PRELIMINARY SURVEY REPORT:

PRE-INTERVENTION QUANTITATIVE RISK FACTOR ANALYSIS

FOR SHIP CONSTRUCTION PROCESSES

at

MARINETTE MARINE CORPORATION SHIPYARD, Marinette, Wisconsin

REPORT WRITTEN BY:
Stephen D. Hudock, Ph.D., CSP
Steven J. Wurzelbacher, M.S.

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U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
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National Institute for Occupational Safety and Health
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Engineering and Physical Hazards Branch
4676 Columbia Parkway, Mailstop R-5
Cincinnati, Ohio 45226

PLANT SURVEYED:	Marinette Marine Corporation shipyard, 1600 Ely Street, Marinette, Wisconsin 54143-2434.
SIC CODE:	3731
SURVEY DATE:	May 8-9, 2000
SURVEY CONDUCTED BY:	Stephen D. Hudock, NIOSH Steven J. Wurzelbacher, NIOSH
EMPLOYER REPRESENTATIVES CONTACTED:	Bill Getchell, Safety Director, Marinette Marine
EMPLOYEE REPRESENTATIVES CONTACTED:	Milan Racic, Health and Safety Specialist, International Brotherhood of Boilermakers, Iron Ship Builders, Blacksmiths, Forgers, and Helpers (IBB)

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ABSTRACT

A pre-intervention quantitative risk factor analysis was performed at various shops and locations within the Marinette Marine shipyard in Marinette, Wisconsin as a method to identify and quantify risk factors that workers may be exposed to in the course of their normal work duties. This survey was conducted as part of a larger project, funded through the Maritech Advanced Shipbuilding Enterprise and the U.S. Navy, to develop projects to enhance the commercial viability of domestic shipyards. Several operations were identified for further analysis including: sheetmetal workers, wire welding in constrained postures, life boat rack installation and shipfitting using comealongs. The application of exposure assessment techniques provided a quantitative analysis of the risk factors associated with the individual tasks. Possible engineering interventions to address these risk factors for each task are briefly discussed.

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.

Since 1976, NIOSH researchers have 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 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.

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 domestic ship building, ship repair, and ship recycling industries have historically had much higher injury/illness incidence rates than those of general industry, manufacturing, or construction. For 1998, the last year available, the Bureau of Labor Statistics reported that shipbuilding and repair (SIC 3731) had a recordable injury/illness incidence rate of 22.4 per 100 full-time employees (FTE), up from 21.4 in 1997. By contrast, in 1998, the manufacturing sector reported a rate of 9.7 per 100 FTE, construction reported a rate of 8.8 per 100 FTE, and all industries reported a rate of 6.7 injuries/illnesses per 100 FTE. When considering only lost workday cases, for 1998, shipbuilding and repair had an incidence rate of 11.5 per 100 FTE, compared to manufacturing at 4.7, construction at 4.0, and all industries at 3.1 lost workday injuries/illnesses per 100 FTE.

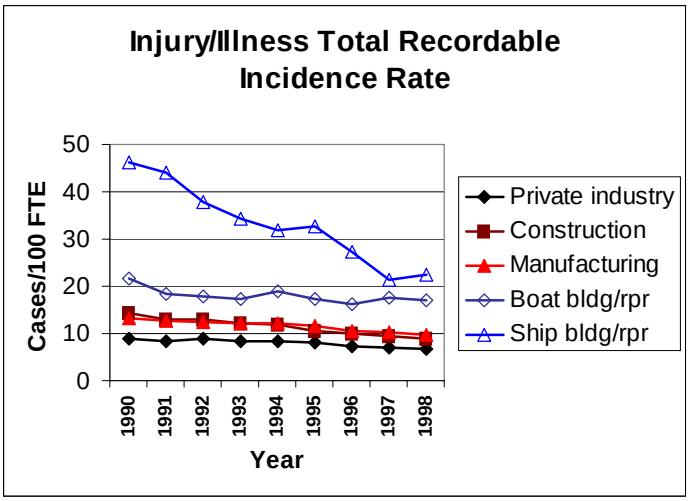

Figure 1. Injury/Illness Total Recordable Incidence Rate

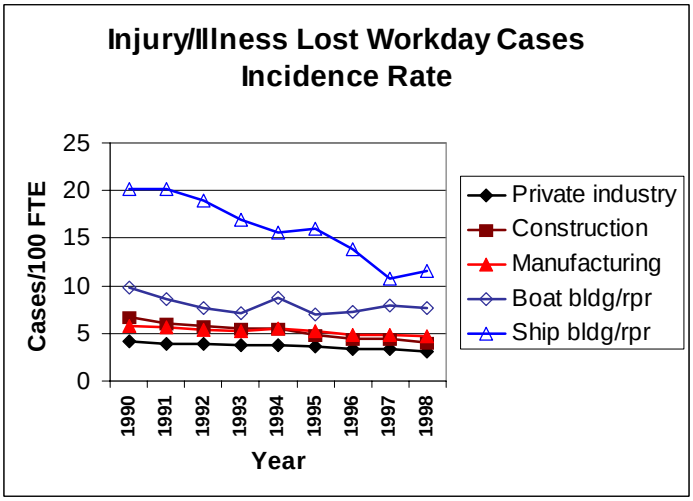

Figure 2. Injury/Illness Lost Workday Cases Incidence Rate

When comparing shipbuilding and repairing to the manufacturing sector for injuries and illnesses to specific parts of the body resulting in days away from work, for the year 1997, shipbuilding is significantly higher in a number of instances. For injuries and illnesses to the trunk including the back and shoulder, shipbuilding reported an incidence rate of 207.7 cases per 10,000 FTE, a rate 2.5 times higher than manufacturing at 82.1 cases. For injuries and illnesses solely to the back, shipbuilding reported 111.1 cases per 10,000 FTE, 2.1 times higher than manufacturing's incidence rate of 52.2 cases. For the lower extremity, shipbuilding reported 145.0 cases per 10,000 FTE, a rate 3.6 times higher than that of manufacturing at 40.8 cases. For upper extremity

injuries and illnesses, shipbuilding reported an incidence rate of 92.2 cases per 10,000 FTE, 1.3 times higher than manufacturing reported (73.4 cases per 10,000 FTE).

When comparing shipbuilding and repairing to the manufacturing sector for injuries and illnesses resulting in days away from work, for the year 1997, by nature of injury, shipbuilding is significantly higher in a number of categories. For sprains and strains, shipbuilding reported an incidence rate of 237.9 cases per 10,000 FTE, 2.6 times higher than manufacturing's incidence rate of 91.0 cases. For fractures, shipbuilding reported 41.7 cases per 10,000 FTE, 2.6 times higher than manufacturing at 15.8 cases. For bruises, shipbuilding reported 61.3 cases per 10,000 FTE, a rate 2.9 times higher than manufacturing at 21.5 cases. The median number of days away from work for all lost day injuries for shipbuilding and repairing is 12 days, compared to manufacturing and private industry's median of 5 days.

Beginning in 1995 the National Shipbuilding Research Program began funding a project looking at the implementation of ergonomic interventions at a domestic shipyard as a way to reduce Workers' Compensation costs and to improve productivity for targeted processes. That project came to the attention of the Maritime Advisory Committee for Occupational Safety and Health (MACOSH), a standing advisory committee to the Occupational Safety and Health Administration (OSHA). The National Institute for Occupational Safety and Health (NIOSH) began an internally funded project in 1997 looking at ergonomic interventions in new ship construction facilities. In 1998, the U.S. Navy decided to fund a number of research projects looking to improve the commercial viability of domestic shipyards, including projects developing ergonomic interventions for various shipyard tasks or processes. Project personnel within NIOSH successfully competed in the project selection process. The Institute currently receives external project funding from the U.S. Navy through an organization called Maritech Advanced Shipbuilding Enterprise, a consortium of major domestic shipyards.

Shipyards participating in this project will receive an analysis of their injury/illness data, will have at least one ergonomic intervention implemented at their facility, and will have access to a website documenting ergonomic solutions found throughout the domestic maritime industries. The implementation of ergonomic interventions in other industries has resulted in decreases in Workers' Compensation costs, and increases in productivity.

Researchers have identified seven participating shipyards and have analyzed individual shipyard recordable injury/illness databases. Ergonomic interventions will be implemented in each of the shipyards and intervention follow-up analysis will be completed following a six- to nine-month period. A series of meetings and a workshop to document the ergonomic intervention program will be held by the end of March 2001.

IC. BACKGROUND FOR THIS SURVEY

The Marinette Marine facility was selected for a number of reasons. It was decided that the project should look at a variety of yards based on product, processes and location. Marinette

Marine is one of the U.S. Coast Guard's leading suppliers of large vessels. Marinette Marine builds two sizes of buoy tenders for the Coast Guard. The Marinette Marine facility is considered to be a medium to small shipyard.

II PLANT AND PROCESS DESCRIPTION

IIA. INTRODUCTION

Plant Description: The Marinette Marine shipyard is located in Marinette, Wisconsin on the south shore of the Menominee River which separates Wisconsin from the Upper Peninsula of Michigan. The river flows into the northern part of Green Bay which in turn opens onto Lake Michigan. The 60-acre yard includes about 500,000 ft^2 of enclosed work space including large fabrication shops and enclosed unit erection areas.

