NIOSH SHIPYARD
ERGONOMICS PROJECT
WORKSHOP

Hotel Monaco
New Orleans, Louisiana
November 15, 2002

Approved for public release; distribution is unlimited
Original Workshop Agenda

0800 - 0815  Opening Remarks  Larry Reed
0815 - 0900  Shipyard Interventions I  Jim Albers
0900 - 1000 Shipyard Interventions II  Steve Hudock
1000 - 1015  Break
1015 - 1100  Shipyard Trade Occupational Risk Matrix  Steve Hudock
1100 - 1130  Where Do We Go From Here?  Larry Reed
1130 - 1145  Closing Comments  Steve Hudock
REVISED Workshop Agenda

0800 - 0815  Opening Remarks  Larry Reed
0815 - 0845  Project Background  Steve Hudock
0845 - 0915  Shipyard Interventions I  Jim Albers
0915 - 1000  Shipyard Interventions II  Matt Jaszkowiak
1000 - 1015  Break
1015 - 1100  Other Interventions and the Shipyard Trade Occupational Risk Matrix  Steve Hudock
1100 - 1130  Where Do We Go From Here?  Larry Reed
1130 - 1145  Closing Comments  Steve Hudock
Project Objective

Determine the effectiveness of ergonomic interventions for select maritime processes through reducing both the number and severity of injuries and lowering Workers’ Compensation costs while improving quality and productivity.
Project Background

- Early interest in shipyard ergonomics by NSRP SP-5 Committee, BIW ('95-96)

- Initial start as NIOSH project for FY98, 9/97

- Initial shipyard walkthrough visits (12 domestic and 5 in Japan), 5-12/98

- MARITECH ASE proposal submitted, 2/99
Project Background (cont.)

- Proposal awarded: $304K + $283K cost share, 9/99

- Risk Factor Analysis shipyard visits (8 shipyards), 10/99 - 6/00

- Intervention follow-up visits (8 visits between 4 shipyards), 8/00 - 7/01
Primary Participating Shipyards

- Bath Iron Works
- Continental Maritime
- Halter Marine Moss Point
- Ingalls
- Jeffboat
- Marinette Marine
- Puget Sound Naval Shipyard
- Todd Pacific
Other Participating Shipyards

- Cascade General
- Electric Boat (Groton and Quonset Point)
- Halter Marine Pascagoula
- NASSCO
- Newport News Shipbuilding

- Ishikawajima-Harima Heavy Industries - Tokyo
- Sumitomo Heavy Industries - Yokosuka
- USN Ship Repair Facility - Yokuska
- Mitsui Engineering and Shipbuilding - Tamano
- Sanoyas Hishino Meisho - Mizushima
- Mitsubishi Heavy Industries - Nagasaki
Steve Hudock

Quantification of Occupational Risk Factors
Exposure Assessment Techniques

- NIOSH Lifting Equation
- Strain Index
- Rapid Upper Limb Assessment
- 3DSSPP
- Ovako Work Analysis System (posture)
Work Processes Observed
-- Welding --

- Onboard Engine Room Wire Welding
- Tripod Subassembly Wire Welding in Shop
- Panel Line Wire Welding
- Onboard Deck Plate Welding
- Honeycomb Hull Welding
Work Processes Observed
-- Subassembly --

- Onboard Lifeboat Rack Assembly
- Assembly Fitter Using Come-along in Shop
- Rakeframe Subassemblies in Shop
- Manhole and Hatch Assembly
- Onboard Reciprocating Saw Use
Work Processes Observed
-- Sheetmetal --

- Onboard Duct Installation
- Sheetmetal Assembly in Shop
Work Processes Observed
-- Deck Work --

- Onboard Deck Fitting
- Onboard Torch Cutting
- Onboard Deck Scraping
- Onboard Removal of Terrazzo Tile with Chipping Hammer
Work Processes Observed
-- Blasting --

- Waterjet Blasting in Drydock
- Abrasive Blasting in Steelyard
Work Processes Observed
-- Pipefitting --

