

FINAL SURVEY REPORT:
ERGONOMICS INTERVENTIONS
FOR SHIP CONSTRUCTION PROCESSES

at

BATH IRON WORKS,

A GENERAL DYNAMICS COMPANY,

Bath, Maine

REPORT WRITTEN BY:

Stephen D. Hudock, Ph.D., CSP

REPORT DATE:
December 2002

REPORT NO. EPHB 229-13c

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
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:	Bath Iron Works Corporation shipyard, General Dynamics, 700 Washington Street, Bath, Maine 04530
SIC CODE:	3731
SURVEY DATE:	April 17-18, 2000
SURVEY CONDUCTED BY:	Stephen D. Hudock Steven J. Wurzelbacher Karl V. Siegfried (MEMIC)
EMPLOYER REPRESENTATIVES CONTACTED:	Allan C. Cameron, President; Kevin Gildart, Vice President, Human Resources and Public Affairs; Wayne McFarland, FNP, Manager Health Care Administration; Dr. Maria Mazorra, Chief of Occupational Medicine; Chris Barbor, Sr. Occupational Health Nurse/Ergonomist
EMPLOYEE REPRESENTATIVES CONTACTED:	Rocky Grenier, IAMS Local S-6

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 at Bath Iron Works shipyard in Bath, Maine to identify and quantify risk factors that workers may be exposed to in the course of their normal work duties. Several operations were identified for further analysis including: unloading of small parts for subassembly, connecting electrical cables at a junction box, pulling cable through the vessel, equipment load-in, insulation installation, welding, and grinding. Possible engineering interventions to address the occupational risk factors for each task were examined in a previous report. Actions taken on those interventions are presented in this report.

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. 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 had 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. 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 is reported in “Preliminary Survey Report: Pre-Intervention Quantitative Risk Factor Analysis for Ship Construction Processes at Bath Iron Works Corporation Shipyard, Bath, Maine,” Report No. EPHB 229-13a by Wurzelbacher et al, 2000 and “Interim Survey Report: Recommendations for Ergonomics Interventions for Ship Construction Processes at Bath Iron Works Corporation Shipyard, Bath, Maine,” Report No. EPHB 229-13b by Hudock et al, 2000. Both these reports are available on the NIOSH website: <http://www.cdc.gov/niosh/ergship/reports.html>.

IC. BACKGROUND FOR THIS SURVEY

Bath Iron Works Corporation was selected as a candidate yard for this study for a number of reasons. In the mid-1990's, a pilot ergonomics intervention project at Bath Iron Works was funded by the National Shipbuilding Research Program. This interest in ergonomics within the shipyard was taken as an indication of the possible cooperativeness in this project. Additionally, it was decided that the project should look at a variety of ship yards based on product, processes and location. Bath Iron Works constructs AEGIS guided missile destroyers for the U.S. Navy and is considered a large shipyard. In fact, Bath Iron Works is the largest private employer in the State of Maine.

II. PLANT AND PROCESS DESCRIPTION

IIA. INTRODUCTION

Plant Description: Bath Iron Works Corporation is located on the Kennebec River in Bath, Maine, approximately thirty miles northeast of Portland, Maine. The main facility of approximately 56 acres includes two principal structural assembly buildings that combine for over 208,000 square feet of covered work area providing space for 28 distinct work station locations. The pre-outfit building of about 91,000 square feet provides space for 18 work stations for equipment installation after structural units are blasted and painted. Bath Iron Works has recently completed an expansion into the Kennebec River of a land-level transfer facility for the assembly and erection of ships. This facility is a construction platform with three side-by-side shipways that allows for simultaneous construction of ships in a level location as opposed to the previously used inclined shipways. In addition, a 750-foot floating drydock has been added for the launch and retrieval of ships.

Corporate Ties: In 1995, Bath Iron Works was purchased by General Dynamics. The Marine Systems group of General Dynamics includes three ship construction and repair companies (Bath Iron Works, Electric Boat, and NASSCO) and one ship operating company (American Overseas Marine).

Products: Bath Iron Works is the lead designer and builder of the ARLEIGH BURKE class AEGIS guided missile destroyers for the U.S. Navy, which are considered to be the most technologically advanced surface combatant ships in the world today. These ships are 505 feet in overall length by 66 feet in beam (width) and displace 8,315 tons under full load.

Age of Plant: Bath Iron Works' first ship was delivered to the U.S. Navy in 1890. The majority of production facilities have been built in the last 25 years. Facility expansion was recently completed to provide a land-level assembly area.