Corporate Ties: Marinette Marine is a privately held corporation.

Products: Marinette Marine is under contract to the U.S. Coast Guard to manufacture both 225'-long seagoing buoy tenders and 175'- long coastal buoy tenders. In addition, the shipyard has recently completed lodging barges for the U.S. Navy.

Age of Plant: The facility has been in operation since 1942. The main buildings appear to be no more than twenty years old.

Number of Employees, etc: As of the date of the survey, the Marinette Marine facility employed approximately 650 workers.

IIB. PROCESS DESCRIPTION

Steelyard -- Steel is delivered to the facility by truck and is stored in an outside storage yard serviced by overhead and mobile tracked cranes.

Surface Preparation -- Steel plate is moved from the supply yard by crane into a surface preparation area. Steel is abrasive blasted to remove any rust or mill residue. Primer paint is applied which coats the steel with an inorganic zinc coating to inhibit rusting.

Plate Shop -- Steel plate is cut to size using large computer-controlled plasma cutting water tables. Smaller shapes are also cut using an automated process with standard burning torches. Steel plates are moved on and off of water tables via overhead magnet cranes. Some shapes/pieces are cut at the shears or punched at the punch presses.

Subassembly – Steel shapes are pieced together and welded to form a variety of sub-assemblies. Smaller subassemblies are joined to create bigger units.

Assembly -- The majority of assembly is performed on one of the main assembly buildings. This is where units are assembled and outfitted with various structures. Some units are inverted to assist with the installation of decks and inner bottom sections. Some piping and ventilation work is also performed at this stage of the fabrication. Once initial assembly is completed the units are blasted and painted and moved further along the production line.

Final Assembly -- The individual units of the ship are welded together to form the hull and house sections. Once this has been completed and the entire hull is water tight, the vessel is placed into the water by sideways launching for further outfitting. Cable pulling, tank painting, piping and ventilation runs, etc. are worked on extensively at this stage of fabrication.

Outfitting -- The installation of propulsion, electrical, HVAC and other systems is begun after sub-assembly and continues well after the vessel is launched.

Painting -- Vessels are painted to customer specifications prior to launch.

IIC. POTENTIAL HAZARDS

Major Hazards: Awkward postures, multiple manual material handling issues including lifting, carrying, pushing and pulling heavy objects, confined space entry, welding fumes, UV radiation from welding, paint fumes, hand/arm segmental vibration.

III. METHODOLOGY

A variety of exposure assessment techniques were implemented where deemed appropriate to the job task being analyzed. The techniques used for analysis include: 1) the Rapid Upper Limb Assessment (RULA); 2) the Strain Index; 3) a University of Michigan Checklist for Upper Extremity Cumulative Trauma Disorders; 4) the OVAKO Work Analysis System (OWAS); 5) a Hazard Evaluation Checklist for Lifting, Carrying, Pushing, or Pulling; 6) the NIOSH Lifting Equation; 7) the University of Michigan 3D Static Strength Prediction Model; and 8) the PLIBEL method.

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

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

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

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

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

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

The University of Michigan 3D Static Strength Prediction Program (University of Michigan, 1997) is a useful job design and evaluation tool for the analysis of slow movements used in heavy materials handling tasks. Such tasks can best be analyzed by describing the activity as a sequence of static postures. The program provides graphical representation of the worker postures and the materials handling task. Program output includes the estimated compression on the L5/S1 vetebral disc and the percentage of population capable of the task with respect to limits at the elbow, shoulder, torso, hip, knee and ankle.

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

IIIA. ENGINE ROOM WIRE WELDING

IIIA1. Engine Room Wire Welding Process

Onboard the vessels under construction, steel structures, whether they are units or subassemblies, must be welded together to form a more complete product. Depending on the location of the work, and the size and training of the individual, the worker may be exposed to constrained and awkward postures. The work may be at or below deck level, on the bulkhead, or over the worker's head. Often one or more other workers are in the vicinity performing their job duties which may or may not be similar to those of the welders.

1. Figure 3 depicts the welding of steel foundation supports onto the deck. Workers either sit or kneel to perform the low work. Note the proximity of the workers.

Figure 3. Engine Room Welding Process

2. When welding is completed, weld splatter and other irregularities must be removed by grinding. Workers kneel on the deck to perform the work. Again note the proximity of the two workers.

Figure 4. Engine Room Grinding Process

IIIA2. Engine Room Wire Welding Ergonomic Risk Factors

Workers in the engine room, and other parts of the hull, often perform their work squatting or sitting on the deck surface. Welding or grinding activities require static postures and awkward postures of the wrist and arm. Some forward flexion of the neck and the torso is performed when working below knee height. This is a moderately physically demanding job.

IIIA3. Ergonomic Analysis of Engine Room Wire Welders

Using several of the exposure assessment tools outlined above, an ergonomic analysis was performed for the engine room welders. A Rapid Upper Limb Assessment was conducted for the engine room welders and grinders (Table 1). Analyses of four sub-tasks with unique postures resulted in a variety of ratings. The sub-task of welding on the deck while seated resulted in a rating of 7, the highest category on a scale of 1 to 7. The sub-task of grinding on the deck while kneeling and setting up equipment while kneeling resulted in ratings of 4 and 3, respectively, on a scale of 1 to 7, falling in the second lowest of four groupings. The other task, getting the tool, rated a 2, in the lowest grouping of scores.

A Strain Index analysis was performed for the engine room welders (Table 2) with the following results:

1) the Intensity of Exertion was rated as “Somewhat Hard” and given a multiplier score of 3.0 on a scale of 1 to 13
2) the Duration of the task was rated as 50 - 79 % of the task cycle, resulting in a multiplier of 2.0 on a scale of 0.5 to 3.0
3) the Efforts per Minute were noted to be static, resulting in a multiplier of 3.0 on a scale of 0.5 to 3.0

4) the Hand/Wrist posture was rated as “Fair,” resulting in a multiplier of 1.5 on a scale of 1.0 to 3.0
5) the Speed of Work was rated as “Normal,” resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0
6) the Duration of Task per Day was rated to be between 4 and 8 hours, resulting in a multiplier of 1.0 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 27. An SI score between 5 and 30 is correlated to an incidence rate of about 77 distal upper extremity injuries per 100 FTE. Therefore, the Strain Index indicates that this task puts the worker at an increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the engine room welder task (Table 3), of the 21 possible responses, fourteen were negative and seven were positive. Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the engine room welder task (Table 4), “corrective measures in the near future” were suggested for welding while sitting, grinding while kneeling, or while setting up the grinder while kneeling on the deck.

The PLIBEL checklist for the engine room welder task (Table 5) reports a moderate percentage (38.1 - 45.4 %) of risk factors present for the upper extremities and back. Several environmental and organizational modifying factors are present as well.

IIIB. TRIPOD SUBASSEMBLY WIRE WELDING IN SHOP

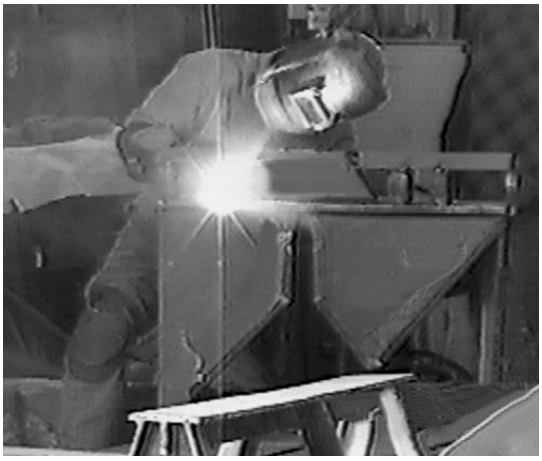

Figure 5. Tripod Welding Task while Seated

IIIB1. Tripod Subassembly Wire Welding in Shop Process

Small subassemblies are brought to this location to be welded together or to add additional pieces of steel to the subassembly. A dedicated work station is provided for the worker to perform these tasks. A number of jigs are available to hold the work piece and saw horses and small tables are available to place the work piece on. The worker must perform the job from a variety of postures, including seated (Figure 5), standing bent over the work as shown in Figure 6, or kneeling as shown in Figure 7.

Figure 6. Tripod Welding with Stooped Posture

Figure 7. Tripod Welder Changing Tools

Occasionally, the worker must turn the work piece over or adjust its position so that the worker can weld or grind a particular seam much easier (Figure 8). In addition to welding the seams, the worker also grinds off any primer paint and flux from the weld as shown in Figures 9 and 10.

Figure 8. Tripod Welder Changing Position of Workpiece

Figure 9. Tripod Welder Using Needle Gun while Kneeling

Figure 10. Tripod Welder Using Needle Gun while Standing

If the worker needs to move the subassembly on or off the work station , the worker may rig it to be lifted by one of the hoists available in the shop area (Figure 11). Before removal of the subassembly, the worker will make a final visual inspection of the work piece (Figure 12).

