INTERIM SURVEY REPORT:

RECOMMENDATIONS FOR ERGONOMICS INTERVENTIONS

FOR SHIP RECYCLING AND REPAIR PROCESSES

at

PUGET SOUND NAVAL SHIPYARD, BREMERTON, WASHINGTON

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Public Health Service
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National Institute for Occupational Safety and Health
Division of Applied Research and Technology
Engineering and Physical Hazards Branch
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PLANT SURVEYED: Puget Sound Naval Shipyard, 1400 Farragut Avenue, Bremerton, Washington 98314-6001

SIC CODE: 3731

SURVEY DATE: October 20 - 21, 1999

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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 Puget Sound Naval Shipyard, a public shipyard that provides ship repair and ship dismantling services for the U.S. Navy. Five specific job tasks were identified for ergonomic analysis. These tasks include: the drydock sorting pad operation, the removal of insulation from vessels, the manual materials handling task in the "cut and carry" process, the use of reciprocating saws to separate components and hulls, and the removal of terrazzo tile with a chipping hammer. Possible engineering interventions to address the risk factors for each task are examined 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. 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 a number of 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 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. Examples of the completed studies include the foundry industry; various chemical manufacturing or processing operations; spray painting; and the recirculation of exhaust air. 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 is reported in “Preliminary Survey Report: Pre-Intervention Quantitative Risk Factor Analysis for Ship Recycling and Repair Processes at Puget Sound Naval Shipyard, Bremerton, Washington,”document number EPHB 229-13a by Hudock et al, 2000.

IC. BACKGROUND FOR THIS SURVEY

The Puget Sound Naval Shipyard (PSNS) was selected for a number of reasons. Puget Sound Naval Shipyard is a public shipyard in the Pacific Northwest, that performs both ship repair and ship recycling on large military vessels. The shipyard has both a developing ergonomics program and a process improvement program that has addressed ergonomic concerns within the yard.

II. PLANT AND PROCESS DESCRIPTION

IIA. PLANT DESCRIPTION

Plant Description: Puget Sound Naval Shipyard is located adjacent to the city of Bremerton, Washington, one hour west of Seattle by ferry, and approximately 30 miles north of Tacoma. The shipyard proper encompasses 344 acres of land, with additional non-adjoining property totalling 1,558 acres. The shipyard facilities include approximately 400 separate buildings, nine permanent piers including 12,310 feet of deep water space, and six drydocks. This shipyard is the Pacific Northwest's largest Naval Shore Activity, and one of the largest industrial installations in the State of Washington.

Corporate Ties: U.S. Navy Sea Systems Command

Products: Puget Sound Naval Shipyard performs overhauls and repairs of all sizes and types of U.S. Navy ships as well as being home port for six active ships. Approximately 41 % of the workload of the shipyard involves the inactivation, reactor compartment disposal, and recycling (IRR) of nuclear-powered submarines and surface vessels. Approximately 12 surface vessels and 88 submarines have been recycled in the past 12 years.

Age of Plant: Puget Sound Naval Shipyard was established in 1891 as a U.S. Naval Station. A number of small buildings from that era still survive on site. Most facilities are less than twenty years old.

Number of Employees, etc: Approximately 8,200 civilian employees, of which 3,500 are production workers. Average age of production workers is approximately 42 years of age.

IIB. PROCESS DESCRIPTION

IIB1. Bin Emptying at Drydock Sorting Pad Process

Figure 1. Emptying Scrap Bin at Drydock Sorting Pad

As the surface vessels and submarines are being dismantled as part of the Inactivation, Reactor Compartment Disposal, and Recycling activity, hundreds of bins of scrap metal are generated. Each bin measures approximately 5 feet by 3 feet by 3 feet. The bins hold a variety of material: stainless steel, painted steel, unpainted steel, aluminum, and other metal components. Each bin is filled during the “cut and carry” dismantling process for the vessel or vessels within the drydock. At the time of the site visit, four submarines were being dismantled within the same drydock. The scrap bins are moved from the vessels to the sorting pad area by forklifts. The sorting pad is surrounded by large shipping containers (approximately 5 feet x 20 feet), each for a specific type of metal.

