FINAL SURVEY REPORT:

ERGONOMICS INTERVENTIONS

FOR SHIP REPAIR PROCESSES

at

TODD PACIFIC SHIPYARDS CORPORATION
Seattle, Washington

REPORT WRITTEN BY:
Stephen D. Hudock, Ph.D., CSP

REPORT DATE:
December 2002

REPORT NO.:
EPHB 229-18c

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health
Division of Applied Research and Technology
4676 Columbia Parkway, Mailstop C-24
Cincinnati, Ohio 45226

PLANT SURVEYED:	Todd Pacific Shipyards Corporation 1801 16th Avenue S.W. Seattle, Washington 98134
SIC CODE:	3731
SURVEY DATE:	April 12-13, 2000
SURVEY CONDUCTED BY:	Stephen D. Hudock, Ph.D., CSP Steven J. Wurzelbacher, M.S., then with NIOSH Jamie Bennett, Ph.D. Thomas R. Hales, M.D. Karl V. Siegfried, MEMIC Safety Services Portland, Maine
EMPLOYER REPRESENTATIVES CONTACTED:	Al Rainsberger, CHMM, CEI, Manager, Environmental/Occupational Safety and Health Andy Posewitz, Benefits and Employment Manager
EMPLOYEE REPRESENTATIVES CONTACTED:	Robert M. Scott, Financial Secretary, Shipwright & Joiners Local 1184

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ABSTRACT

A pre-intervention quantitative risk factor analysis was performed at various shops and locations within Todd Pacific Shipyard, as a means to identify and quantify ergonomic risk factors that workers may be exposed to in the course of their normal work duties. The application of exposure assessment techniques provided a quantitative analysis of the risk factors associated with the individual tasks. Based on these analyses, four ergonomic interventions were suggested for the Todd Pacific Shipyard: 1) an ergonomics training program for all production workers, 2) an orbital nozzle mount for the water jet blasting process in the dry dock area, 3) industrial knee pads for workers as PPE and 4) wheeled, adjustable work stools for shipboard welders, torch cutters, and grinders where feasible. Of these interventions, it was expected that the development of the ergonomic training program would have significant impact on reducing musculoskeletal injuries at the shipyard. Other projects in ergonomics started at the shipyard beyond the initial scope of this project are also mentioned.

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. 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 processes of interest, and to create a more general awareness of the need for or availability of an effective system of hazard control measures. Initially, a series of walk-through surveys are conducted to select plants or processes with effective and potentially transferable control technology 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 will build a database 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 EPHB Report No. 229-18a, "Preliminary Survey Report: Pre-Intervention Quantitative Risk Factor Analysis for Ship Repair Processes at Todd Pacific Shipyards Corporation, Seattle, WA" by Hudock and Wurzelbacher, 2000 and EPHB Report No. 229-18b, "Interim Survey Report: Recommendations for Ergonomics Interventions for Ship Repair Processes at Todd Pacific Shipyards Corporation, Seattle, Washington" by Wurzelbacher and Hudock, 2000. Both reports are available at the NIOSH website: http://www.cdc.gov/niosh/ergship/reports.html.

IC. BACKGROUND FOR THIS SURVEY

Todd Pacific Shipyards Corporation was selected for a number of reasons. It was decided to sample a variety of yards based on product, processes, and location. Todd Pacific Shipyards Corporation is a private shipyard located in the Northwest corner of Harbor Island, in Elliott Bay, near downtown Seattle, Washington. Todd Pacific Shipyards Corporation currently performs vessel repair and overhaul, but has recently finished new vessel construction projects. This yard is considered to be a medium- to small-size yard. Currently, the primary work at the shipyard is the repair and overhaul of both commercial vessels, such as automobile and

passenger ferries for the State of Washington, fishing vessels, and military vessels, such as U.S. Navy fast combat support ships (AOEs). Todd Pacific Shipyards Corporation is a member of the Shipbuilders Council of America.

II. PLANT AND PROCESS DESCRIPTION

IIA. INTRODUCTION

Plant Description: Todd Pacific Shipyards Corporation was founded in its present location near downtown Seattle, Washington, in 1916. Todd Pacific has repaired or converted thousands of vessels since its start and has constructed over 300 new vessels. The 46-acre facility has three dry docks, including the largest floating dry dock in Puget Sound, at 873 feet long by 134 feet wide. Two wharves and five piers provide a total of over 6,000 feet of berthing space for outfitting and repair work. A dual shipway allows for the simultaneous construction of two ships with a maximum length of 550 feet and a maximum beam of 59 feet. If both shipways are combined, a vessel 550 feet in length by 95 feet in beam can be constructed. The yard is serviced by fifteen whirled traveling cranes, having lifting capacities up to 136 metric tons. While several original buildings remain on site, Todd Pacific undertook a major site reorganization and capital improvement plan in the mid-1990s. During this time, the shipyard incorporated modern shipbuilding techniques, as acquired from Ishikawajima-Harimi Heavy Industries of Japan. Shops received new equipment and consolidated or relocated to facilitate new technology and work methods at that time.