Figure 11. Tripod Welder Attaching Hoist Hook onto Subassembly

Figure 12. Tripod Welder Inspecting Work

IIIB2. Tripod Subassembly Wire Welding Ergonomic Risk Factors

The worker is exposed to a variety of musculoskeletal risk factors of the performance of the job tasks including: awkward and static postures, power tool use resulting in some amount of hand-arm vibration, and manual material handling of the subassembly occasionally.

IIIB3. Ergonomic Analysis of Tripod Subassembly Wire Welding

Using several of the exposure assessment tools outlined above, an ergonomic analysis was performed for the tripod subassembly wire welder. A Rapid Upper Limb Assessment was conducted for the tripod assembly wire welding task (Table 6). Analyses of six sub-tasks with unique postures resulted in a variety of ratings. The sub-tasks of welding and using a needlegun to remove slag resulted in ratings of 7, the highest category on a scale of 1 to 7. The sub-tasks of hooking the piece to a hoist and inspecting the work both resulted in ratings of 3 on a scale of 1 to 7, falling in the second lowest of four groupings. The other tasks rated a 2, in the lowest grouping of scores.

A Strain Index analysis was performed for the tripod assembly wire welder (Table 7) with the following results:

1) the Intensity of Exertion was rated as “Somewhat Hard” and given a multiplier score of 3.0 on a scale of 1 to 13
2) the Duration of the task was rated as 50 - 79 % of the task cycle, resulting in a multiplier of 2.0 on a scale of 0.5 to 3.0

3) the Efforts per Minute were noted to be static, resulting in a multiplier of 3.0 on a scale of 0.5 to 3.0
4) the Hand/Wrist posture was rated as "Fair," resulting in a multiplier of 1.5 on a scale of 1.0 to 3.0
5) the Speed of Work was rated as "Normal," resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0
6) the Duration of Task per Day was rated to be between 4 and 8 hours, resulting in a multiplier of 1.0 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 27. An SI score between 5 and 30 is correlated to an incidence rate of about 77 distal upper extremity injuries per 100 FTE. Therefore, the Strain Index indicates that this task puts the worker at an increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the tripod subassembly wire welder (Table 8), of the 21 possible responses, fourteen were negative and seven were positive. Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the tripod subassembly wire welder (Table 9), "corrective measures immediately" were suggested for the welding tasks. The other 5 tasks resulted in recommendations for either "corrective measures in the near future" or "no corrective measures" required.

The PLIBEL checklist for the tripod subassembly wire welder task (Table 10) reports a moderate to high percentage (42.9 - 63.6 %) of risk factors present for the upper extremities and back. Several environmental and organizational modifying factors are present as well.

IIIC. LIFE BOAT RACK ASSEMBLY

IIIC1. Life Boat Rack Assembly Process

As each of the current series of vessels nears completion, the upper deck is fitted with lifeboat racks from which the boats can be launched in time of need. The worker is required to perform a number of tasks at or near deck level. The frames are composed of a number of angle irons which are torch cut to exact size (Figure 13) and ground smooth on the edges (Figures 14 and 15).

Figure 13. Lifeboat Rack Worker Torch Cutting

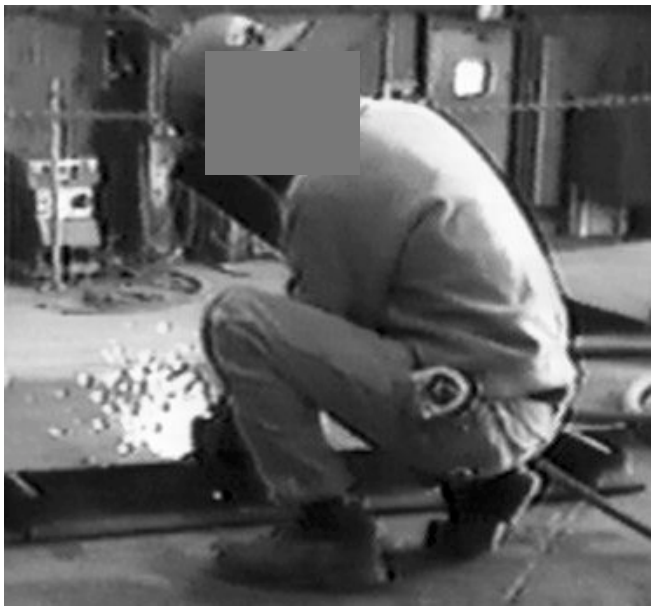

Figure 14. Lifeboat Rack Worker Grinding while Squatting

Figure 15. Lifeboat Rack Worker Grinding while Stooped

The angle irons are then moved into their places on the deck by hand (Figure 16) where they are welded into place on the deck (Figure 17). Adjustment of rack position is occasionally made by sledge hammer, especially if part of the rack has already been welded to the deck (Figure 18).

Figure 16. Lifeboat Rack Worker Moving Workpiece

Figure 17. Lifeboat Rack Worker Welding while Kneeling

Figure 18. Lifeboat Rack Worker Adjusting Workpiece with Sledge Hammer

IIIC2. Life Boat Rack Assembly Ergonomic Risk Factors

The lifeboat rack worker is exposed to similar musculoskeletal risk factors as other workers in the shipyard doing similar work with steel including: awkward and static postures, power tool use resulting in some amount of hand-arm vibration, and manual material handling of the subassembly occasionally.

IIIC3. Ergonomic Analysis of Life Boat Rack Assembly

Using several of the exposure assessment tools outlined above, an ergonomic analysis was performed for the lifeboat rack assembly task. A Rapid Upper Limb Assessment was conducted for the lifeboat rack workers (Table 11). Analyses of six sub-tasks with unique postures resulted in a variety of ratings. The sub-tasks of grinding either while squatting or stooping resulted in a rating of 7, the highest category on a scale of 1 to 7. The three sub-tasks of torch cutting on the subassembly or moving the piece by hand or by sledge hammer resulted in ratings of 5 and 6 on a scale of 1 to 7. The other task, wire welding, rated a 4.

A Strain Index analysis was performed for the lifeboat rack assembly worker (Table 12) with the following results:

1) the Intensity of Exertion was rated as "Somewhat Hard" and given a multiplier score of 3.0 on a scale of 1 to 13
2) the Duration of the task was rated as 50 - 79 % of the task cycle, resulting in a multiplier of 2.0 on a scale of 0.5 to 3.0
3) the Efforts per Minute were noted to be somewhat static, resulting in a multiplier of 1.0 on a scale of 0.5 to 3.0
4) the Hand/Wrist posture was rated as "Fair," resulting in a multiplier of 1.5 on a scale of 1.0 to 3.0
5) the Speed of Work was rated as "Normal," resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0
6) the Duration of Task per Day was rated to be between 4 and 8 hours, resulting in a multiplier of 1.0 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 9. An SI score between 5 and 30 is correlated to an incidence rate of about 77 distal upper extremity injuries per 100 FTE. Therefore, the Strain Index indicates that this task puts the worker at an increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the engine room welder task (Table 13), of the 21 possible responses, sixteen were negative and six were positive (one answered both yes and no). Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the lifeboat rack assembly worker (Table 14), all six components of the task rated a 2 on a scale of 1 to 4, suggesting that "corrective measures in the near future" should be considered.

The Three-Dimensional Static Strength Prediction Program was applied to the lifeboat rack assembly worker when lifting a piece of angle iron off the deck and into position (Table 15). The calculated compression load on the worker's back was 769 pounds, just under NIOSH recommended compression limit of 770 pounds.

The PLIBEL checklist for the lifeboat rack assembly worker (Table 16) reports moderate to high percentages (57.1 - 63.6 %) of risk factors present for the upper extremities and back. Moderate percentages of risk factors (37.5 %) were also reported for the lower extremity. Several environmental and organizational modifying factors are present as well.

IIID. SHEETMETAL ASSEMBLY IN SHOP

IIID1. Sheetmetal Assembly in Shop Process

Ventilation ductwork and other sheet metal subassemblies are built on land within the fabrication shops as much as possible. The sheet metal is formed to shape and then fit together in the prescribed size and shape (Figure 19). The worker must move the subassembly around on the fixed height work table to get to necessary work locations (Figure 20). Before completion the worker must visually inspect the work (Figure 21), making sure it is built to exact specifications (Figure 22) and then sign off on the work before it is passed on to another work area (Figure 23).

Figure 19. Sheet Metal Worker Hammering

Figure 20. Sheet Metal Worker Moving Duct

Figure 21. Sheet Metal Worker Inspecting Duct

Figure 22. Sheet Metal Worker Measuring Duct

Figure 23. Sheet Metal Worker Record Duct Data

IIID2. Sheetmetal Assembly Ergonomic Risk Factors

The sheet metal worker is exposed to a number of musculoskeletal risk factors is the course of the job including: awkward postures and tool usage.

IIID3. Ergonomic Analysis of Sheetmetal Assembly

Using several of the exposure assessment tools outlined above, an ergonomic analysis was performed for the sheet metal shop workers. A Rapid Upper Limb Assessment was conducted for the sheet metal shop workers (Table 17). Analyses of six sub-tasks with unique postures resulted in a variety of ratings. The sub-tasks of hammering and measuring the ductwork resulted in ratings of 6 and 5, respectively, the second highest grouping on a scale of 1 to 7. The sub-tasks of moving the ductwork, inspecting it, or recording information resulted in ratings of 3 and 4 on a scale of 1 to 7, falling in the second lowest of four groupings. The other task, resting, rated a 2, in the lowest grouping of scores.