✧ Onboard Pipe Welding Process (2)

✧ Shop Pipe Welding
Work Processes Observed
--- Steelyard ---

- Angle Iron Unload in Steelyard

- Angle Iron Positioning by Gator Bar
Work Processes Observed
-- Insulation --

✦ Onboard Insulation Installation

✦ Onboard Insulation Removal
Work Processes Observed
-- Shear --

Shear Operation in Plate Shop (2)
Work Processes Observed
-- MMH --

- Bin Loading by Material Handlers in Shop
- Bin Emptying and Sorting in Drydock
- Onboard Rigger Equipment Load-In
- Onboard Manual Material Handling
Work Processes Observed
-- Grinding --

- Onboard Tank Grinding
- Onboard Grinding
- Panel Line Grinding
Work Processes Observed
--- Electrical ---

- Onboard Cable Connection
- Onboard Cable Pulling (2)
Jim Albers

Todd Pacific and Marinette Marine Interventions
Ergonomic Interventions at the Marinette Marine and Todd Shipyards

Jim Albers & Steve Hudock
Organizational Science & Human Factors Branch (OSHFB)
Division of Applied Research & Technology (DART)
National Institute for Occupational Safety & Health (NIOSH)
Purpose of Project

To evaluate recognized risk factors for work-related musculoskeletal disorders (WMSDs) and to provide effective ergonomic interventions to reduce risk
Project Objectives

1. Identify shipyard tasks that expose workers to recognized risk factors for WRMDs
2. Perform a quantitative ergonomic analysis for each of the selected activities using exposure assessment tools
3. Recommend ergonomic interventions that are technologically and economically feasible
4. Determine the effectiveness of the ergonomic intervention and publicize the results
Marinette & Todd Shipyards

Marinette Marine
- Marinette, WI
- Build seagoing & long coastal buoy tenders and lodging barges
- Built in 1942 & occupies 60 acres
- 500,000 ft² enclosed workspaces
- 650 employees

Todd Pacific
- Seattle, WA
- Repair & overhaul commercial & military vessels
- Built in 1916 & occupies 46 acres
- 3 dry docks, 6000 ft. berthing space
- 1,000 employees (~ 800 production workers)
 Jobs Evaluated at Marinette

- Engine room wire welding
- Tripod subassembly wire welding in shop
- Life boat rack assembly
- Sheet metal assembly in shop
- Assembly shipfitting in shop

[Hudock & Wurzelbacher, 2001a]
NIOSH Job Evaluation

Engine room wire welding

Tasks: Weld together and grind steel structure on vessel

Risk factors: Prolonged awkward wrist & arm postures when welding. Prolonged knee bending (hyper-flexion) when squatting. Forward bending and neck flexion for work below knee height.

[Hudock & Wurzelbacher, 2001a]
NIOSH Job Evaluation

Tripod subassembly wire welding

**Tasks:** Weld and grind subassemblies in shop at fixed workstation

**Risk factors:** Awkward and static wrist & arm postures and forward bending when welding. Prolonged knee bending (hyper-flexion) when squatting and kneeling. Hand-arm vibration when using needlegun.

[Hudock & Wurzelbacher, 2001a]
NIOSH Job Evaluation

Life boat rack assembly

**Tasks:** Torch cut & grind angle irons. Weld angle irons together on upper deck of vessel.

**Risk factors:** Awkward and static wrist, arm and back postures. Prolonged knee bending (hyper-flexion) when squatting. Contact stress on knee when kneeling. Hand-arm vibration when using needlegun.

[Hudock & Wurzelbacher, 2001a]
Sheet metal assembly in shop

Tasks: Form and fit (hammer) sheet metal together. Handle metal sheets and finished ducts, etc.

Risk factors: Awkward wrist, arm and back postures.

[Hudock & Wurzelbacher, 2001a]
NIOSH Job Evaluation

Assembly shipfitting in shop

**Tasks:** Torch cut, grind and weld angle iron, steel plate and other materials into place so that subassemblies can be matched and secured.