The sorting pad worker removes the individual pieces of metal from the scrap bin by hand. The worker makes a determination of the type of metal in hand and then carries the item to the appropriate shipping container. The worker then places or throws the item into the shipping container and returns to the scrap bin for the next item. Each bin takes approximately 20 minutes to empty and sort. Individual items can weigh anywhere from a few ounces for metal strapping to in excess of fifty pounds for triple valve assemblies.

Figure 2. Worker Carrying Triple Valve Assembly to Shipping Container

The sorting pad worker often must reach far in front or deep into the bin while grasping objects of unknown weight. Awkward postures of the back and neck, such as extreme lumbar flexion and neck extension, are fairly common. Strain of the shoulder, neck, and back are possible due to the manual lifting tasks. Some items are relatively heavy resulting in increased physiological strain on the worker.

IIB2. Insulation Removal on Surface Ship in Drydock

Figure 3. Worker Removing Insulation Tie Cap with Short Pry Bar

Insulation from the bulkheads and ceilings of vessels being dismantled is removed by insulators. The workers first cordon off the immediate work area to discourage entry by unauthorized personnel. This action is done by hanging warning tape and placards (e.g., “WARNING Man-Made Vitreous Fibers”) around the work area. The insulators don totally encapsulating chemical protective suits and supplied-air hoods under positive pressure. The initial task of the worker is to remove the insulation tie caps. These small, round disks secure the insulation onto the metal insulation studs. These disks are removed using pry bars or wrecking bars of various sizes while standing on ladders to reach the overhead insulation. Once all the insulation tie caps have been removed, the worker uses a hawksbill knife (i.e., a knife with a short, downward-curved blade) to cut the insulation into manageable widths of approximately 18 inches. While cutting into the insulation, a co-worker sprays the surrounding air with a water mist to entrap any loose fibers that may otherwise be respirable.

Figure 4. Insulation Worker Cutting into Insulation with Hawksbill Knife

The worker then pulls on the insulation to break it free from the bulkhead or overhead area. The insulation is bagged and disposed of properly.

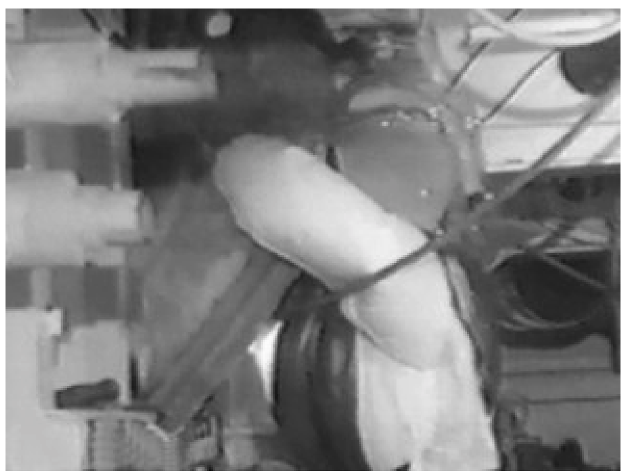

Figure 5. Pulling Section of Insulation Off Bulkhead by Hand

The vast majority of work for the insulation removal workers is performed with arms overhead or out in front and away from the body, either using pry bars or knives, straining the arms, shoulders, and neck. Often the worker is on a ladder and is leaning backward (back extension) to get to the work as opposed to repositioning the ladder. Back extension such as this can be stressful to the worker. Pulling the insulation off the bulkheads or overhead areas requires the use of force to separate the insulation from the surface areas. This task is stressful to the arms, shoulders, neck and back. All of these tasks are performed while the worker is wearing an encapsulating chemical-protective suit with a supplied air respirator causing an increased physiological strain on the worker.