A Strain Index analysis was performed for the sheet metal shop worker (Table 18) with the following results:

1) the Intensity of Exertion was rated as "Light" and given a multiplier score of 1.0 on a scale of 1 to 13
2) the Duration of the task was rated as 50 - 79 % of the task cycle, resulting in a multiplier of 2.0 on a scale of 0.5 to 3.0
3) the Efforts per Minute were rated to be less than four per minute, resulting in a multiplier of 0.5 on a scale of 0.5 to 3.0
4) the Hand/Wrist posture was rated as "Fair," resulting in a multiplier of 1.5 on a scale of 1.0 to 3.0
5) the Speed of Work was rated as "Normal," resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0
6) the Duration of Task per Day was rated to be between 4 and 8 hours, resulting in a multiplier of 1.0 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 1.5. An SI score less than 5 is correlated to an incidence rate of about 2 distal upper extremity injuries per 100 FTE. Therefore, the Strain Index indicates that this task does not put the worker at an increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the sheet metal shop worker (Table 19), of the 21 possible responses, twelve were negative and nine were positive. Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the sheet metal shop worker (Table 20), six unique

sub-tasks were considered. Only visually inspect the work resulted in the highest rating of 4 on a scale of 1 to 4. Two tasks, hammering and moving the duct, resulted in scores of 2 out of 4. The other three sub-tasks rated a 1, the lowest category.

The PLIBEL checklist for the sheet metal shop worker (Table 21) reports a low percentage (4.8 - 27.3 %) of risk factors present for the upper extremities and back. A low percentage of environmental and organizational modifying factors are present as well.

IIIE. ASSEMBLY FITTER USING COMEALONG IN SHOP

IIIE1. Assembly Fitter Using Comealong in Shop Process

The shipfitter must torch cut (Figure 24), grind and weld angle iron, steel plate and other materials into place so that subassemblies can be matched and secured exactly in place. The shipfitter uses a variety of tools in the performance of the job (Figure 25) and must be very exact in the task, inspecting it frequently (Figure 26).

Figure 24. Bow Assembly Shipfitter Torch Cutting

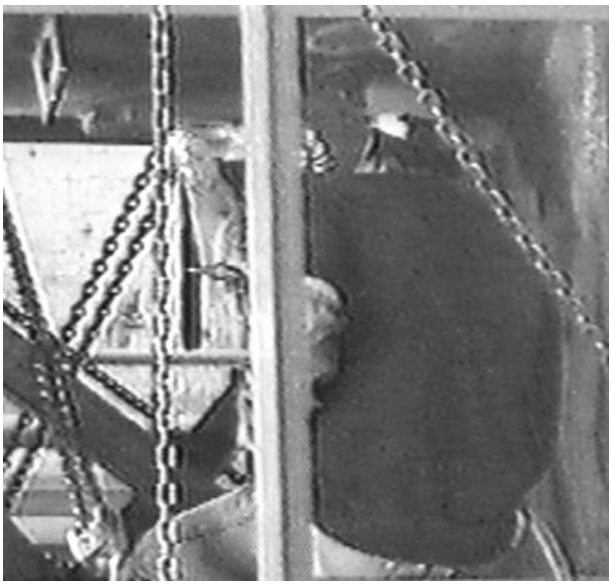

Figure 25. Bow Assembly Shipfitter Changing Tools

Figure 26. Bow Assembly Shipfitter Inspecting Setup

Occasionally the two subassemblies being put together do not exactly match. Often the pieces can be forced into place by using comealongs to maintain force to hold the steel in its proper position (Figures 27 and 28) and then the subassemblies are welded together.

Figure 27. Bow Assembly Shipfitter Adjusting Comealong

Figure 28. Bow Assembly Shipfitter Cranking Comealong

IIIE2. Assembly Fitter Using Comealong Ergonomic Risk Factors

The bow assembly shipfitter is exposed to numerous musculoskeletal risk factors in performance of the job tasks including: awkward and static postures, power tool use resulting in some amount of hand-arm vibration, manual material handling of the subassembly or tools such as the comealong, and high physical effort in getting subassemblies to join together in exactly the right manner.

IIIE3. Ergonomic Analysis of Assembly Fitter Using Comealong

Using several of the exposure assessment tools outlined above, an ergonomic analysis was performed for the bow assembly shipfitters. A Rapid Upper Limb Assessment was conducted for the shipfitters (Table 22). Analyses of six sub-tasks with unique postures resulted in a variety of ratings. Torch cutting, attaching and adjusting the comealong, and pulling the handle of the comealong, resulted in ratings of 5 or 6, the second highest grouping on a scale of 1 to 7. The other three sub-tasks resulted in ratings of 3 and 4, falling in the second lowest of four groupings.

A Strain Index analysis was performed for the bow assembly shipfitters (Table 23) with the following results:

1) the Intensity of Exertion was rated as "Somewhat Hard" and given a multiplier score of 3.0 on a scale of 1 to 13
2) the Duration of the task was rated as being between 10 - 29 % of the task cycle, resulting in a multiplier of 1.0 on a scale of 0.5 to 3.0
3) the Efforts per Minute were noted to be less than four per minute, resulting in a multiplier of 3.0 on a scale of 0.5 to 3.0
4) the Hand/Wrist posture was rated as "Fair," resulting in a multiplier of 1.5 on a scale of 1.0 to 3.0
5) the Speed of Work was rated as "Normal," resulting in a multiplier of 1.0 on a scale of 1.0 to 2.0
6) the Duration of Task per Day was rated to be between 4 and 8 hours, resulting in a multiplier of 1.0 on a scale of 0.25 to 1.50.

The multiplier values for each segment are multiplied together resulting in a final Strain Index (SI) score. For this task the SI score was 2.25. An SI score less than 5 is correlated to an incidence rate of about 2 distal upper extremity injuries per 100 FTE. Therefore, the Strain Index indicates that this task does not put the worker at an increased risk of developing a distal upper extremity injury.

In applying the University of Michigan Upper Extremity Cumulative Trauma Disorder Checklist to the bow assembly shipfitter task (Table 24), of the 21 possible responses, thirteen were negative and seven were positive (one question not applicable). Negative responses are indicative of conditions associated with the risk of developing cumulative trauma disorders.

When the OWAS technique was applied to the bow assembly shipfitter task (Table 25), two of the six sub-tasks rated a 2, on a scale of 1 to 4. The remaining four sub-tasks rated a 1, the lowest category.

The PLIBEL checklist for the bow assembly shipfitter task (Table 26) reports a moderate to high percentage (47.6 - 63.6 %) of risk factors present for the upper extremities and back. A moderate percentage of risk factors (37.5 %) were also present for the lower extremity. Several environmental and organizational modifying factors are present as well.

IV. CONTROL TECHNOLOGY

Possible interventions and control technologies are mentioned briefly here. A more detailed report of possible interventions is in preparation. For the engine room workers, not much can be suggested since the work is at deck level on board the vessel. The use of knee pads, knee supports and low stools may alleviate some of the strain on the lower back and legs. Training in proper positioning and on the benefits of micro-breaks may minimize problems associated with static postures. Better scheduling of associated job tasks may eliminate some of the overcrowding issues. Postural issues are also a concern in each of the other jobs reviewed. Deck-level work may not be avoided but perhaps the individual can be slightly removed from constant exposure to the hard deck surface. The use of jigs in subassembly manufacturing reduces the need for awkward postures if the unit can be easily moved or adjusted to fit the worker, not the other way around.

V. CONCLUSIONS AND RECOMMENDATIONS

Five work processes at Marinette Marine Shipbuilding were surveyed to determine the presence of risk factors associated with musculoskeletal disorders. These processes included engine room welding, tripod subassembly, lifeboat rack assembly, sheet metal work and bow assembly using comealongs . 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.

It is suggested 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 suggested that ergonomic interventions can be implemented at Marinette Marine shipbuilding facilities to minimize hazards in the identified job tasks.

VI. REFERENCES

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University of Michigan Software, *3D Static Strength Prediction Program Version 4.0*, 3003 State St., #2071 Ann Arbor, MI 48109-1280, Copyright 1997 The Regents of The University of Michigan.