Number of Employees, etc: Bath Iron Works employs approximately 7,000 workers. About 4,300 production workers are employed at the main facility. The approximate average age of the production workers is 45 years old.

IIB. PROCESS DESCRIPTION

IIB1. Bin Loading by Material Handlers in the Panel Line Area Process

Pre-cut shapes are shipped into the east end of the panel line from off-site facilities in large metal shipping containers. Shipping containers are delivered by forklift and are placed into the material handling area by utilizing a hand operated pallet jack. Workers remove individual pieces from the shipping containers and identify hull, unit and job and other pertinent numbers.

Once an item has been identified, it is carried and placed onto the appropriate shelf and location. Shapes/pieces are then arranged on the shelves to allow easy retrieval by shipfitters working within the area. The musculoskeletal risk factors associated with this job are the repetitive trunk flexion to retrieve material from the bottom of the bins and manual material handling of the items resulting in excessive loads to the low back and shoulders.

IIB2. Cable Connection Process

Often referred to as switchboard installers, electricians identify routes and hook up wire cable ends to large switchboard units located throughout the ship. The process involves identifying specific cables and attachment locations. Cable is routed in, around and through the bottom of the switchboard to the specific hook-up/connection lug. Once at the desired location, wire ties are used to secure the cables. Cable covering is removed and ends are stripped back to permit good attachment of cable ends. The lugs are then secured to the switchboard units. Hook-up is then inspected to assure proper arrangement has been achieved in the switchboard. The musculoskeletal risk factors associated with this job are the repetitive use of non-powered hand tools, such as wire strippers and screwdrivers, and the static, awkward postures the workers assume to reach the electrical panel openings on the equipment.

IIB3. Shipboard Cable Pulling Process

Multiple lines of cable varying in length, size and weight are pulled by hand throughout areas of the ship. The larger cable pulls are performed by workers in groups numbering as high as 20. The size of the crew is largely dependent on the size, length, routing and final location of cable. The cables can range in size from thin fiber optic cable to large diameter cable weighing over seven pounds per foot. Cable runs are located overhead, along bulkheads, and below deck plate level. Installing cable requires the workers to assume a variety of postures. The awkward postures combined with the heavy exertions associated with the pushing, pulling, lifting and handling of the cable can result in musculoskeletal discomfort or injury. When pulling cable below deck plate level, forward neck and trunk flexion is common. When pulling cable overhead, significant loads are placed on the shoulder and low back. Shoulder flexion and neck extension is common when pulling cable overhead with force being exerted at arm's length.

IIB4. Shipboard Rigger Equipment Load-In Process

Equipment is lifted off of the transportation vehicle via a large gantry crane and lowered into the ship. Depending on the final location of equipment and location of access hole, the degree of manual manipulation of the object will vary. Once the equipment is unhooked from the crane, shipboard riggers are responsible for getting the equipment/item to its final position.

A tag line is used to safely guide the load down to the shipboard riggers located below deck. Shipboard riggers maneuver the equipment into the general vicinity of its final destination using low cart rollers, which can be very effective for moving equipment over flat decks with no lips or protrusions. Unfortunately, only a few areas within the ship are suitable for this mode of

transport. Once the equipment or item is close to its final destination, or must be moved off of the low profile cart, it is slid across the deck. When feasible, shipboard riggers place a one-inch pipe under the equipment permitting it to be rolled with less effort. To place or remove the pipe roller from underneath the equipment, the item being moved must be tilted on one end, which permits the pipe to be set in place. Once the equipment or item is in place, the process repeats until truck is unloaded. At times, shipboard riggers carry heavy mechanical lift assist devices on board to get heavier equipment through shipboard doorways. The musculoskeletal risk factors associated with this job are the heavy exertions due to pushing, pulling, lifting and handling the equipment and the awkward postures that workers may use in confined spaces.