Corporate Ties: Todd Pacific Shipyards Corporation is a wholly owned subsidiary of Todd Shipyards Corporation.

Products: Todd Pacific just recently completed the construction of three 460 feet long car ferries for the Washington State Ferry System. The shipyard is currently occupied with the repair and overhaul of factory (fishing) trawlers, containerships, barges, tugs, and ferries. Todd Pacific was recently awarded the contract by the U.S. Navy for all long-term life-cycle maintenance on all Puget Sound homeported fast combat support ships (AOEs). The shipyard was also contracted by the Navy for non-nuclear maintenance for the aircraft carriers USS Vinson, USS Lincoln, and USS Stennis.

Age of Plant: The site of Todd Pacific Shipyards has been functioning as a shipyard since 1916. Most of the facility has been updated or rebuilt since that time, as discussed above.

Number of Employees, etc: The facility employs approximately 1,000 production and administrative employees. Of these, typically about 800 are production workers. Eleven different unions represent workers at Todd Pacific.

IIB. SELECTED PROCESS DESCRIPTIONS

Five specific processes were identified for further analysis. These processes were pipe welding, torch cutting, water jet blasting, grinding, and welding operations. All tasks were observed onboard a vessel undergoing repair.

IIB1. Pipe Welding Process Onboard Vessel

Numerous pipe connections may be required in any repair task. Pipefitters piece together the piping subassemblies and weld them into place. In the shipboard pipe welding process, the pipefitter must first get into position to weld the pipe together. This may involve working in a confined space, working from an elevated surface, and/or working overhead. The primary musculoskeletal risk factors associated with this work are static and awkward postures of the trunk, beck, neck, and arms including lumbar flexion and extension, shoulder abduction, wrist flexion, and wrist ulnar and radial deviation.

IIB2. Torch Cutting Process Onboard Vessel

There are many ship repair processes in which torch cutting is used to remove steel decking or bulkheads. At times, individual components scheduled for replacement are located in such confined spaces that it is easier to torch cut an opening either beside, above or below an item in order to remove it from its original location. At other times, the physical dimensions of compartments are slated to change for one reason or another, again calling for the removal of decking or bulkheads. The musculoskeletal risk factors associated with torch cutting are trunk and neck flexion, static and awkward postures, and contact stresses to the lower extremities.

IIB3. Waterjet Blasting of Vessel in Drydock Process

When a vessel comes in for hull repair work, it may be placed in a drydock to lift the vessel out of the water. Instead of using an abrasive blasting agent within the drydock to remove paint, a high-pressure water cannon is used. This process eliminates the need to recover the abrasive agent. A worker enters the platform of a powered lift truck, which has been moved beside the vessel in the drydock. The worker raises and positions the platform to be near the work area. The worker activates the waterjet and proceeds to remove paint from the work surface. The waterjet blasting unit operates at very high pressure. This results in a high amount of force leaving the handheld unit, making the worker use a great deal of physical effort to maintain control. Since postures are fairly static with high force, it is possible that workers operating the waterjet blasting unit may experience upper extremity musculoskeletal discomfort or injuries. Additionally, awkward postures and slippery standing surfaces may create undue lumbar stress.

IIB4. Grinding Onboard Vessel Process

In any ship repair process, grinding is a primary task. Paint must be removed from bulkheads or decks prior to painting; weld beads must be ground flush with the plates or attachments. Grinding surfaces can be vertical or horizontal and at floor level, overhead, or somewhere in between. The worker may be standing, kneeling, squatting, or even laying down to perform the task. The worker often must assume awkward or constrained postures to get into position to grind. The grinders transmit vibration to the hand and arm of the worker. The work is primarily static which is generally very fatiguing for involved muscles.

