work postures, work movements, and design of tools and the workplace to specific body regions. In addition, any stressful environmental or organizational conditions should be noted. In general, the PLIBEL method was designed as a standardized and practical assessment tool for the evaluation of ergonomic conditions in the workplace.

ANALYSIS

A total of 47 work processes chosen from among the eight participating shipyards were analyzed with respect to the musculoskeletal risk factors that may have been present for the specific tasks. The following tasks are representative of those identified and analyzed: electric cable pulling and connecting, plate and pipe welding, grinding, cutting by torch or reciprocating saw, insulation installation and removal, abrasive blasting, manual materials handling, and small unit assembly. To simplify analysis, the processes were divided into 12 trade-specific categories: blasters, burners, cutters, electricians, grinders/chippers/scrapers, insulators, machinists, material handlers/riggers, sheet metal workers, shipfitters, subassemblers, and welders. A quantitative risk factor analysis was conducted for each of the identified processes utilizing appropriate exposure assessment tools from those described previously (Hudock et al 2000a-l, Wurzelbacher et al 2000a-b).

For the RULA, 11 of 12 trades were analyzed using this method, excluding machinists. The average for the 11 trades was 5.7 on a scale of 1 to 7 on increasing urgency to modify the process. For the OWAS method, all 12 trades were analyzed, resulting in a mean score of 2.6 on a scale of 1 to 4, of increasing urgency to modify the process. For the Strain Index, blasters, cutters, electricians, grinders/chippers/scrapers, and insulators performed processes that resulted in scores that placed the processes in the upper half of four categories linked to the occurrence of distal upper extremity injury.

For the PLIBEL method, looking at the neck, shoulder, and upper back, blasters, cutters, electricians, material handlers/riggers, shipfitters, and subassemblers exhibited greater than 50% of the associated risk factors in the completion of their work processes. For the PLIBEL method for the elbow, forearms, and hands, all trades except machinists and sheetmetal workers exhibited greater than 50% of the associated risk factors for their work processes.

For the Michigan Checklist method, all 12 trades exhibited greater than 50% of the associated risk factors in the performance of their work processes. Three trades, material handlers/riggers, shipfitters, and subassemblers, exceeded the NIOSH recommended compression limit on the back of 770 pounds in the 3DSSPP analysis for manual material handling tasks. Work processes of both machinists and material handlers/riggers exceeded a Lifting Index of 1.0 when evaluating the work with the NIOSH Lifting Equation. A Lifting Index greater than 1.0 indicates that the lifting tasks pose an increased risk for lifting-related low back pain for some fraction of the workforce.

RECOMMENDATIONS

Blasters

Possible interventions for abrasive blasters in a beach blast area (Figure 6) include adjustable racks to hold the materials to be blasted at approximately knee to waist height. This would reduce the amount of back flexion required for the job. Racks that allow certain work pieces to be hung would also reduce the amount of material handling that the abrasive blaster is required to perform in order to blast all sides of the material.

Figure 6 - Abrasive Blaster

A primary concern with the water jet blasting process is the fact that the worker is required to hold the water cannon in their hands to control and direct the high-pressure water spray (Figure 7). It is suggested that an orbital nozzle mount, similar to those found on fire engines, be fixed to the railing of the platform of the powered lift truck. The water spray can still be directed to the hull or other work surface with a high degree of flexibility while the nozzle mount removes the worker from the strain of holding the water cannon directly. Remote control nozzles would eliminate the need to have a person next to the water jet-blasting unit.

Figure 7 - Water Jet Blaster

Burners/Cutters

Possible interventions for burners/cutters primarily relate to the confined spaces in which they are required to work and the associated awkward and constrained body postures that result. Work at deck level (Figure 8) requires kneeling or squatting that can be alleviated by the use of kneepads, low-wheeled stools, or other support devices. Overhead work should be minimized where feasible to lessen the strain on the neck and shoulders.

Electricians

Possible interventions for the shipboard cable pullers include work rotation among pullers so that time spent in postures involving overhead work (Figure 9), kneeling, and back flexion are minimized and work practices to begin pulls in the middle of the cable rather than at the end (which requires pulling the entire length of cable in one pull). Semi-automated cable pulling systems are also commercially available and may be integrated into the current manual pulling method. Preliminary testing with similar systems aboard Navy vessels indicate a potential for reducing cable pulling time and costs by as much as 50% with no personnel injuries. Possible interventions for shipboard cable connectors include work practices, which reduce the amount of cable preparation (stripping, tying etc.) at the switchboard, where the confined space limits work movements and postures.