IIB5. Shipboard Insulation Installation Process

Insulators usually work in teams consisting of one installer and one cutter. The installer measures the area to be covered and relays this information to the cutter, who measures, marks and cuts the piece of insulation to size. The piece is then handed up or over to the installer who may re-measure the piece, pushes the insulation into place, piercing the insulation material onto the insulation stud. The installer then installs a cap over the end of the stud securing it with a hammer strike. Installers and cutters will trade places from day to day. It is common for installers to work off of stepladders when performing overhead and some bulkhead installation. Cutters usually set up makeshift workbenches using several boxes of the insulation and/or sawhorses. Most of the insulation is a foam type of material, however, some fiberglass is still used. Sheets are usually 2 feet by 4 feet. The primary musculoskeletal risk factor for insulation cutters is moderate neck flexion assumed when transferring measurements to the insulation piece and during the cutting process. Depending on the grip used on the insulation knife, ulnar deviation of the wrist is common; however, the force exerted is light. Working at or above shoulder level is common when installing insulation overhead. Shoulder flexion, wrist extension and neck extension are common when performing this work. While force exertions are minimal, stresses created by awkward postures of the upper extremities and neck are significant.

IIB6. Wire Welding in Panel Line Process

Welders working in the panel line building are responsible for welding sheets and other structural members to form bulkheads, decks and overhead units. Items to be welded have been tacked into place by the shipfitters. If necessary, welders grind the area to remove any foreign debris and using wire welding equipment perform the welding operation. Once a bead has been run, it is cleaned using a slag hammer, offset wire brush or other pneumatic tool. It is common for welders to sit, kneel, crouch, bend and even lay down on the steel when welding. The primary musculoskeletal risk factors of this job are the static awkward postures of the back, neck, arms and wrist. Some contact stresses occur to the knees, hands and arms.

IIB7. Shipboard Tank Grinding Process

Primary responsibilities include removing paint, rust and other foreign objects from tanks, the bilge, bulkheads, etc. The main purpose is to prepare surface for painting. In some areas all paint is removed while in others a feathered edge is created. Tank grinders use multiple pneumatic tools, depending on specific task to be completed and available workspace. The most common pneumatic tools used include the 5- and 3-inch disc sanders, offset wire brush and needle gun. After the area has been ground, it is cleaned using various cleaning solutions. Musculoskeletal risk factors that were observed with the tank grinders include the awkward static postures of the trunk and upper extremities. Work postures are at times dictated by the amount of space available for the employee to perform job tasks. Static gripping of pneumatic or vibrating tools is performed on a regular basis. Contact stresses may occur to the knees, hands and arms.

III. CONTROL TECHNOLOGY

IIIA. PANEL LINE BIN LOADING BY MATERIAL HANDLERS POSSIBLE INTERVENTIONS

Possible interventions for the bin loaders in the panel line assembly area include adjustable bin lifters that raise and tilt the load towards the worker. Many inexpensive models of this type are commercially available. Prior to the preliminary site visit, Bath Iron Works had installed this type of bin lifter in various locations across the facility with positive results and their placement along the panel line was under consideration (Barbor, 2000a)

A hook-like tool for grasping individual workpieces may also help to bring the load closer to the material handler and also reduce the need for pinch-grip hand postures. However, for a hook-like tool to work, there would need to be a hole or pad-eye on the piece through which the hook can be attached. Some pieces may have such holes available, many other components such as steel plates would not have such holes. This intervention would be of limited usefulness for those items.

Work practices of pre-sorting heavier items and emptying them by forklift onto a rotatable table top before handling may also be feasible. At Bath Iron Works, the Production Planning Division has streamlined the process of material handling by sorting work pieces by hull and delivering these kits as they are needed (Barbor, 2000a), which effectively reduced the amount of material handling performed.

IIIB. SHIPBOARD CABLE CONNECTORS POSSIBLE INTERVENTIONS

Possible interventions for the shipboard cable connectors include work practices that reduce the amount of cable preparation (stripping, tying, etc.) at the switchboard, where the confined space limits work movements and postures. According to correspondence with Barbor (2000a), this

practice is already used at Bath Iron Works, but only when preparing short pieces of wire between 10 and 12 inches in length. When this practice was applied to larger pieces of cable, the stripped cable ends were vulnerable and sustained considerable damage in manual material handling operations.

The use and maintenance of specialized cable tools may also reduce grip and other upper extremity forces. Many hand tool companies are beginning to develop and market tools such as “ergonomic” wire strippers. The applicability of these tools to specific tasks should be considered by the shipyard. In fact, ergonomic wire strippers have been considered and implemented in the shop environment at the shipyard. No NIOSH research is underway to catalog and compare these tools.

IIIC. SHIPBOARD CABLE PULLERS POSSIBLE INTERVENTIONS

Possible interventions for the shipboard cable pullers include work rotation among pullers so that time spent in postures involving overhead work, 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). The cable crew at Bath Iron Works is rotated. The most experienced teams tend to sustain the fewest injuries (Barbor, 2000a). The vast majority of the cable pulls at Bath Iron Works start from the middle of the cable run.