APPENDIX

TABLES

A1. Engine Room Wire Welding Worker

Table 1. Engine Compartment Hull Wire Welder/ Grinder RULA

Rapid Upper Limb Assessment (RULA)
(Matamney and Corlett, 1993)

Date/ Time	**Facility**	**Area/Shop**	**Task**
5/08/00	Marinette	Outfitting Assembly South	Wire Welding/ Grinding

RULA: Posture Sampling Results								
RULA Component	**Frame # 199770 Weld, Sitting**		**Frame # 205560 Grind Kneeling**		**Frame # 159750 Setup Grinder**		**Frame # 204450 Get Tool**	
	Specific	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***
Shoulder Extension/ Flexion	sl flx	2	sl flx	2	sl flx	2	sl flx	2
Shoulder is Raised (+1)		0		0		0		0
Upper Arm Abducted (+1)		0		0		0		0
Arm supported, leaning (-1)		-1		-1		0		0
Elbow Extension/ Flexion	neut	2	neut	2	ext	1	ext	1
Shoulder Abduction/ Adduction	mod abd	1	mod abd	1	neut	0	neut	0
Shoulder Lateral/ Medial* *not included in RULA analysis	lat	0	lat	0	lat	0	neut	0
Wrist Extension/ Flexion	ext	2	ext	2	neut	0	neut	0
Wrist Deviation	ulnar	1	radial	1	neut	0	neut	0
		0		0		0		0
Wrist Twist (1) In mid range Or (2) End of range		1		1		1		1
Arm and Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0		0
Arm and Wrist Force/ load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		1		1		1

Table 1. Engine Compartment Hull Wire Welder/ Grinder RULA (continued)

RULA Component	**Frame # 199770 Weld, Sitting**		**Frame # 205560 Grind Kneeling**		**Frame # 159750 Setup Grinder**		**Frame # 204450 Get Tool**	
	Specific	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***
Neck Extension/ Flexion	sl flx	2	mod flx	3	sl flx	2	neut	1
Neck Twist (+1)		0		0		0		0
Neck Side-Bent (+1)		0		0		0		0
Trunk Extension/ Flexion	mod flx	3	mod flx	3	sl flx	2	sl flx	2
Trunk Twist (+1)		0		0		0		0
Trunk Side Bend (+1)		0		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0		0
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		1		1		1
Total RULA Score	**7**		**4**		**3**		**2**	

1 or 2 = Acceptable
3 or 4 = Investigate Further
5 or 6 = Investigate Further and Change Soon
7 = Investigate and Change Immediately

Table 2. Engine Compartment Hull Wire Welder/ Grinder Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
(Moore and Garg, 1995)

Date/ Time	**Facility**	**Area/Shop**	**Task**
5/08/00	Marinette	Outfitting Assembly South	Wire Welding/ Grinding

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**% MS** (percentage of maximal strength)	**Borg Scale** (Compare to Borg Cr-10 Scale)	**Perceived Effort**	**Rating**	**Multiplier**
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat hard	**10 - 29%**	**3**	**noticeable or definite effort**	**2**	**3.0**
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					**3.0**

Table 2. Engine Compartment Hull Wire Welder/ Grinder Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0

Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
% Duration of Exertion = 100 x duration of all exertions (sec) / Total observation time (sec) = 100 x 1045 (sec)/ 1384 (sec) = 75	< 10	1	0.5
	10 - 29	2	1.0
	30 - 49	3	1.5
	50 -79	**4**	**2.0**
	> or = 80	5	3.0
Duration of Exertion Multiplier			**2.0**

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0

Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
Efforts per Minute = number of exertions / total observation time (min) = 21/23 = 2.2, but very static tasks, set multiplier to 3.0	< 4	1	0.5
	4 - 8	2	1.0
	9 -14	3	1.5
	15 -19	4	2.0
	> or = 20	**5**	**3.0**
Efforts per Minute Multiplier			**3.0**

Table 2. Engine Compartment Hull Wire Welder/ Grinder Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**Wrist Extension**	**Wrist Flexion**	**Ulnar Deviation**	**Perceived Posture**	**Rating**	**Multiplier**
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	**26 -40 degrees**	**16 - 30 degrees**	**16 - 20 degrees**	**non-neutral (*estimated, based on RULAs performed)**	**3**	**1.5**
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						**1.5**

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**Compared to MTM** (observed pace is divided by MTM's predicted pace and expressed as %)	**Perceived Speed**	**Rating**	**Multiplier**
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	**91 -100%**	**"normal" speed of motion**	**3**	**1.0**
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				**1.0**

Table 2. Engine Compartment Hull Wire Welder/ Grinder Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet: Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + ... = (estimate ~ 4-8 hrs)	**Rating Criterion**	**Rating**	**Multiplier**
	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
	4 - 8 hrs	**4**	**1.00**
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**1.00**

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**		**SI SCORE**
3.0 X	**2.0 X**	**3.0 X**	**1.5 X**	**1.0 X**	**1.00**	**=**	**27**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:
- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 3. Engine Compartment Hull Wire Welder/ Grinder UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
(Lifshitz and Armstrong, 1986)

Date/ Time	**Facility**	**Area/Shop**	**Task**
5/08/00	Marinette	Outfitting Assembly South	Wire Welding/ Grinding

Risk Factors	**No**	**Yes**
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?	N	
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?		Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?		Y
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?		Y
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?		Y
6.3 Is the handle of the tool made from material other than metal?	N (grinder)	
6.4 Is the weight of the tool below 4 kg (9lbs)?	N (grinder)	
6.5 Is the tool suspended?	N	
TOTAL	**14 (67%)**	**7 (33%)**

* "No" responses are indicative of conditions associated with the risk of CTD's

Table 4. Engine Compartment Hull Wire Welder/ Grinder OWAS

OWAS: OVAKO Work Analysis System
Louhevaara and Suurnäkki (1992)

Date/ Time	**Facility**	**Area/Shop**	**Task**
5/08/00	Marinette	Outfitting Assembly South	Wire welding/ Grinding

Risk Factor	**Work Phase1 Weld, Sitting**	**Work Phase 2 Grind, Kneeling**	**Work Phase 3 Setup Grinder**	**Work Phase 4 Get Tool**
TOTAL Combination Posture Score	**2**	**2**	**2**	**1**
Common Posture Combinations (collapsed across work phases)				
Back	2	2	1	
Arms	1	1	1	
Legs	4	6	7	
Posture Repetition (% of working time)	71	5	3	
Back % of Working Time Score	2	1	1	
Arms % of Working Time Score	1	1	1	
Legs % of Working Time Score	4	1	1	

ACTION CATEGORIES:
1 = no corrective measures
2 = corrective measures in the near future
3 = corrective measures as soon as possible
4 = corrective measures immediately

Table 4. Engine Compartment Hull Wire Welder/ Grinder OWAS (continued)

Risk Factor	**Work Phase1 Weld, Sitting**	**Work Phase 2 Grind, Kneeling**	**Work Phase 3 Setup Grinder**	**Work Phase 4 Get Tool**
Posture				
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	2	2	2	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	4	6	6	7
Load/ Use of Force				
1 = weight or force needed is = or <10 kg (<22lbs)	1	1	1	1
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)				
3 = weight or force > 20 kg (>44 lbs)				
Phase Repetition				
% of working time (0,10,20,30,40,50,60,70,80,90,100)	71	3	2	3

Table 5. Engine Compartment Hull Wire Welder/ Grinder PLIBEL

PLIBEL Checklist, Kemmlert (1995)

Date/ Time	**Facility**	**Area/Shop**	**Task**
5/08/00	Marinette	Outfitting Assembly South	Wire welding/ Grinding

Section I: Musculoskeletal Risk Factors

Methods of Application:

1) Find the injured body region, answer yes or no to corresponding questions

2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	N	N	N	N	N
3: Are tools and equipment unsuitably designed for the worker or the task?	N	N	N	N	N
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	N				N
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			Y	Y	Y
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	Y				Y
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table 5. Engine Compartment Hull Wire Welder/ Grinder PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				
d) extended backwards?	Y				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	Y				Y
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	Y				Y
f) handling below knee length	N				N
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	Y				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed?					
a) weight of working materials or tools	N	N			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Is repeated work, with forearm and hand, done with:					
a) twisting movements?		N			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 5. Engine Compartment Hull Wire Welder/ Grinder PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	**Elbows, Forearms, and Hands**	**Feet**	**Knees and Hips**	**Low Back**
SUM	**11**	**5**	**2**	**2**	**8**
PERCENTAGE	**42.3**	**45.4**	**25**	**25**	**38.1**
Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	N				
20: Is the job performed under time demands or psychological stress?	N				
21:Can the work have unusual or expected situations?	N				
22: Are the following present?					
a) cold	N				
b) heat	Y				
c) draft	Y				
d) noise	Y				
e) troublesome visual conditions	Y				
f) jerks, shakes, or vibration	Y				
Environmental / Organizational Risk Factors Score					
SUM	**5**				
PERCENTAGE	**50.0**				

A2. TRIPOD SUBASSEMBLY WIRE WELDER IN SHOP

Table 6. Tripod Subassembly Wire Welder RULA

Rapid Upper Limb Assessment (RULA)
(Matamney and Corlett, 1993)

Date/ Time	**Facility**	**Area/Shop**	**Task**
5/08/00	Marinette	Module Assembly North	Tripod Wire Welding