IIB3. Reciprocating Saw Operations in the IRR Process

Figure 6. Two-Person Cutting Operation for Ductwork with Possible Hazardous Material

Ship dismantling, or Inactivation, Reactor Compartment Disposal, and Recycling as the process is known by at PSNS, requires the separation of components, bulkheads, and hull sections from adjoining locations. This separation is accomplished either by torch cutting or by using a reciprocating saw to cut through the steel, aluminum or other material. Torch cutting requires a fire-watch crew to stand by and a certain level of expertise by the user. Cutting with a reciprocating saw does not require the fire-watch crew and can be accomplished by nearly every worker making it the preferred method among supervisors. Also, areas containing suspected hazardous materials must be mechanically cut to minimize worker exposure to the substance. Chemical protective clothing is worn when there is the possibility of exposure to known hazards. Mechanical cutting can take place overhead to remove wire hangers, between shoulder and floor height to remove bulkheads, or below floor level to remove decking and supports. Some components are lowered to the deck to be cut to reduce the amount of overhead work.

Figure 7. Worker Using Reciprocating Saw While Kneeling

Workers assume a variety of postures to cut the pieces of metal including kneeling, sitting, lying down, bending over, standing on ladders, etc. Workers typically cut for 2-3 hours and then carry cut material to a disposal area for another 2 hours. Workers often work in pairs, switching between cutting the material with the eight pound reciprocating saw and supporting the item being cut. Heavier items are removed using tandem lifts.

The ergonomic risk factors for reciprocating saw operators include: awkward postures of the spine and wrist, static kneeling postures, forceful exertion of the upper extremity to hold the reciprocating saw, and high noise exposure.   Particularly significant is the exposure to hand-arm or segmental vibration from using the powered reciprocating saw. (Vibration damping gloves are required personal protective equipment while using the saw). Normal operation of the saw results in vibration that has been reduced by an anti-vibration mechanism incorporated into the design of the saw. However, when initiating a cut (plunge cutting) or when the blade binds in the material, an extreme amount of vibration is transferred to the arm of the user. The manual material handling of the cut pieces may result in back, neck or shoulder strain of the workers.

IIB4. Removal of Terrazzo Tile with Chipping Hammer

Figure 8. Worker Using Chipping Hammer to Remove Terrazzo Tile from Deck Surface

During the outfitting of vessels, some of the decking surfaces are covered in tile. This is particularly true of mess hall and lavatory facilities. Before the deck plate can be cut be either torch or reciprocating saw, a path must be cleared of tile. The tile is removed by using a chipping hammer to break the tile and flake the tile off the deck surface. This task requires the worker to kneel, sit or bend over the deck surface to operate the chipping hammer.

Chipping tile from deck surfaces puts the worker in awkward postures, having to kneel or sit on the deck. The back and neck are flexed. Exposure to hand-arm or segmental vibration is bad, having to hold the chipping blade in place with one hand while holding the tool weight and operating the trigger with the other hand. Few improvements to these tools have been made since the turn of the century. Noise exposure is also very high with the use of chipping hammers.

IIB5. Manual Material Handling in the "Cut and Carry" Process within IRR

Figure 9. Workers Performing Tandem Lift of Scrap Material Inside Vessel

As part of the Inactivation, Reactor Compartment Disposal, and Recycling process at PSNS, material is cut apart and stored at temporary locations within the vessel being dismantled. This material is then manually moved from the internal storage areas to scrap bins for removal from the ship by crane. Depending on how the material was cut, it may require more than one individual to safely lift the object and carry it to the scrap bin. Somewhat confined spaces and the clutter of the stored material create tripping hazards in the narrow passageways.

Figure 10. Workers Placing Scrap in Bin for Transport Off Ship

The manual material handling of scrap metal may result in strains of the lower back, neck, shoulder and upper extremities. Tripping hazards may be present. Sharp edges on the cut metal may cause lacerations to ungloved hands.

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.