Semi-automated cable pulling systems are also commercially available and may be able to be integrated into the current manual pulling method. These systems typically use a cable-pulling winch (capstan), double braided low stretch ropes, sheaves, and Teflon sheets to reduce cable friction. The ropes are attached to the end of the cable and capstan pulls at a range of speeds and in a wide range of positions. Most capstans are self-contained and allow for easy transport and set-up shipboard. The capstan pulling system may be able to be coupled with portable inline pullers that are also commercially available. 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” (U.S. Navy, Navy Occupational Safety and Health Program, “1,001 Success Stories” website, 2002). However, initial testing of a similar system at Bath Iron Works lead to the conclusion that, due to the multiple turns in the cable run in the current ship design which would necessitate numerous set-ups of the system, the cable pulling system was not feasible (Barbor, 2000a). Bath Iron Works has instituted the use of double braided stretch rope to assist in pulling degaussing cable.

IIID. EQUIPMENT LOAD-IN BY SHIPBOARD RIGGERS POSSIBLE INTERVENTIONS

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. This technique is already used at Bath Iron Works wherever feasible (Barbor, 2000a).

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 also 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 the 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 omnidirectional movement. Again this technique is utilized at Bath Iron Works where feasible (Barbor, 2000a), however the movement of material through hatches and down ship's ladders complicates the manual material handling process.

IIIE. SHIPBOARD INSULATORS POSSIBLE INTERVENTIONS

Possible interventions for the shipboard insulators (cutters) include angled knives to maintain neutral wrist postures. Possible interventions for the shipboard insulators (installers) include an alternate insulation securing process involving semi-automatic stud guns or re-designed knives and hammers. Ergonomically designed handtools are made available to Bath Iron Works employees whenever possible (Barbor, 2000a). NIOSH currently has no catalog of "recommended" handtools. However, NIOSH researchers are developing guidelines for the selection of both powered and non-powered hand tools.

Work rotation between the cutters and installers may also reduce the time spent in overhead postures by the worker performing the installation task. Insulators at Bath Iron Works are rotated through a variety of insulation tasks unless they are medically restricted. Insulation teams often alternate between cutting and installing (Barbor, 2000a).

IIIF. PANEL LINE WELDING POSSIBLE INTERVENTIONS

Possible interventions for the 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. Such carts may be able to be custom designed to include upper body supports and knee supports that allow a variety of postures, such as semi-sitting or kneeling and leaning forward. Carts are already in place in the Panel Line at Bath Iron Works and are used successfully by the operator of the automatic plate-welding machine and by those performing tack welding (Barbor, 2000a). However, there is some concern whether similar carts for the rest of the welders would result in prolonged and static lumbar and cervical postures and keep the welders out of close proximity to the welds.

Kneepads and thigh-supports to prevent hyperflexion of the knees during squatting are also commercially available. Bath Iron Works has tried several different types of these products with limited success (Barbor, 2000a), finding that a 12" x 18" welding pad offers the most useful protection.

IIIG. SHIPBOARD TANK GRINDERS POSSIBLE INTERVENTIONS

Possible interventions for the shipboard tank grinders include lighter tools that induce less vibration. Many tools claiming to be “ergonomic” in nature are available commercially. The specifics of why a particular model of tool is deemed to be “ergonomic” must be carefully determined. An “ergonomic” tool does not necessarily mean it passes a lower level of vibration to the tool user. NIOSH has no current project to catalog or suggest particular “ergonomic” tools for certain work processes; however, NIOSH researchers are developing guidelines for use in the selection on both powered and non-powered handtools. The buyer is urged to exercise caution and to make an informed decision in the selection of new tools.

Another possible intervention is the use of support devices such as spring returns for areas where extended vertical grinding is required. Appropriate tool balancers cost about \$50-150. There are numerous types of tool balancers available, some of which can be implemented in confined spaces.

Process changes (e.g. weldable primer, more efficient and clean welding processes) to reduce the amount of required grinding may also be explored. However, the acceptance and implementation of these changes lies with the customer, the U.S. Navy, not just the manufacturer, Bath Iron Works. There are efforts underway to address some of these concerns in future contracts.

Portable, self-contained abrasive blasting units may also be used instead of manual grinding in some cases. Bath Iron Works was pursuing this technology for use throughout the shipyard (Barbor, 2000a).