RULA: Posture Sampling Results												
RULA Component	**Frames # 8430, 17190, 20340 Wire Weld**		**Frame # 23130 Get/ Change Tool**		**Frame # 30210 Change Position**		**Frame # 23970, 31650 Needlegun Deslag**		**Frame # 37200 Hook/ Unhook Hoist**		**Frame # 41250 Inspect**	
	Spec	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***
Shoulder Extension/ Flexion	sl flx	2	sl flx	2	sl flx	2	sl flx	2	sl flx	2	neut	1
Shoulder is Raised (+1)		0		0		0		0		0		0
Upper Arm Abducted (+1)		0		0		0		0		0		0
Arm supported, leaning (-1)		0		0		0		0		0		0
Elbow Extension/ Flexion	neut	2	ext	1	flx	2	neut	2	ext	1	ext	1
Shoulder Abduction/ Adduction	neut	0	neut	0	neut	0	neut	0	neut	0	neut	0
Shoulder Lateral/ Medial* *not included in RULA analysis	lat	0	lat	0	neut	0	lat	0	neut	0	neut	0
Wrist Extension/ Flexion	ext	2	neut	0	neut	0	ext	2	ext	2	neut	0
Wrist Deviation	ulnar	1	neut	0	neut	0	ulnar	1	neut	0	neut	0
		0		0		0		0		0		0
Wrist Twist (1) In mid range Or (2) End of range		1		1		1		1		1		1
Arm/ Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0		1		0		0
Arm and Wrist Force/ load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		1		1		2		1		1

Table 6. Tripod Subassembly Wire Welder RULA (continued)

RULA Component	**Frames # 8430, 17190, 20340 Wire Weld**		**Frame # 23130 Get/ Change Tool**		**Frame # 30210 Change Position**		**Frame # 23970, 31650 Needlegun Deslag**		**Frame # 37200 Hook/ Unhook Hoist**		**Frame # 41250 Inspect**	
	Spec	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***
Neck Extension/ Flexion	mod flx	3	neut	1	neut	1	mod flx	3	sl flx	2	mod flx	3
Neck Twist (+1)		0		0		0		0		0		0
Neck Side-Bent (+1)		1		0		0		1		0		0
Trunk Extension/ Flexion	sl flx	2	neut	1	neut	1	sl flx	2	mod flx	3	sl flx	2
Trunk Twist (+1)		0		0		0		0		0		1
Trunk Side Bend (+1)		1		0		0		1		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0		1		0		0
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		2		1		1		2		1		1
Total RULA Score	**7**		**2**		**2**		**7**		**3**		**3**	

1 or 2 = Acceptable
3 or 4 = Investigate Further
5 or 6 = Investigate Further and Change Soon
7 = Investigate and Change Immediately

Table 7. Tripod Subassembly Wire Welder Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
Moore and Garg, 1995

Date/ Time	**Facility**	**Area/Shop**	**Task**
5/08/00	Marinette	Module Assembly North	Tripod Wire Welding

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**% MS** (percentage of maximal strength)	**Borg Scale** (Compare to Borg Cr-10 Scale)	**Perceived Effort**	**Rating**	**Multiplier**
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat hard	**10 - 29%**	**3**	**noticeable or definite effort**	**2**	**3.0**
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					**3.0**

Table 7. Tripod Subassembly Wire Welder Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0

Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
% Duration of Exertion = 100 x duration of all exertions (sec) / Total observation time (sec) = 100 x 1723 (sec)/ 2323 (sec) = 74	< 10	1	0.5
	10 - 29	2	1.0
	30 - 49	3	1.5
	50 -79	**4**	**2.0**
	> or = 80	5	3.0
Duration of Exertion Multiplier			**2.0**

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0

Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
Efforts per Minute = number of exertions / total observation time (min) = 76/39 = 2, but very static tasks, set multiplier to 3.0	< 4	1	0.5
	4 - 8	2	1.0
	9 -14	3	1.5
	15 -19	4	2.0
	> or = 20	**5**	**3.0**
Efforts per Minute Multiplier			**3.0**

Table 7. Tripod Subassembly Wire Welder Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**Wrist Extension**	**Wrist Flexion**	**Ulnar Deviation**	**Perceived Posture**	**Rating**	**Multiplier**
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	**26 -40 degrees**	**16 - 30 degrees**	**16 - 20 degrees**	**non-neutral (*estimated, based on RULAs performed)**	**3**	**1.5**
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						**1.5**

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**Compared to MTM** (observed pace is divided by MTM's predicted pace and expressed as %)	**Perceived Speed**	**Rating**	**Multiplier**
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	**91 -100%**	**"normal" speed of motion**	**3**	**1.0**
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				**1.0**

Table 7. Tripod Subassembly Wire Welder Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet:	***Rating Criterion***	***Rating***	***Multiplier***
Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + ... = (estimate ~ 4-8 hrs)	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
	4 - 8 hrs	**4**	**1.00**
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**1.00**

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**	=	**SI SCORE**
3.0 X	**2.0 X**	**3.0 X**	**1.5 X**	**1.0 X**	**1.00**		**27**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:
- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 8. Tripod Subassembly Wire Welder UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders

Lifshitz and Armstrong (1986)

Date/ Time	**Facility**	**Area/Shop**	**Task**
5/08/00	Marinette	Module Assembly North	Tripod Wire Welding

Risk Factors	**No**	**Yes**
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?	N	
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?		Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?		Y
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?		Y
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?		Y
6.3 Is the handle of the tool made from material other than metal?	N (needlegun)	
6.4 Is the weight of the tool below 4 kg (9lbs)?	N (needlegun)	
6.5 Is the tool suspended?	N	
TOTAL	**14 (67%)**	**7 (33%)**

* "No" responses are indicative of conditions associated with the risk of CTD's

Table 9. Tripod Subassembly Wire Welder OWAS

OWAS: OVAKO Work Analysis System
Louhevaara and Suurnäkki (1992)

Date/ Time	**Facility**	**Area/Shop**	**Task**
5/08/00	Marinette	Module Assembly North	Tripod Wire Welding

Risk Factor	**Work Phase1 Wire Weld**	**Work Phase 2 Get/ Change Tool**	**Work Phase 3 Change Position**	**Work Phase 4 Needle-gun De-slag**	**Work Phase 5 Hook/ Unhook Hoist**	**Work Phase 6 Inspect**
TOTAL Combination Posture Score	**4**	**1**	**1**	**2**	**2**	**2**
Common Posture Combinations (collapsed across work phases)						
Back	2, 4	1	1	2	2	
Arms	1	1	1	1	1	
Legs	6	6	7	7	2	
Posture Repetition (% of working time)	59	11	6	4	9	
Back % of Working Time Score	3	1	1	1	1	
Arms % of Working Time Score	1	1	1	1	1	
Legs % of Working Time Score	3	1	1	1	1	

ACTION CATEGORIES:
1 = no corrective measures
2 = corrective measures in the near future
3 = corrective measures as soon as possible
4 = corrective measures immediately

Table 9. Tripod Subassembly Wire Welder OWAS (continued)

Risk Factor	**Work Phase1 Wire Weld**	**Work Phase 2 Get/ Change Tool**	**Work Phase 3 Change Position**	**Work Phase 4 Needle-gun De-slag**	**Work Phase 5 Hook/ Unhook Hoist**	**Work Phase 6 Inspect**
Posture						
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	2,4	1	1	2,4	2	2
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	1	1	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	1,6,4	6	7	1,6,4	7	2
Load/ Use of Force						
1 = weight or force needed is = or <10 kg (<22lbs)	1	1	1	1	1	1
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)						
3 = weight or force > 20 kg (>44 lbs)						
Phase Repetition						
% of working time (0,10,20,30,40,50,60,70,80,90,100)	52	11	6	7	4	9

Table 10. Tripod Subassembly Wire Welder PLIBEL

PLIBEL Checklist, Kemmlert (1995)

Date/ Time	**Facility**	**Area/Shop**	**Task**
5/08/00	Marinette	Module Assembly North	Tripod Wire Welding

Section I: Musculoskeletal Risk Factors

Methods of Application:

1) Find the injured body region, answer yes or no to corresponding questions

2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	**Body Regions**				
	Neck, Shoulder, and Upper Back	**Elbows, Forearms, and Hands**	**Feet**	**Knees and Hips**	**Low Back**
1: Is the walking surface uneven, sloping, slippery or nonresilient?			N	N	N
2: Is the space too limited for work movements or work materials?	N	N	N	N	N
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			Y	Y	Y
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	Y				Y
c) bent sideways or mildly twisted?	Y				Y
d) severely twisted?	N				N

Table 10. Tripod Subassembly Wire Welder PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	Y				
c) severely twisted?	N				
d) extended backwards?	Y				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	Y				Y
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	N				N
f) handling below knee length	N				N
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	Y				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed?					
a) weight of working materials or tools	N	N			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Repeated work, with forearm and hand, performed w/:					
a) twisting movements?		N			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 10. Tripod Subassembly Wire Welder PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	**Elbows, Forearms, and Hands**	**Feet**	**Knees and Hips**	**Low Back**
SUM	**14**	**7**	**2**	**2**	**9**
PERCENTAGE	**53.8**	**63.6**	**25**	**25**	**42.9**
Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	N				
20: Is the job performed under time demands or psychological stress?	N				
21:Can the work have unusual or expected situations?	N				
22: Are the following present?					
a) cold	N				
b) heat	Y				
c) draft	Y				
d) noise	Y				
e) troublesome visual conditions	Y				
f) jerks, shakes, or vibration	Y				
Environmental / Organizational Risk Factors Score					
SUM	**5**				
PERCENTAGE	**50.0**				