**Risk factors:** Awkward & static postures. High physical forces fitting subassemblies. Handling materials and tools (come-along). Hand-arm vibration.

[Hudock & Wurzelbacher, 2001a]
NIOSH Recommended Intervention

Engine room wire welding & life boat rack assembly

Recommendation: Utilize industrial sit-stools, knee support, and knee pads to address knee hyper-flexion, forward bending, and contact stress on knees.

Outcome: All interventions not yet fully implemented. Shipyard working with knee pad provider on design concerns.

[Hudock & Wurzelbacher, 2001b]
NIOSH Recommended Intervention

Tripod subassembly wire welding

Recommendation: Use tilting, rotating and height adjustable weld positioner
- eliminate need for sustained awkward postures
- increase efficiency and quality

Outcome: Intervention not yet implemented
[Hudock & Wurzelbacher, 2001b]
NIOSH Recommended Intervention

Sheet metal assembly in shop

Recommendation: Provide ergonomic awareness training so workers will use available sheet metal equipment (e.g., bench-mount hand brakes, and metal forming presses), rather than hand tools.

Outcome: Ergonomic awareness training through Shipbuilders Council of America anticipated.

[Hudock & Wurzelbacher, 2001b]
NIOSH Recommended Intervention

Assembly shipfitting in shop

Recommendation: Provide high leverage puller to reduce physical force requirements

- **Load capacity**: Maximum pull
  - 1500-1650 lbs: 45-68 lbs
  - 3000-3300 lbs: 55-73 lbs
  - 6000-6600 lbs: 62-77 lbs

- **Example**: American Power Pull Model 144-D 2 Ton come-along with 36:1 leverage rating

- **Outcome**: Several new come-alongs purchased at shipyard
  [Hudock & Wurzelbacher, 2001b]
Jobs evaluated at Todd

- Pipe welding onboard vessel
- Torch cutting onboard vessel
- Water-jet blasting of vessel in dry-dock
- Grinding onboard vessel
- Semi-automatic wire welding onboard vessel

[Hudock & Wurzelbacher, 2001c]
NIOSH Job Evaluation

Water-jet blasting of vessel

Tasks: Manually hold water-jet during blasting while working on powered elevated platform

Risk factors: High physical forces and awkward static postures, especially the hands, wrists, & elbows

[Hudock & Wurzelbacher, 2001c]
NIOSH Job Evaluation

Pipe stick welding onboard vessel

Tasks: Fit piping together, weld pipe, remove slag and grind weld in confined areas

Risk factors: Static and awkward postures
- hand-wrist flexion and ulnar & radial deviation
- shoulder abduction
- back flexion and extension

[Hudock & Wurzelbacher, 2001c]
NIOSH Job Evaluation

Torch cutting onboard vessel

Tasks: Operate torch to cut steel onboard the vessel, e.g., decking, bulkhead while standing, kneeling or squatting

Risk factors: Awkward and static postures of the knees, hips & torso and hand-wrist (welding). Contact stress (knees).

[Hudock & Wurzelbacher, 2001c]
NIOSH Job Evaluation

Grinding onboard vessel

Tasks: Grind paint and welding beads from horizontal and vertical surfaces on board vessel while standing, kneeling, or squatting.


[Hudock & Wurzelbacher, 2001c]
Wire welding onboard vessel

Tasks: Operate semi-automatic welder and wire welding onboard vessel. Remove slag from welds.

Risk factors: Awkward and static postures of the knees and hips, hands-wrists, and shoulders. Contact stress (knees).

[Hudock & Wurzelbacher, 2001c]
NIOSH Recommended Intervention

Water-jet blasting of vessel

- **Recommendation:** Place a mount on the lift platform, e.g., railing, to hold and position water-jet.

- **Outcome:**
  - Mount to hold and position water-jet placed on lift. Not used due to engineering concerns, e.g., load capacity of the lift.
  - NSRP funded project to investigate use of ultra high pressure water methods (NSRP, 2001).