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

- Avoidance of current expenses and ongoing losses
  - Reducing workers compensation costs
  - Overtime for replacement workers
  - Lost productivity, quality or yields from less skilled workers
  - Increased training and supervisory time

- Enhanced existing performance
  - Increased productivity including fewer bottlenecks in production, higher output, fewer missed delivery dates, less overtime, labor reductions, and better line balancing
  - Improved quality including fewer critical operations, more tasks with every operator's control and capacity, and fewer assembly errors
  - Increased operating uptime including faster setups, fewer operating malfunctions, and less operator lag time.
  - Faster maintenance including increased access, faster part replacement, fewer tools needed, more appropriate tools, more power and faster tool speeds.

- Enhanced quality of worklife
  - Less turnover
  - Less employee dissatisfaction

- Fewer traumatic injuries

- Fewer human errors resulting in lost product or operating incidents

- 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 are listed below.

- Costs of replacement workers
    - Hiring costs for permanent replacements plus training and other costs
    - Additional costs for temporary workers who may also have lower work skills

- Lower productivity
    - Fewer units per hour
    - Lower yields
    - Damage to material or equipment that would not occur with an experienced worker
- Lower quality
    - Number of rejects
    - Amount of rework
    - Timeliness of product delivery

- Increased supervision
    - Cost to manage/train a less skilled worker

- Training to develop and maintain job skills
    - Amount of lost work time
    - 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 all benefits received from implementing the intervention, then the intervention is not worth undertaking. 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. BIN EMPTYING BY SORTING PAD WORKER POSSIBLE INTERVENTIONS

Changes in how the scrap bins are presented to the worker may help in eliminating the extreme back flexion required to reach to the bottom of the bins to remove items. The current layout of the sorting bin in the drydock is illustrated in Figure 11.

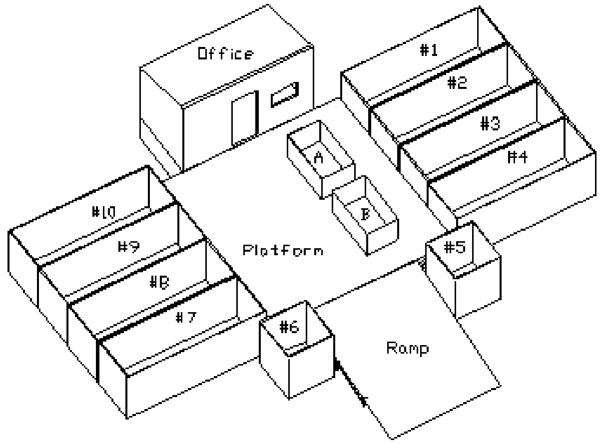

Figure 11. Current Sort Pad Configuration

Tilting pallet jacks can be used to tilt the scrap bin once some of the material has been distributed to the shipping containers. Alternatively, the scrap material can be dumped from the bins onto an elevated rotating turntable, as illustrated in Figure 12. This elevated turntable would minimize the need of the worker to bend into the bins to remove materials. Short hooked poles can be provided to move material from the center of the table to the edge to allow the worker to grasp it (Figure 13). Ultimately, the accurate sorting of material into separate scrap bins at the vessel would eliminate the need for the sorting pad.