A3. LIFE BOAT RACK ASSEMBLY

Table 11. Life Boat Rack Installer RULA

Rapid Upper Limb Assessment (RULA)
(Matamney and Corlett, 1993)

Date/ Time	**Facility**	**Area/Shop**	**Task**
5/08/00	Marinette	Module Assembly North	Lifeboat Rack Installation

RULA: Posture Sampling Results												
RULA Component	**Frame # 80850 Torch-cutting**		**Frame # 5160 Grind Squatting**		**Frame # 12750 Grind Stooped**		**Frame # 42270 Move Workpiece**		**Frame # 75510 Wire Weld kneeling**		**Frame # 85529 AdjustPos. w/ Sledge**	
	Spec	***RULA***	***Spec***	***RULA***	***Spec***	***RULA***	***Spec***	***RULA***	***Spec***	***RULA***	***Spec***	***RULA***
Shoulder Extension/ Flexion	sl flx	2	sl flx	2	mod flex	3	mod flex	3	sl flx	2	sl flx	2
Shoulder is Raised (+1)		0		0		0		0		0		0
Upper Arm Abducted (+1)		0		0		0		0		0		0
Arm supported, leaning (-1)		0		0		0		0		0		0
Elbow Extension/ Flexion	ext	1	ext	1	ext	1	ext	1	ext	1	ext	1
Shoulder Abduction/ Adduction	neut	0	add	1	add	1	add	1	neut	0	neut	0
Shoulder Lateral/ Medial* *not included in RULA analysis	neut	0	mod med	0	mod med	0	mod med	0	neut	0	neut	0
Wrist Extension/ Flexion	ext	2	ext	2	ext	2	flx	2	flx	2	ext	2
Wrist Deviation	ulnar	1	ulnar	1	ulnar	1	neut	0	ulnar	1	ulnar	1
		0		0		0		0		0		0
Wrist Twist (1) In mid range Or (2) End of range		1		1		1		1		1		1
Arm Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		1		1		0		0		0
Arm and Wrist Force/ load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		1		2		2		1		1		1

Table 11. Life Boat Rack Installer RULA (continued)

RULA Component	**Frame # 80850 Torch-cutting**		**Frame # 5160 Grind Squatting**		**Frame # 12750 Grind Stooped**		**Frame # 42270 Move Workpiece**		**Frame # 75510 Wire Weld kneeling**		**Frame # 85529 Adjust Pos. w/ Sledge**	
	Spec	***RULA***	***Spec***	***RULA***	***Spec***	***RULA***	***Spec***	***RULA***	***Spec***	***RULA***	***Spec***	***RULA***
Neck Extension/ Flexion	ext	4	sl flx	2	ext	4	ext	4	sl flx	2	sl flx	2
Neck Twist (+1)		0		0		0		0		0		0
Neck Side-Bent (+1)		0		0		0		0		0		0
Trunk Extension/ Flexion	mod flx	3	sl flx	2	hyp flx	4	hyp flx	4	sl flx	2	mod flx	3
Trunk Twist (+1)		0		0		0		0		0		1
Trunk Side Bend (+1)		0		0		0		0		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		1		1		0		0		0
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		1		2		2		1		1		1
Total RULA Score	**6**		**7**		**7**		**5**		**4**		**5**	

1 or 2 = Acceptable
3 or 4 = Investigate Further
5 or 6 = Investigate Further and Change Soon
7 = Investigate and Change Immediately

Table 12. Life Boat Rack Installer Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
(Moore and Garg, 1995)

Date/ Time	**Facility**	**Area/Shop**	**Task**
5/08/00	Marinette	Module Assembly North	Lifeboat Rack Installation

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**% MS** (percentage of maximal strength)	**Borg Scale** (Compare to Borg Cr-10 Scale)	**Perceived Effort**	**Rating**	**Multiplier**
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat hard	**10 - 29%**	**3**	**noticeable or definite effort**	**2**	**3.0**
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					**3.0**

Table 12. Life Boat Rack Installer Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0

Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
% Duration of Exertion = 100 x duration of all exertions (sec) / Total observation time (sec) = 100 x 1896 (sec)/ 3173 (sec) = 60	< 10	1	0.5
	10 - 29	2	1.0
	30 - 49	3	1.5
	50 -79	4	2.0
	> or = 80	5	3.0
Duration of Exertion Multiplier			**2.0**

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0

Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
Efforts per Minute = number of exertions / total observation time (min) = 118/53 = 2.2, but somewhat static tasks, set multiplier to 1.0	< 4	1	0.5
	4 - 8	**2**	**1.0**
	9 -14	3	1.5
	15 -19	4	2.0
	> or = 20	5	3.0
Efforts per Minute Multiplier			**1.0**

Table 12.Life Boat Rack Installer Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.						
Rating Criterion	**Wrist Extension**	**Wrist Flexion**	**Ulnar Deviation**	**Perceived Posture**	**Rating**	**Multiplier**
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	**26 -40 degrees**	**16 - 30 degrees**	**16 - 20 degrees**	**non-neutral (*estimated, based on RULAs performed)**	**3**	**1.5**
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						**1.5**

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.				
Rating Criterion	**Compared to MTM** (observed pace is divided by MTM's predicted pace and expressed as %)	**Perceived Speed**	**Rating**	**Multiplier**
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	**91 -100%**	**"normal" speed of motion**	**3**	**1.0**
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				**1.0**

Table 12. Life Boat Rack Installer Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet: Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + ... = (estimate ~ 4-8 hrs)	**Rating Criterion**	**Rating**	**Multiplier**
	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
	4 - 8 hrs	**4**	**1.00**
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**1.00**

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**	=	**SI SCORE**
3.0 X	**2.0 X**	**1.0 X**	**1.5 X**	**1.0 X**	**1.00**		**9**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:
- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 13. Life Boat Rack Installer UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
(Lifshitz and Armstrong, 1986)

Date/ Time	Facility	Area/Shop	Task
5/08/00	Marinette	Module Assembly North	Lifeboat Rack Installation

Risk Factors	No	Yes
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?	N	
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?	N	Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?	N	
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?		Y
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?		Y
6.3 Is the handle of the tool made from material other than metal?	N (grinder)	
6.4 Is the weight of the tool below 4 kg (9lbs)?	N (grinder)	
6.5 Is the tool suspended?	N	
TOTAL	**16 (73%)**	**6 (27%)**

* "No" responses are indicative of conditions associated with the risk of CTD's

Table 14. Life Boat Rack Installer OWAS

OWAS: OVAKO Work Analysis System
(Louhevaara and Suurnäkki, 1992)

Date/ Time	**Facility**	**Area/Shop**	**Task**
5/08/00	Marinette	Module Assembly North	Lifeboat Rack Installation

Risk Factor	**Work Phase1 Torch-cutting**	**Work Phase 2 Grind Squatting**	**Work Phase 3 Grind Stooped**	**Work Phase 4 Move Workpiece**	**Work Phase 5 WireWeld Kneeling**	**Work Phase 6 Adjust Pos. w/ Sledge**
TOTAL Combination Posture Score	**2**	**2**	**2**	**2**	**2**	**2**
Common Posture Combinations (collapsed across work phases)						
Back	2	2				
Arms	1	1				
Legs	6	4				
Posture Repetition (% of working time)	6	31				
Back % of Working Time Score	1	2				
Arms % of Working Time Score	1	1				
Legs % of Working Time Score	1	3				

ACTION CATEGORIES:
1 = no corrective measures
2 = corrective measures in the near future
3 = corrective measures as soon as possible
4 = corrective measures immediately

Table 14. Life Boat Rack Installer OWAS (continued)

Risk Factor	**Work Phase1 Torch-cutting**	**Work Phase 2 Grind Squatting**	**Work Phase 3 Grind Stooped**	**Work Phase 4 Move Workpiece**	**Work Phase 5 Wire Weld Kneeling**	**Work Phase 6 Adjust Pos. with Sledge**
Posture						
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	2	2	2	2	2	2
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	1	1	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	6	4	4	4	6	4
Load/ Use of Force						
1 = weight or force needed is = or <10 kg (<22lbs)	1	1	1	2	1	1
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)						
3 = weight or force > 20 kg (>44 lbs)						
Phase Repetition						
% of working time (0,10,20,30,40,50,60,70,80,90,100)	4	14	6	6	2	5

Table 15. Life Boat Rack Installer 3D Static Strength Prediction Program

3D Static Strength Prediction Program
(University of Michigan, 1997)

Date/ Time	**Facility**	**Area/Shop**	**Task**
5/08/00	Marinette	Module Assembly North	Lifeboat Rack Installation
Work Elements: **Moving Workpiece (30 lbs estimated)** **Frame Components**		**Disc Compression (lbs) @ L5/S1** **(Note: NIOSH Recommended Compression Limit (RCL) is 770 lbs)**	
Worker lifts end of angle into place 		769 pounds	