IIB5. Welding Onboard Vessel Process

There are three primary types of welding that occur during ship repair processes: manual stick welding, manual wire welding, and semi-automatic wire welding. Stick welding has already been addressed previously for pipe welding. Semi-automatic welding is performed primarily for long straight welds on horizontal surfaces, such as decks. This type of welding is often flux core arc welding where the wire is continuously fed to the arc and the electrode wire has a flux core center that helps to shield the weld. The machine is positioned on the seam to be welded, activated, and then guided by the operator. During semi-automatic welding on deck plates, the worker must kneel or squat low to align and operate the automatic welding unit. These postures may result in strain to the legs, lower back and neck. Wire welding is performed for the majority of welding tasks. The wire electrode is continuously fed to the arc and may or may not be shielded by a flux core. For wire welding, the worker may assume a variety of postures, often constrained, to perform the welding task. Often, the work is static, resulting in muscle fatigue of the arms.

III. CONTROL TECHNOLOGY

The following section presents various ergonomic interventions that were suggested for implementation in the Todd Pacific Shipyard. These interventions are based on the risk factor analysis that was performed at Todd in April of 2000 and detailed in the previous NIOSH reports (EPHB Report Nos. 229-18a and -18b, Hudock and Wurzelbacher, 2000 and Wurzelbacher and Hudock, 2000). These reports are available on the NIOSH website: http://www.cdc.gov/niosh/ergship/reports.html.

IIIA. ERGONOMICS TRAINING PROGRAM INTERVENTION FOR USE IN ALL PRODUCTION DEPARTMENTS

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 work station redesign or even engineering interventions, in general. Since it is difficult to make direct changes to the work environment due to the constraints of ship repair, it may be possible to educate the workforce on proper procedures, better work methods and postures to assume while performing the work onboard vessels. It may also be possible to address concerns raised by improper tool selection and tool usage and poor body positioning. Therefore, it was suggested that basic ergonomics awareness training be considered for all production workers, emphasizing the areas cited above.

In February 2001, NIOSH project personnel and one contractor provided three 2.5-hr sessions of ergonomics awareness training to the labor-management team and first-line supervisors at Todd Pacific Shipyards. This training was deemed successful by the shipyard's Safety Manager. While ergonomic training has not yet been offered to the rest of the workforce, the shipyard is a member of the Shipbuilders Council of America (SCA) that has recently received a grant through OSHA to develop an ergonomics training program for all shipyard workers. An additional concern over regulatory jurisdiction lead to further delay in implementing the ergonomic training. Federal OSHA has jurisdiction over all "floating" work, including ships and floating dry docks; the State of Washington has jurisdiction over the shoreside work. The State of Washington does have an ergonomics standard, whereas, the Federal OSHA does not. The shipyard wanted to include pertinent information from both jurisdictions before presenting the training to all workers.

IIIB. POSSIBLE INTERVENTIONS FOR THE SHIPBOARD WELDERS, TORCH CUTTERS, AND GRINDERS

Whenever a worker has to kneel or squat for long periods of time to conduct their work, whether it be torch cutting, grinding, or welding, it was suggested that adequate stools or benches be provided which allow 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. Wedge-shaped knee supports are also commercially available that attach to the back of the calf to prevent hyperflexion of the knees while assuming squatting postures. Todd Pacific does supply and encourage employees to wear industrial kneepads when necessary. It is not known whether or not any wedge-shaped knee supports have been put in use at the shipyard.

IIIC. POSSIBLE INTERVENTIONS FOR THE WATERJET BLASTING PROCESS

The primary concern with the waterjet blasting process is that workers are required to hold the water cannon in their hands to control and direct the high-pressure water spray. 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 lift. 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. Upon NIOSH's suggestion Todd set up an apparatus on a manlift to hold and position the waterjet. However, this arrangement brought about other engineering concerns, including the load capacity of the manlift.

After the initial NIOSH visit, Todd Pacific entered into a cooperative agreement with another shipyard, Atlantic Marine, to further pursue the ultra-high pressure water blasting idea (NSRP, 2001). Among the findings were a number of suggestions to address the worker fatigue found in using the ultra-high pressure water blasting as initially configured. The first suggestion was to provide ergonomic awareness training to the waterjet operators. The second suggestion was to develop an ergonomic intervention to support the vertical (and horizontal) forces of the blasting gun (kickback). One way to do that is to mount the waterjet in a nozzle mount similar to those on aerial platform firetrucks. The third suggestion with an ergonomics focus was to investigate constructing the waterjet blasting gun out of lighter-weight components to reduce the weight of the blasting gun from its current weight of 22 pounds. A double trigger mechanism placed additional strain on the arms of the blast workers, and warranted further investigation. Three additional suggestions addressed the awkward postures of blast workers when spraying overhead in areas with low clearance or other constrained work postures. First, it was suggested that some sort of "ergonomic support device" be incorporated to the work platform to minimize the strain on the worker's back and lower extremities. It was also suggested that wedge-shaped knee support wedges be incorporated as personal protective equipment for blast operators to eliminate hyperflexion of the knee when in a squatting posture. The final ergonomic suggestion was to better manage scheduled work rotations due to an observable decrease in productivity as the work shift progressed due in part to the physical fatigue of the workers. The waterjet blasting process continues to be a high priority project for shipyard personnel.