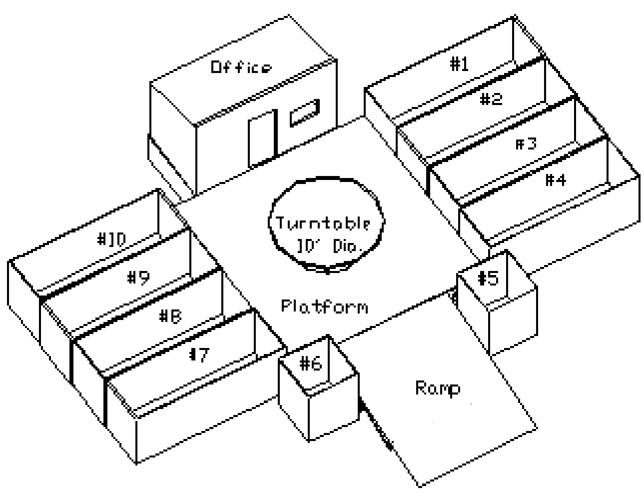

Figure 12. Elevated Rotating Sorting Table

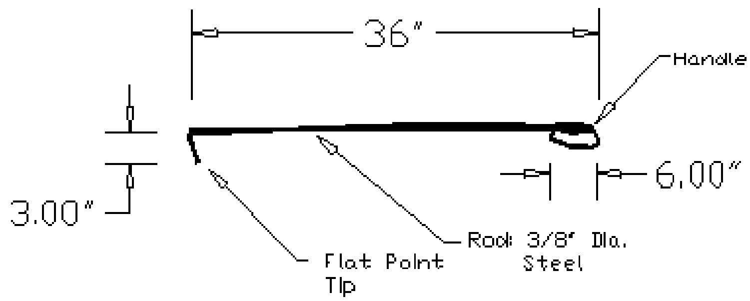

Figure 13. Sorting Parts Hook

Table 1. Approximate Specifications for Portable Box Tilter

Capacity	4,000 pounds
Cradle Width	36 inches
Shipping Weight	660 pounds
Cost	$2,700

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 approximate costs associated with this shipyard's Workers' Compensation data for the years 1997 and 1998, it is possible to determine average medical and indemnity costs associated with musculoskeletal injuries by nature of injury, as summarized in Table 2.

Table 2. Approximate Direct Medical and Indemnity Costs by Nature of Injury

Arthritis/Bursitis	$3,971
Back Strain	$5,870
Carpal Tunnel Syndrome	$5,452
Chondromalacia	$1,011
Degenerative Disease	$9,363
Inflammatory Disease	$2,242
Hernia	$3,802
Multiple Strains	$5,240
Neck Strain	$3,533
Nerve Injury	$21,793
Unclassified	$3,559

From 1997 through 1998, this particular shipyard experienced fourteen musculoskeletal injuries related directly to removal or placing of items into bins, resulting in a total estimated medical and indemnity cost of $76,308, based upon the nature of injury. An estimated yearly average total musculoskeletal injury direct cost for this specific process within this shipyard is $38,154. If indirect costs are conservatively assumed to be 75% of the direct costs, the total cost of these injuries is $66,769 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. Assuming negligible operating and maintenance costs, a simple benefit-cost ratio for the first year would be $66,769 /$2,700 or 24.73. Since the benefit to cost ratio is greater than one, it is advantageous to implement the proposed intervention, given the parameters cited above. In fact, the intervention is likely to pay for itself within the first month of operation.

However, possibly, only one-tenth the estimated annual injury cost is saved each year. It is also possible that the portable bin tilter 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:

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

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 $6,677 (1/10 of the estimated annual injury cost) 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 $10,201. Assuming initial costs of the portable bin tilter are $2,700 and negligible annual costs, the benefit to cost ratio of implementing this intervention is $10,201/$2,700 or 3.78, greater than one, and therefore still economically advantageous.

Alternatively, the installation of an elevated rotating sorting table may be considered. The estimated associated cost of this option are detailed in Table 3. A steel plate approximately ten feet in diameter can be welded to the rotating ring of the table to allow the material from the bins to be dumped onto the surface.

Table 3. Cost Summary of Elevated Rotating Sorting Table

Cost of Raw Materials	$650
Cost of Lift Table	$1,950
Cost of Labor	$400
Total Cost	$3,000

Again, assume an estimated yearly average total musculoskeletal injury cost (direct + indirect) for this specific process within this shipyard of $66,769 . Assuming negligible operating and maintenance costs, a simple benefit-cost ratio for the first year would be $66,769/$3,000 or 22.26. Since the benefit to cost ratio is greater than one, it is advantageous to implement the proposed intervention, given the parameters cited above. Again, this intervention is likely to pay for itself within the first month of operation.