[Hudock & Wurzelbacher, 2001d]
NIOSH Recommended Intervention
Welding, torch cutting & grinding

Recommendation:
Ergonomic awareness training for production workers due to limited opportunities to modify workstations & implement engineering controls.

Outcome: Three ergonomic awareness training sessions provided to Todd labor-management team and front-line supervisors during February 2001.

[Hudock & Wurzelbacher, 2001d]
NIOSH Recommended Intervention

Welding, torch cutting & grinding

Recommendation: Utilize industrial sit-stools, knee support, and knee pads to address knee hyperflexion, forward bending, and contact stress on knees.

Outcome: Knee pads provided as PPE. Stools not yet implemented as intervention.

[Hudock & Wurzelbacher, 2001d]
Shipyard initiated interventions

Marinette Marine

Fabricated paint ‘pallets’ with open sides to prevent forward flexion when accessing 5 gallon containers and welded eyes on four corners of paint pallets to facilitate crane transport.
Shipyard initiated interventions

Todd Pacific Shipyards

- Japanese-style ‘5S’ manufacturing program implemented in 18 installations, including the paint shop, tool room, bull maintenance, rigging shop, carpenters’ shop and welding maintenance shop.
  - Training for key personnel included ergonomic principles, e.g., placing work at appropriate heights and distances, reducing manual material handling, and providing adequate illumination.
- Active participant in NSRP “lean ship repair” program. Includes 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.
Conclusion

Marinette Marine interventions:
- Most interventions were not fully implemented. The wheeled, adjustable work stools were expected to provide a significant impact on reducing musculoskeletal injuries for workers in kneeling postures. The wheeled stools, however, were not widely accepted by employees.

Todd Pacific
- Several interventions were implemented. The ergonomic awareness training was expected to have significant impact on reducing musculoskeletal injuries for a ship repair facility. Future ergonomics training is anticipated for all employees through the SCA grant from OSHA.
References


Matt Jaszkowiak

Puget Sound Naval Shipyard
Intervention
NIOSH Shipyard Ergonomics Project Workshop
Puget Sound Intervention
Matthew N. Jaszkowiak
Dwight M. Werren
Stephen D. Hudock, Ph.D.

Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health
Project Objectives

• Assessment of High Risk job.

• Reduced injury rates and lost workdays associated with scrap metal sorting operation.

• Reduced turnover associated with this task.
History of Project

• Manual sorting of scrap metal from dismantling of ships

• Sorting task was chosen from several tasks identified by the shipyard.

• Tasks were identified based on their history of turnover and injury.
Pre-intervention Risk Factor Analysis

- University of Michigan 3DSSP
- Strain Index
- NIOSH Lifting Equation
- NIOSH Checklist for Manual Materials Handling
- OWAS
- University of Michigan Upper Extremity Cumulative Trauma Disorder checklist
- PLIBEL
Worker Reaching to Bottom of Scrap Bin to Reach Object
Worker Hanging Over Side of Scrap Bin on One Leg to Reach Object
Worker Lifting Valve Assembly from Sorting Bin
Development of Intervention

Collaboration between the Shipyard and a vendor
Intervention in Operation
Moving Scrap from Back of Bin
Quantitative Evaluation of Intervention

- Laboratory mock-up
- Peak motion capture with anatomical markers
- Task analysis using JACK® Human Modeling and Ergonomics Analysis software
Pre-Intervention Laboratory Mock-up
Post Intervention Laboratory Mock-up
PEAK Motus Motion Capture Stick Figure with Markers
JACK Mannequin Animation
Lower Back Analysis – 50 lb lift near bottom of bin
Lower Back Analysis Tool – 50 lb lift near front of bin
## Pre and Post Intervention Lower Back Analysis