Figure 8 - Torch Cutting on Deck

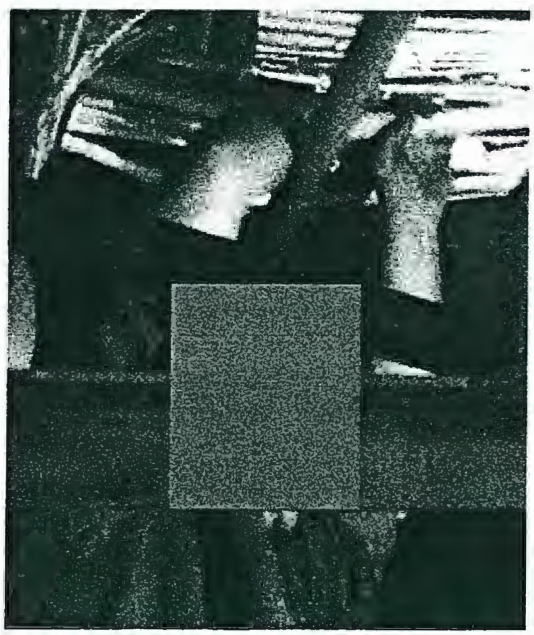

Figure 9 - Overhead Cable Pulling

Grinders/Chippers/Scrapers

Possible interventions for shipboard tank grinders include the use of support devices such as spring returns that support the weight of the tool for areas where extended vertical grinding is required. Appropriate tool balancers cost in the range of about $50-150. Process changes (e.g., use of weldable primer, more efficient and clean welding processes) and portable, self-contained abrasive blasting units to reduce the amount of required grinding may also be implemented where appropriate.

Although large scaling machines are difficult to use around various encumbrances on the deck surface, there are commercially available long-handled pneumatic tools including deck scalers, needle guns and scrapers. These may reduce the need for the worker to squat, sit, kneel, crawl or lie down in order to reach all the areas that must be stripped and may reduce the exposure to vibration (Figure 10). Another option for the deck scrapers is the use of commercially available seats designed specifically for kneeling and squatting.

Figure 10 - Deck Scraping

These seats may at least improve the postures associated with the use of hand-held scraping tools by enabling the worker to sit to lessen the stress on the knees while still enabling the worker to perform the assigned task at or near floor level without additional strain on the lower back. Knee supports are also commercially available that attach to the back of the calf to prevent over flexion of the knees during squatting postures.

Removing tile from deck surfaces requires the worker to kneel or sit on the deck. Providing kneepads or cushions minimizes some of the contact stresses. Depending on the application, worker postures may benefit from using low-wheeled stools as well. If chipping hammers cannot be replaced as the tool of choice for this task, it is recommended that the widest blade possible (at least 2 inches) be used to minimize exposure time. It is suggested that the most vibration-damped tool available be used to minimize exposure to hand-arm vibration.

Insulators

Possible interventions for the shipboard insulators (cutters) include angled knives to maintain neutral wrist postures or pneumatic powered shears to reduce grip forces and repetition. Work rotation between the cutters and installers may also reduce the time spent in overhead postures by the worker performing the installation task. Another possible intervention is the use of powered shears to reduce the upper extremity force required and deviated wrist posture required to cut the insulation with the hawksbill cutters. Pneumatic models that can be used on a variety of materials (e.g., vinyl, textiles, wire, metal, and fiberglass) are commercially available.

Machinists

The primary concern for shear operators or helpers is the constant bending at the waist or kneeling to pick up material from the back of the shear at floor level (Figure 11). One possible solution is to provide an adjustable lift table at the chute at the back of the shear to collect the pieces and then be raised to transfer the pieces at waist height instead of at floor level.