Consider that only one-tenth the estimated annual injury cost is saved each year. It is also possible that the elevated rotating sorting 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 Equation 1. Using an annual savings of just $6,677 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 $10,201. Assuming initial costs of the elevated rotating sorting table are $3,000 and negligible annual costs, the benefit to cost ratio of implementing this intervention is $10,201/$3,000 or 3.4, greater than one, and therefore still economically advantageous.

IVB. INSULATION REMOVAL POSSIBLE INTERVENTIONS

The vast majority of work for the insulation removal workers is performed with arms overhead or out in front and away from the body, either using pry bars or knives, straining the arms, shoulders, and neck. Often the worker is on a ladder and is leaning backward (back extension) to get to the work as opposed to repositioning the ladder. Back extension such as this can be stressful to the worker. Pulling the insulation off the bulkheads or overhead areas requires the use of force to separate the insulation from the surface areas. This task is stressful to the arms, shoulders, neck and back. All of these tasks are performed while the worker is wearing an encapsulating chemical-protective suit with a supplied air respirator causing an increased physiological strain on the worker.

One 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 (industrial fabrics- -i.e. vinyl, textiles, wire, metal, and fiberglass) are commercially available. Approximate technical and cost specifications of a particular shear model are provided below in Table 4.

Table 4. Powered Hand Shear Parameters

Type of Powered Shear:	Pneumatic, automatic spring return
Air Requirements:	80 -120 psi
Blade Configurations:	Straight, Straight with Serrated Edge, Curved, Gate Cutting, Pruning
Blade Length:	Variable; 1 to 5 inches depending on blade configuration
Blade Type	Stainless Steel
Other Features:	Lightweight and balanced, safety latch
Price	$2195 (includes shear power unit with extra large air cylinder plus blade)

One must consider the cost justification of implementing the intervention to determine whether the implementation makes economic sense. Assuming that a crew size supply of the above powered shears would be purchased and that the training costs and implementation costs associated with the shears would be negligible, the total costs for the intervention is summarized in Table 5.

Table 5. Cost Summary of Powered Hand Shear Intervention

Cost of Hand Shear (x 5 crew size)	$10,975
Cost of Training	Negligible
Cost of Installation	Negligible (operates off conventional air line)
Total Cost	$10,975

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 participating shipyards, it is possible to determine average medical and indemnity costs associated with musculoskeletal injuries by injury nature/ body part, as summarized in Table 2. From 1994 through 1998, this particular shipyard experienced at least 48 musculoskeletal injuries within their insulator department as a result of removing insulation, resulting in a total estimated medical and indemnity cost of $281,789, based upon nature of injury/ part of body injured. An estimated yearly average total musculoskeletal injury direct cost for this specific process within the shipyard is $56,358. If indirect costs are conservatively assumed to be 75% of the direct costs, the total cost of these injuries is $98,626 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 $98,626 /$10,975 or 8.99. 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 powered hand shears last only half a year before needing replacements. 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 Equation 1.

Using an annual savings of just $49,313 at an interest rate of 20 percent over a six month period, the present worth of the proposed savings over a six month period is $21,483. Assuming initial costs of the lift table are $10,975 and negligible costs before replacement, the benefit to cost ratio of implementing this intervention is $21,483/$10,975 or 1.96, greater than one, and therefore still economically advantageous.

IVC. POSSIBLE INTERVENTIONS FOR THE RECIPROCATING SAW OPERATIONS IN THE IRR PROCESS

The ergonomic risk factors for reciprocating saw operators include: awkward postures of the spine and wrist, static kneeling postures, forceful exertion of the upper extremity to hold the reciprocating saw, and high noise exposure. Particularly significant is the exposure to hand-arm or segmental vibration from using the powered reciprocating saw. (Vibration damping gloves are required personal protective equipment while using the saw). Normal operation of the saw results in vibration that has been reduced by an anti-vibration mechanism incorporated into the design of the saw. However, when initiating a cut (plunge cutting) or when the blade binds in the material, an extreme amount of vibration is transferred to the arm of the user. The manual material handling of the cut pieces may result in back, neck or shoulder strain of the workers.