Bath Iron Works loaned to NIOSH two pair of pneumatic grinders: one set of 14,000 rpm angle grinders and one set of 18,000 rpm die grinders. Each set consisted of a brand new tool and a tool ready for issuing from the shipyard’s tool supply crib. These tools served as the basis for a series of laboratory tests to determine the effect of wear and attachment type on the vibration characteristics of the tools (Wasserman et al, 2002). New grinding, deburring, sanding and wire brush attachments, or implements, were used each time a tool was tested.

Results of the limited study showed that hand-arm vibration standards (ACGIH TLV and ANSI S3.34) were not exceeded, but there was a consistent tendency for the acceleration levels to increase between the new and used tool while using grinding wheels and carbide burrs, both hard implements. The weighted acceleration levels for the angle grinder with grinding wheel were consistently higher for the used tool over the new tool for all three axes measured. This increase in acceleration levels in the used angle grinder ranged from 58.3 percent (X-axis) to 65.7 percent (Z-axis). These increases were not statistically significant, however, due to the limited sample size. The weighted acceleration levels for the die grinders equipped with carbide burr attachments were also consistently higher for the used tool over the new tool for all three axes measured. This increase in acceleration levels in the used die grinder ranged from 11.0 percent (Z-axis) to 43.8 percent (X-axis). Again, these increases were not statistically significant due to

the limited sample size. Weighted acceleration levels were mixed on the die grinders when soft implements such as flap wheels and wire brushes were used on the tools. These results are possibly due to the inability to maintain consistent pressure of the soft tool attachment on the steel test piece.

In general, with no knowledge of the previous hours of operation for the used tool, but with identical implement usage, the overall results suggest the need for and implementation of a regular tool vibration monitoring and maintenance program as a primary element to help maintain tool acceleration levels to a minimum level. A study with more tool pairs and with known hours of usage for the tools may have posited a correlation between hours of use and vibration levels. While Bath Iron Works currently runs a very comprehensive tool maintenance program, the program does not include tool vibration monitoring.

IV. OTHER ERGONOMIC INTERVENTIONS AT BATH IRON WORKS

The Bath Iron Works shipyard established an ergonomics program in 1989. This occupational health program, based on the application of human factors principles to engineering processes, provides workers with a mechanism for identification, analysis, and control of ergonomic hazards. The following section summarizes the ergonomic interventions implemented at Bath Iron Works (Barbor, 2000b).

IVA. ENGINEERING INTERVENTIONS

IVA1. Material Handling

Height-adjustable lift tables are provided throughout the shops at Bath Iron Works to bring the load to be transferred to approximately waist height to minimize strain on the lower back. Easy-reach tilt storage boxes are used for small part storage in subassembly areas to provide easier access to these components. Overhead hoists and jib cranes are available at workbenches where manual material handling of fairly large or heavy items is common. Suction and magnet cranes are available for unique lifts that cannot be rigged in a traditional manner.

A conveyor system was installed in the warehouse for delivery of items. Stock-pickers and scissor manlifts are utilized to raise the worker to the height of the item to be pulled from the storage racks.

Instead of having workers carry the 81-pound individual welding converters up the scaffolding to the deck of the vessel for work onboard, Bath Iron Works created welding converter racks that house eight 81-pound converters at a time that are transferred by crane up onto the deck, eliminating the manual material handling on the scaffolding.

Bath Iron Works has contracted with a number of its suppliers to provide items in smaller and lighter packages or groupings that are easier to carry by an individual. Another example is the

reduction in size of the welding wire wheels to approximately 50 percent of their previous weight.

IVA2. Job Design

A number of job design issues were addressed at Bath Iron Works in conjunction with the recent development of the land-level transfer facility including: 1) work flow redesign in numerous areas, 2) yard-wide illumination improvements, 3) the installation of pre-fabricated buildings, and 4) the ergonomic redesign of hand and foot controls in portal cranes.

IVA3. Tooling

A number of tool-related issues were addressed at Bath Iron Works. Pneumatic tools are continuously upgraded to include damping devices, isolated handles, composite handles with increased diameter, two-handled grinders, etc. Welding guns with adjustable nozzles have been adopted in the yard. In one of the metal fabrication areas, clamping devices have replaced bent metal pins or “dogs” which were used to secure a subassembly to a work surface. These “dogs” were installed by striking them repeatedly with a hammer.