IIID. OTHER PERTINENT PROJECTS AT TODD PACIFIC SHIPYARD

5S Program – Todd Pacific Shipyard is an active participant in a National Shipyard Research Program project titled "5S – Applications and Education Programs for Shipyards." The "5S" system was developed in Japan as an outgrowth of the Total Quality movement, where attention is placed on the state of the workplace itself. The name "5S" comes from the Japanese key words associated with the components. Table 1 lists the original Japanese word, the direct translation, and an English-equivalent "S" key word (DiBarra, 2002).

Table 1. "5S" Components

Original Japanese word	Direct translation	English-equivalent "S" word
Seiri	Organization	Sorting
Seiton	Neatness	Simplifying
Seiso	Cleaning	Systematic cleaning
Seiketzu	Standardization	Standardizing
Shitsuke	Discipline	Sustaining

"Sorting" stands for separating what is essential and required to conduct a particular job task from what is not needed. This will reduce workplace clutter and reduce the possibility of hazards from contact with extraneous material (trips, struck by accidents, etc.), "Simplifying" means that all items needed for the immediate work task are stored in particular and unique locations near the work area for ease of retrieval and minimal downtime. "Systematic cleaning" means that the work place is neat and clean. Once normal operating conditions are established, any abnormal conditions are more easily recognized and acted upon, such as the need for preventive maintenance. "Standardizing" stands for the development of common work practices and consistency in how items are stored, how production processes are executed, and how changes are implemented in the workplace. "Sustaining" means the maintenance of gains and the constant improvement on those gains.

To date, Todd Pacific has implemented the "5S" program in approximately twenty locations across the shipyard including: yard maintenance; rigging area; electric, hose and pump repair; dry dock riggers; welder maintenance; carpenters; inside and outside machine shops; central tool room; and indoor blasting and painting facilities. On average, Todd Pacific Shipyard has identified and documented a 30% decrease in cycle time throughput, or a 30% reduction in wasted time, from the implementation of this program. Specific examples of how the workplaces were improved are illustrated in the article by DiBarra (2002). Todd Pacific reported that the best gains came from their 5S program when it was used as a vehicle for addressing productivity, workflow, culture change, continuous process improvement, safety, ergonomics, and total productive maintenance.

Lean Ship Repair – Todd Pacific Shipyards is also an active participant in a second project of the National Shipbuilding Research Program titled "A Lean Enterprise Model for U.S. Ship Construction, Overhaul and Repair." This project addresses the application of lean manufacturing principles to the work processes of the various shipyard industries. Lean manufacturing focuses on the elimination of sources of waste or any non-value-added activity. Todd Pacific has combined a "lean ship repair" program with a "mobilize, maintain, and demobilize" (MMD) program which plans for the layout of temporary facilities which allows an orderly and systematic "pullback" of equipment following completion of the repair operations.

IV. CONCLUSIONS

Five distinct repair processes were examined at Todd Pacific Shipyard facilities to quantify the musculoskeletal risk factors associated with these processes. The processes included: pipe welding, torch cutting, waterjet blasting, grinding, and welding. Based on ergonomic task analyses, four ergonomic interventions are suggested for the Todd Pacific Shipyard: 1) an ergonomics training program for use in all production departments, 2) an orbital nozzle mount for the water jet blasting process in the dry dock area, 3) industrial knee pads as PPE, and 4) wheeled, adjustable work stools for shipboard welders, torch cutters, and grinders when necessary. Since ship repair work greatly differs from ship construction processes, particularly with respect to the ability to change the work environment, it was expected that the development of the ergonomic training program would have significant impact on reducing musculoskeletal injuries.

The implementation of engineered ergonomic interventions has been found to reduce the amount and severity of musculoskeletal disorders within the working population in various industries. Therefore, it was suggested that the other suggested ergonomic interventions may also be implemented at Todd Pacific shipyard to minimize hazards in the identified job tasks, if feasible.

Each of the interventions proposed in this document were 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. Each intervention was developed for a particular set of circumstances and may or may not be directly transferable to other similar work situations.

V. REFERENCES

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