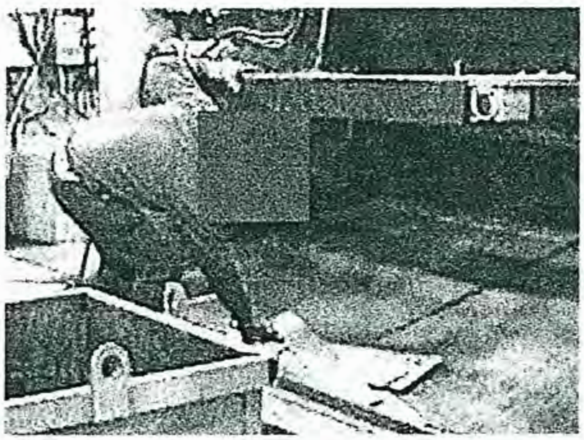

Figure 11 - Shear Operator Handling Parts

Material Handlers/Riggers

Possible interventions for supply or scrap bin loaders or unloaders (Figure 12) include adjustable bin lifters that raise and tilt the load towards the worker. Many inexpensive models of this type are commercially available. A hook-like or grasping tool for grabbing individual work pieces may also help to bring the load closer to the material handler and also reduce the need for pinch-grip hand postures. Work practices of pre-sorting heavier items and emptying them by forklift onto a rotating table top before handling may also be feasible in certain situations.

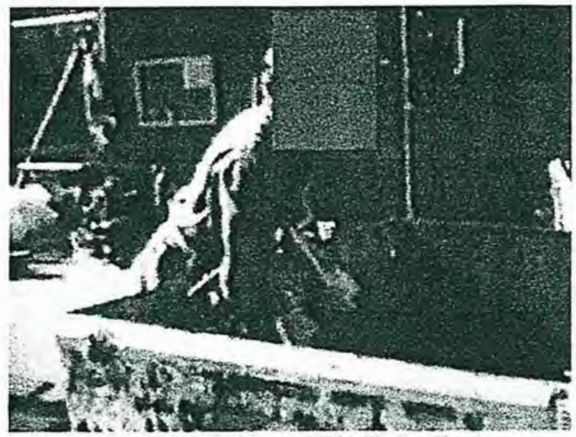

Figure 12 - Manual Bin Unloading

Possible interventions for the shipboard riggers during equipment load-in include the work practice of preparing the temporary deck surface to reduce the number of uneven plate and plywood surfaces that inhibit cart travel. Modified, low-profile carts with ball-bearing plates for top and bottom surfaces that utilize lowered axles and adjustable wheels located outside the perimeter of the transported equipment may then be used to maneuver taller pieces of equipment into place. Such carts should reduce or eliminate the need for tilting the equipment on and off pipe rollers allow for a smoother placement of the equipment into the retaining bracket. Multiple air bearing movers may also be used to lift equipment using normal compressed air, thus eliminating floor friction and allowing omni directional movement.

Ship breaking and repair often requires that all internal components be removed from portions of the vessel. Manual material handling currently performs the removal of components through ship passageways to staging areas. There is the possibility that flexible conveyor systems or cable pulley systems can be used to either move material to the staging area or to move material into scrap bins in the staging areas. Portable hoists may be useful in the staging areas as well to move heavy or bulky material.

Sheet Metal

Commercially available portable work benches may be used to position a piece of duct at a height sufficient to reduce back flexion (Figure 13) and the need to kneel while the worker performs a variety of operations on the duct. Many of these benches come equipped with vises or straps, which can be used to secure the duct during work and eliminate the need for a second worker to hold the piece. If feasible, sheet metal workers should use bench-mounted hand brakes, and metal forming presses/machines rather than hammers, hand seamers,

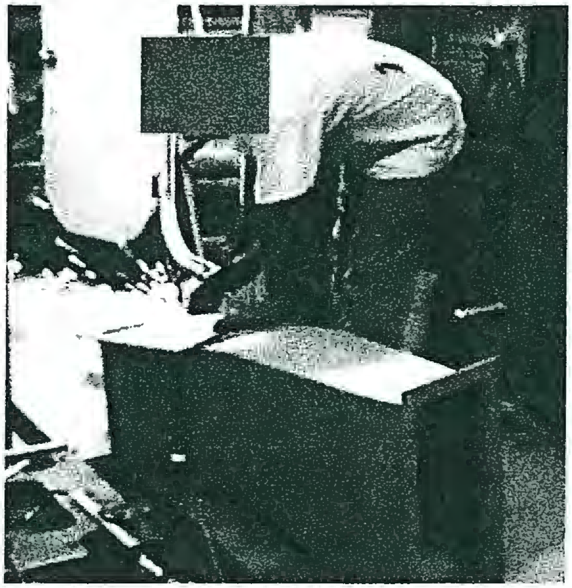

Figure 13 - Sheet Metal Worker at Duct

and hand crimpers. In most shipyards visited, shop sheet metal workers did have access to these types of machines. Thus, worker awareness training about the ergonomic benefit of these machines may be required.