IVB. ADMINISTRATIVE INTERVENTIONS

IVB1. Training

Customized training was delivered to all manufacturing trades at Bath Iron Works, including lower back, cumulative trauma disorder, knee, and shoulder education. In addition, comprehensive training was delivered to all employees working in the office environment including video display terminal and cumulative trauma disorder education.

IVB2. Stretch Program

Bath Iron Works developed trade-specific (customized) stretching programs for manufacturing, as well as office environment employees. Workers were encouraged to perform stretches at the start of each work shift and throughout the workday.

IVC. WORK PRACTICE CONTROLS

IVC1. Manufacturing

Trials of vibration-damping equipment including tool-handle wraps and anti-vibratory gloves were conducted at Bath Iron Works. Anti-fatigue matting was installed where standing was an issue. Light-activated welding hoods were acquired to eliminate the “neck snap” common to welders lowering their hoods without using their hands. Custom kneeling, elbow, and shoulder protection was introduced in the shipyard.

IVC2. Office Environment

A number of improvements were made to the office environments around Bath Iron Works several years ago including: 1) adjustable, lumbar-support chairs, 2) adjustable computer tables, 3) forearm, wrist, and foot rests, 4) document holders, task lighting, and anti-glare screens, and 5) alternative input devices such as fully articulating keyboards and other “ergonomic” input devices, including trackballs and mice. Several of these interventions are no longer considered to be optimal by shipyard personnel. Forearm rests and wrist rests have been replaced with adjustable keyboard trays. Foot rests are used only for the shorter or smaller worker as necessary. Anti-glare screens are used only as a last resort when repositioning the monitor or the light sources are not viable alternatives.

V. CONCLUSIONS

Seven work processes within Bath Iron Works were surveyed to determine the presence of risk factors associated with musculoskeletal disorders. These processes included panel line bin unloading, shipboard cable connecting, shipboard cable pulling, shipboard equipment load-in, shipboard insulation cutting and installing, panel line welding, and shipboard tank grinding. In each process, certain work elements were found to be associated with one or more factors, including excessive force, constrained or awkward postures, contact stresses, vibration, and repetitive motions. Bath Iron Works chose to address these issues in their own manner; in fact, some issues had already been addressed.

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 other ergonomic interventions may be implemented at Bath Iron Works facilities to minimize hazards, as has already been done in a number of different locations throughout the shipyard.

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 financial 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.

VI. REFERENCES

- American Conference of Governmental Industrial Hygienists (ACGIH). 2001. Threshold Limit Values for Physical Agents – Hand-Arm Vibration. Cincinnati, Ohio.
- American National Standards Institute (ANSI). 1986. ANSI S3.34: Guide for the Measurement and Evaluation of Human Exposure to Vibration Transmitted to the Hand. New York, New York.
- Barbor, C. A. 2000a. Personal correspondence as response to Interim Survey Report, August 10, 2000.
- Barbor, C. A. 2000b. Personal correspondence about Bath Iron Works' Ergonomics Program, November 9, 2000.
- Hudock, S. D., S. J. Wurzelbacher, and K. Siegfried. 2000. Interim Survey Report: Recommendations for Ergonomics Interventions for Ship Construction Processes at Bath Iron Works Corporation Shipyard, Bath, Maine. July 2000. Report No. EPHB 229-13b, NIOSH, Cincinnati, OH, 42 pp. Available at <http://www.cdc.gov/niosh/ergship/reports.html>
- U.S. Navy Occupational Safety and Health website. 2002. *1,001 NAVOSH Success Stories*, Improved Ergonomic Cable Pulling Method. <http://www.navosh.net/strategic/success/stories/pdfs/cable.pdf>, October 2002.
- Wasserman, D. E., S. D. Hudock, J. F. Wasserman, L. Mullinix, S. J. Wurzelbacher, and K.V. Siegfried. 2002. Hand-Arm Vibration in a Group of Hand-Operated Grinding Tools. *Human Factors and Ergonomics in Manufacturing*, 12(2):211-226, March 16, 2002.
- Wurzelbacher, S. J., K. Siegfried, and S. D. Hudock. 2000. Preliminary Survey Report: Pre-Intervention Quantitative Risk Factor Analysis for Ship Construction Processes at Bath Iron Works Corporation Shipyard, Bath, Maine. July 2000. Report No. EPHB 229-13a, NIOSH, Cincinnati, OH, 186 pp. Available at <http://www.cdc.gov/niosh/ergship/reports.html>