The most basic and effective method to reduce the number of musculoskeletal injuries due to the reciprocating saw use is to encourage the use of torch cutting whenever the material is non-hazardous and burnable. Although the reciprocating saw is the preferred method because it requires less training, set-up, and does not require a fire watch, these are not sufficient reasons to preclude torch cutting where appropriate. Since most reciprocating saw operators currently work in teams, each person can alternately serve as firewatcher while the other torchcuts. If one assumes that the torch cut operation would require an additional hour of set-up time per member of a five person IRR crew, the cost of this administrative intervention can estimated as below.

Table 6. Approximate Cost of Increased Torch Cutting in IRR

Labor: additional Set-up Time of 1 hour per day for each member of five person crew (1300 hours a year @ $20/hour)	$26,000

From 1997 through 1998, this particular shipyard experienced thirty eight musculoskeletal injuries within their steelyard as a direct result of working reciprocating saws, resulting in a total estimated medical and indemnity cost of $210,342, based upon estimated costs associated with the nature of injury/ part of body injured. An estimated yearly average total musculoskeletal injury direct cost for this specific process within the shipyard is $105,171. If indirect costs are conservatively assumed to be 75% of the direct costs, the total cost of these injuries is $184,049 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. Thus, if the above increased torch cutting administrative intervention eliminates just one fourth of these injuries, a simple benefit-cost ratio for the first year would be $46,012/$26,000 or 1.77. Since the benefit to cost ratio is greater than one, it is advantageous to implement the proposed intervention, given the parameters cited above.

If saws are utilized, the use of wheeled tripods or standing jigs as already developed at Puget Sound Naval Shipyard, will remove the worker from the vibration exposure. The addition of a stabilizing handle near the front of the tool that isolates some of the vibration from the worker is also a promising idea. Modifying the saw trigger mechanism to work from palm pressure as opposed to finger pressure was also done at Puget Sound Naval Shipyard to minimize trigger finger complaints.

IVD. TILE CHIPPING POSSIBLE INTERVENTIONS

Removing tile from deck surfaces requires the worker to kneel or sit on the deck. Providing knee pads or cushions minimizes some of the contact stresses. Low industrial seating wheeled stools are available for approximately $150 each. Depending on the application, worker postures may benefit from using the stools.

If chipping hammers can not 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 and the most vibration-damped tool available be used. New chipping hammers range in price from $400 to $750. From 1997 through 1998, this particular shipyard experienced thirteen musculoskeletal injuries related directly to chipping and removal of tile or other material. These injuries, including six identified as carpal tunnel syndrome and seven identified as strains, resulted in a total estimated medical and indemnity cost of $69,390, or an annual direct cost of $34,695.

IVE. MANUAL MATERIAL HANDLING IN "CUT AND CARRY" OPERATION POSSIBLE INTERVENTIONS

Ship dismantling requires that all internal components are removed from the vessel before the hull is cut to pieces. The removal of components through ship passageways to staging areas is currently performed by manual material handling. From 1997 through 1998, this particular shipyard experienced thirty-three musculoskeletal injuries related directly to manual materials handling in the "cut and carry"operation. These injuries, including twenty-eight back strains, resulted in a total estimated medical and indemnity cost of $186,239, or an annual direct cost of $93,120.

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 the scrap bins in the staging areas. Portable hoists may be useful in the staging areas as well to move heavy or bulky material.

V. CONCLUSIONS AND RECOMMENDATIONS

Five distinct work processes within a ship dismantling operation were surveyed to determine the presence of risk factors associated with musculoskeletal disorders.   Possible interventions highlighted here were discussed at length.

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 recommended that further action may 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 recommended that ergonomic interventions may be implemented at Puget Sound Naval Shipyard to minimize hazards in the identified job tasks.

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