<table>
<thead>
<tr>
<th>Measure</th>
<th>Pre-Intervention</th>
<th>Post-Intervention</th>
<th>Percent Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>L4 / L5 Disc Compression</td>
<td>7084 N</td>
<td>2922 N</td>
<td>59 %</td>
</tr>
<tr>
<td>Anterior / Posterior Shear</td>
<td>1234 N</td>
<td>511 N</td>
<td>59 %</td>
</tr>
<tr>
<td>Erector-Spiniae Muscle Tension</td>
<td>3338 N</td>
<td>1362 N</td>
<td>59 %</td>
</tr>
</tbody>
</table>
Static Strength Prediction – 50 lb lift near bottom of bin
3D Static Strength Prediction – 50 lb lift near front of bin
Michigan 3D Static Strength Prediction

<table>
<thead>
<tr>
<th>Measure (Male % Capability 30kg load)</th>
<th>Pre-Intervention</th>
<th>Post-Intervention</th>
<th>Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torso</td>
<td>39 %</td>
<td>89 %</td>
<td>50 %</td>
</tr>
<tr>
<td>Hip</td>
<td>31 %</td>
<td>87 %</td>
<td>56 %</td>
</tr>
<tr>
<td>Shoulder</td>
<td>46 %</td>
<td>99 %</td>
<td>53 %</td>
</tr>
</tbody>
</table>
### NIOSH Lifting Equation

<table>
<thead>
<tr>
<th>Measure</th>
<th>Pre-Intervention</th>
<th>Post-Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lifting Index (LI)</td>
<td>5.46</td>
<td>1.93</td>
</tr>
<tr>
<td>30 Kg load (LI)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recommended Weight Limit (RWL)</td>
<td>5.50 Kg</td>
<td>16.08 Kg</td>
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</tbody>
</table>
Low back pain prevalence by LI category

Waters et al., 1999

Percent Reporting

Lifting Index Category

NIOSH

CDC

Centers for Disease Control and Prevention
Post-Intervention Evaluation

• Interview workers to determine effectiveness of intervention

• Follow-up with shipyard on injury rates and turnover associated with this task
Steve Hudock

Other Ergonomic Interventions and STORM
- Vibration Analysis of New vs. Used Pneumatic Tools
- Shear Lift Table at Jeffboat
- Cable Pulling System (U.S. Navy)
- Improved Welding Whip Trial (Ingalls)
Shipyard Trade Occupational Risk Matrix (STORM)

Occupation by Risk Factor Based on Incidence and Severity
RISK FACTORS:

Body parts are listed under the risk factors that affect the parts for each trade. (#) Shows how common and costly the body part injured by workers in each trade per year, with (1) being the most common.

Color Shows importance of risk factor for causing injuries in that trade. For example, red is most important, followed by orange, and then yellow. Green means that this is not a strong factor in causing muscle and joint injuries for that trade.

<table>
<thead>
<tr>
<th>TRADE</th>
<th>Position held for a long time</th>
<th>Awkward positions</th>
<th>Repeated movement</th>
<th>Vibration</th>
<th>Too much force</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abrasive Blasters</td>
<td>(1) ARMS (2) SHOULDERS (3) BACK</td>
<td>(1) ARMS (2) SHOULDERS (3) BACK</td>
<td></td>
<td></td>
<td>(1) ARMS (2) SHOULDERS (3) BACK</td>
</tr>
<tr>
<td>Burners/Torch Cutters</td>
<td>(1) KNEES (2) BACK (3) NECK (4) SHOULDERS (5) ARMS (6) HAND/ WRIST</td>
<td>(1) KNEES (2) BACK (3) NECK (4) SHOULDERS (5) ARMS (6) HAND/ WRIST</td>
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<td>TRADE</td>
<td>RISK FACTORS:</td>
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<tr>
<td></td>
<td>Position held for a long time</td>
<td>Awkward positions</td>
<td>Repeated movement</td>
<td>Vibration</td>
<td>Too much force</td>
</tr>
<tr>
<td>Electricians</td>
<td>(1) BACK</td>
<td>(2) KNEES</td>
<td>(3) HAND/ WRIST</td>
<td>(5) ARMS</td>
<td></td>
</tr>
<tr>
<td>Grinders/ Chippers</td>
<td>(1) BACK</td>
<td>(2) KNEES</td>
<td>(3) ARMS</td>
<td>(4) SHOULDERS</td>
<td>(5) HAND/ WRIST</td>
</tr>
<tr>
<td>Insulators</td>
<td>(1) HAND/ WRIST</td>
<td>(2) SHOULDERS</td>
<td>(3) HAND/ WRIST</td>
<td></td>
<td>(1) BACK</td>
</tr>
<tr>
<td>Machinists</td>
<td>(1) BACK</td>
<td>(2) NECK</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