Shipfitters

The come-along (lever-operated chain or wire rope devices designed for pulling) is a common shipfitting tool that can require the operator to produce pulls up to 100 lbs. The required pull depends on the brand and load capacity of the come-along. Workers should use the lowest possible capacity puller to do the job and tool personnel should take the tool's required pull into consideration when purchasing new come-alongs. Brands with lower maximum required pulls are generally slightly more expensive for a given capacity and length.

Subassemblers

Possible interventions for workers in a subassembly area include adjustable lift tables with jig tops to elevate the various subassemblies prior to grinding and needlegun operations to minimize back flexion (Figure 14). Tables or shelves to support and elevate raw stock also minimize back flexion. Training

Figure 14 - Subassembly Worker Posture

in proper lifting techniques and in the setting of adjustable equipment to optimal working heights may also be useful.

Welders

Possible interventions for panel line welders include the use of low profile, wheeled carts or stools as movable seats for the welders to reduce back flexion and the need to assume kneeling postures (Figure 15). Kneepads and supports to prevent hyper flexion of the knees during squatting are also commercially available. A possible intervention for shop welders using positioners is to train the worker to optimally set the weld positioner to provide a work height that both reduces back flexion and still enables flat welding to be performed.

Figure 15 - Panel Line Welder

All Trades

Since each repair process to be carried out onboard a vessel is constrained by the physical layout and dimensions of the existing structure, very little can be done in the area of workstation redesign or even engineering interventions, in general. It is, however, possible to address concerns raised by improper tool selection and tool usage and poor body positioning. It is suggested that basic ergonomics awareness training be considered for all production workers, emphasizing the areas cited above. While direct changes to the work environment are minimized due to the constraints of ship repair, it is possible to educate the workforce on proper procedures, better work methods and postures to assume while performing the work onboard vessels. Management is also encouraged to provide administrative controls in terms of worker rotation and scheduling to reduce the time individual workers are assigned to such tasks, subject to the constraints of any standing labor agreement. The use of teams which alternate between set-up work and welding is one such method observed in a number of shipyards.

Developing cost justifications for ergonomic interventions at any shipyard is difficult due to the fact that often the current injury database collects only OSHA 200 information and includes only a breakdown of production hours for the total yard. Thus, the foremost-recommended intervention is the utilization of an injury tracking system that will enable the identification of specific work processes that result in injuries or musculoskeletal disorders. The reduction of injuries or musculoskeletal disorders throughout any given shipyard can be greatly facilitated by the implementation of a computerized injury tracking system that integrates safety data workers compensation data, and production hour reporting and which is also based on the Bureau of Labor Statistics (BLS) injury reporting method.

CONCLUSIONS

Within ship construction, repair and breaking operations, there exist a number of specific work processes that expose the workers performing the tasks to significant risk factors associated with the development of musculoskeletal disorders. Interventions have been identified that can reduce the exposure to the associated risk factors. Implementation of ergonomic interventions has been shown in various industries to reduce musculoskeletal disorders and associated costs without adversely effecting productivity. There is no reason to believe that the implementation of ergonomic interventions in the shipbuilding, ship repair and ship breaking industries will be any less successful. The ultimate goal of this project is to produce a set of guidelines developed by consensus with industry, labor, and government on the best ergonomics practices available to the shipyard industries. The dissemination and utilization of these practices throughout the industry should result in significant reduction of musculoskeletal disorders and associated costs for all shipyards that choose to implement those best ergonomic practices.

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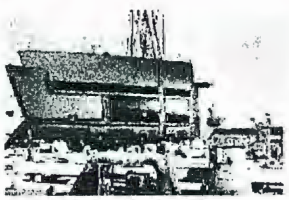
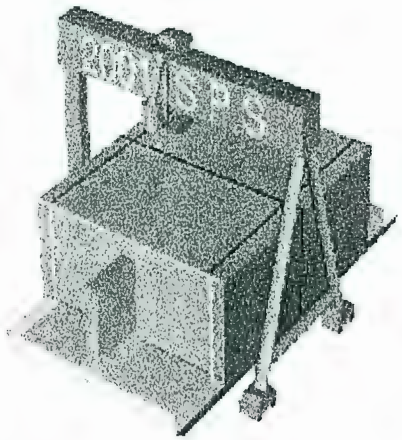
TECHNOLOGY DEVELOPMENT, DEPLOYMENT, EDUCATION AND TRAINING



2001 SHIP PRODUCTION SYMPOSIUM AND EXPO



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