- **Too much force**
- **Vibration**
- **Repeated movement**
- **Awkward positions**
- **Position held for a long time**
- **Back**
- **Knees**
- **Arms**
- **Shoulders**
- **Hands/Wrist**
- **Neck**
<table>
<thead>
<tr>
<th>TRADE</th>
<th>RISK FACTORS:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Position held for a long time</td>
</tr>
<tr>
<td><strong>Material Handlers</strong></td>
<td>(1) BACK</td>
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<tr>
<td></td>
<td>(2) SHOULDERS</td>
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<tr>
<td></td>
<td>(3) ARMS</td>
</tr>
<tr>
<td><strong>Outfitters</strong></td>
<td>(1) BACK</td>
</tr>
<tr>
<td></td>
<td>(2) ANKLES</td>
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<tr>
<td></td>
<td>(3) KNEES</td>
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<tr>
<td></td>
<td>(4) HAND/ WRIST</td>
</tr>
<tr>
<td><strong>Pipefitters</strong></td>
<td>(1) BACK</td>
</tr>
<tr>
<td></td>
<td>(2) KNEES</td>
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<tr>
<td></td>
<td>(3) ARMS</td>
</tr>
<tr>
<td></td>
<td>(4) NECK</td>
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<tr>
<td><strong>Riggers</strong></td>
<td>(1) SHOULDERS</td>
</tr>
<tr>
<td></td>
<td>(2) BACK</td>
</tr>
<tr>
<td></td>
<td>(3) KNEES</td>
</tr>
<tr>
<td>TRADE</td>
<td>RISK FACTORS:</td>
</tr>
<tr>
<td>-------------</td>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td><strong>Position held for a long time</strong></td>
</tr>
<tr>
<td>Saw Operators</td>
<td>(1) HAND/ WRIST (2) ARMS (3) SHOULDERS (4) BACK</td>
</tr>
<tr>
<td>Sheetmetal</td>
<td>(1) BACK (2) NECK (3) KNEES</td>
</tr>
<tr>
<td>Shipfitters</td>
<td>(1) BACK (2) KNEES (3) NECK (4) HAND/ WRIST (5) ARMS (6) SHOULDERS</td>
</tr>
<tr>
<td>Welders</td>
<td>(1) KNEES (2) BACK (3) NECK (4) SHOULDERS (5) ARMS (6) HAND/ WRIST</td>
</tr>
</tbody>
</table>
Where do we go from here?
Compendium Document
Workshops
Voluntary Industry Guidelines
Steve Hudock

Information Dissemination
and Closing Remarks
INFORMATION DISSEMINATION
CONFERENCE PRESENTATIONS


COMMITTEE MEETINGS

MACOSH, Baltimore, Maryland, December 2000.
MACOSH, King’s Point, New York, July 2000.
MACOSH, Annapolis, Maryland, November 1999.
JOURNAL ARTICLES


TECHNICAL REPORTS

- 8 Preliminary Reports: Pre-Intervention Quantitative Risk Factor Analyses

- 8 Interim Reports: Suggested Ergonomic Interventions

- 1999, 2000 OSHA 200 Log Injury/Illness Incidence Reports

- Above reports available at [www.cdc.gov/niosh/ergship/reports.html](http://www.cdc.gov/niosh/ergship/reports.html)

- 8 Final Reports: Actions Taken (under review by shipyards)

- Compilation Report (under preparation)
WEBSITE

Ergonomic Interventions in the Building, Repair, and Dismantling of Ships

at www.cdc.gov/niosh/ergship/ergship.html
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