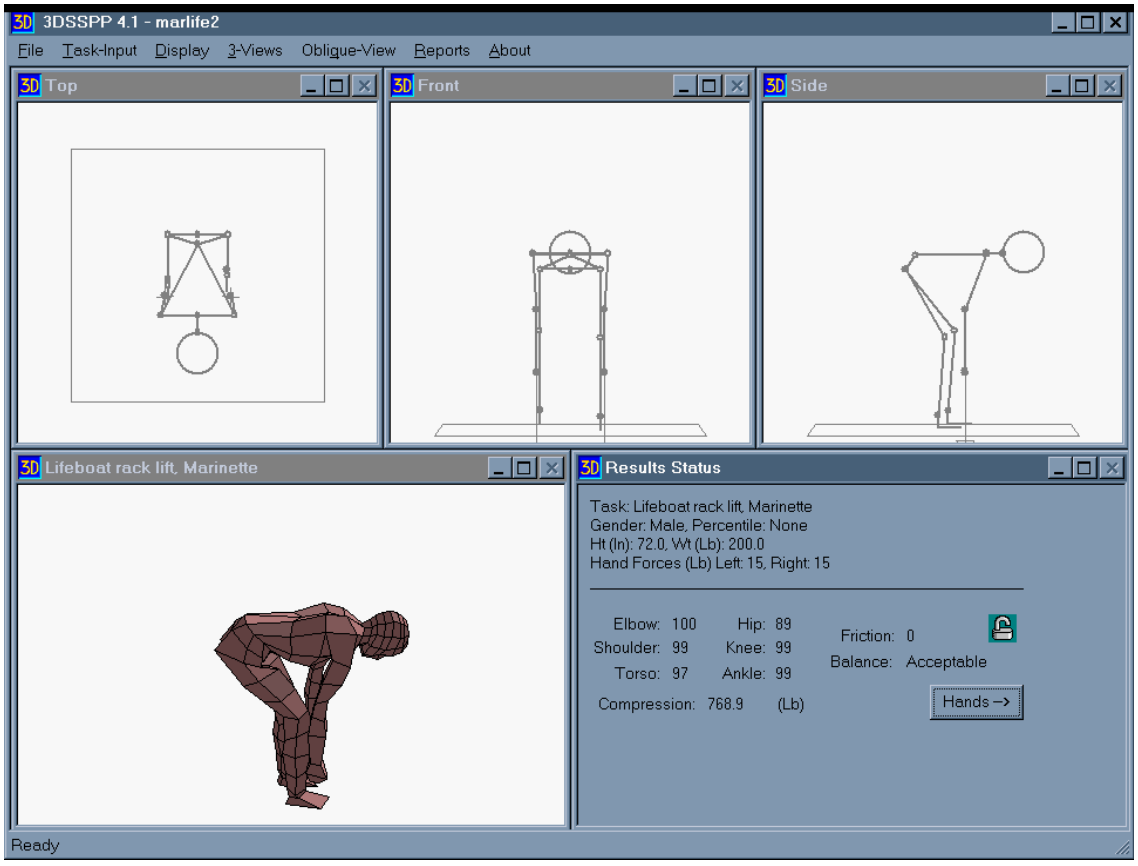

Table 16. Life Boat Rack Installer PLIBEL

PLIBEL Checklist
(Kemmlert, 1995)

Date/ Time	Facility	Area/Shop	Task
5/08/00	Marinette	Module Assembly North	Lifeboat Rack Installation

Section I: Musculoskeletal Risk Factors

Methods of Application:

1) Find the injured body region, answer yes or no to corresponding questions
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, Upper Back	Elbows, Forearms Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	N	N	N	N	N
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	Y				Y
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			Y	Y	Y
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	Y				Y
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table 16. Life Boat Rack Installer PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				
d) extended backwards?	Y				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	Y				Y
d) awkward location of load at onset or end of lifting	Y				Y
e) handling beyond forearm length	Y				Y
f) handling below knee length	Y				Y
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	Y				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed?					
a) weight of working materials or tools	N	N			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Repeated work, with forearm and hand, performed w/:					
a) twisting movements?		N			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 16. Life Boat Rack Installer PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, Upper Back	**Elbows, Forearm, Hands**	**Feet**	**Knees and Hips**	**Low Back**
SUM	**16**	**7**	**3**	**3**	**12**
PERCENTAGE	**61.5**	**63.6**	**37.5**	**37.5**	**57.1**
Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	N				
20: Is the job performed under time demands or psychological stress?	N				
21:Can the work have unusual or expected situations?	N				
22: Are the following present?					
a) cold	Y				
b) heat	Y				
c) draft	Y				
d) noise	Y				
e) troublesome visual conditions	Y				
f) jerks, shakes, or vibration	Y				
Environmental / Organizational Risk Factors Score					
SUM	**6**				
PERCENTAGE	**60.0**				

A4. SHEETMETAL ASSEMBLY

Table 17. Sheetmetal Ductworker RULA

Rapid Upper Limb Assessment (RULA)
(Matamney and Corlett, 1993)

Date/ Time	**Facility**		**Area/Shop**		**Task**							
5/08/00	Marinette		Shops Building (21)		Sheetmetal Ductwork							
RULA: Posture Sampling Results												
RULA Component	**Frame # 169710 Hammer**		**Frame # 173940 Move Duct**		**Frame # 177270 Visually Inspect**		**Frame # 176970 Measure/ Inspect**		**Frame # 177420 Record Info**		**Frame # 166199 Rest**	
	Spec	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***
Shoulder Extension/ Flexion	sl flx	2	sl flx	2	neut	1	mod flex	3	neut	1	neut	1
Shoulder is Raised (+1)		1		0		0		1		0		0
Upper Arm Abducted (+1)		0		0		0		1		0		0
Arm supported, leaning (-1)		0		-1		0		0		0		0
Elbow Extension/ Flexion	ext	1	ext	1	ext	1	flex	2	neut	2	ext	1
Shoulder Abduction/ Adduction	mod abd	1	neut	0	neut	0	neut	0	neut	0	neut	0
Shoulder Lateral/ Medial* *not included in RULA analysis	neut	0	neut	0	neut	0	neut	0	mod med	0	neut	0
Wrist Extension/ Flexion	ext	2	ext	2	neut	1	neut	1	neut	1	neut	1
Wrist Deviation	rad	1	neut	0	neut	0	ulnar	1	neut	0	neut	0
		0		0		0		0		0		0
Wrist Twist (1) In mid range Or (2) End of range		1		1		1		1		1		1
Arm Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		1		0		0		0		0		0
Arm and Wrist Force/ load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		1		1		0		0		1		0

Table 17. Sheetmetal Ductworker RULA (continued)

RULA Component	**Frame # 80850 Hammer**		**Frame # 5160 Move Duct**		**Frame # 12750 Visually Inspect**		**Frame # 42270 Measure/ Inspect**		**Frame # 75510 Record Info**		**Frame # 85529 Rest**	
	Spec	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***
Neck Extension/ Flexion	ext	2	neut	1	flex	3	neut	1	sl flx	2	neut	1
Neck Twist (+1)		0		0		1		1		0		0
Neck Side-Bent (+1)		0		0		0		1		0		0
Trunk Extension/ Flexion	sl flx	2	sl flx	2	hyp flx	3	ext	1	sl flx	2	neut	1
Trunk Twist (+1)		0		0		0		0		0		1
Trunk Side Bend (+1)		0		0		1		1		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		0		1		1		0		0		0
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		1		1		1		1		1		1
Total RULA Score	**6**		**3**		**4**		**5**		**3**		**2**	

1 or 2 = Acceptable
3 or 4 = Investigate Further
5 or 6 = Investigate Further and Change Soon
7 = Investigate and Change Immediately

Table 18. Sheetmetal Ductworker Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
(Moore and Garg, 1995)

Date/ Time	**Facility**	**Area/Shop**	**Task**
5/08/00	Marinette	Shops Building (21)	Sheetmetal Ductwork

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**% MS** (percentage of maximal strength)	**Borg Scale** (Compare to Borg Cr-10 Scale)	**Perceived Effort**	**Rating**	**Multiplier**
Light	**< 10%**	**< or = 2**	**barely noticeable or relaxed effort**	**1**	**1.0**
Somewhat hard	10 - 29%	3	noticeable or definite effort	2	3.0
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					**1.0**

Table 18. Sheetmetal Ductworker Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0

Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
% Duration of Exertion = 100 x duration of all exertions (sec) / Total observation time (sec) = 100 x 338 (sec)/ 562 (sec) = 60	< 10	1	0.5
	10 - 29	2	1.0
	30 - 49	3	1.5
	50 -79	**4**	**2.0**
	> or = 80	5	3.0
Duration of Exertion Multiplier			**2.0**

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0

Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
Efforts per Minute = number of exertions / total observation time (min) = 27/9.4 =2.9	**< 4**	**1**	**0.5**
	4 - 8	2	1.0
	9 -14	3	1.5
	15 -19	4	2.0
	> or = 20	5	3.0
Efforts per Minute Multiplier			**0.5**

Table 18. Sheetmetal Ductworker Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**Wrist Extension**	**Wrist Flexion**	**Ulnar Deviation**	**Perceived Posture**	**Rating**	**Multiplier**
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	**26 -40 degrees**	**16 - 30 degrees**	**16 - 20 degrees**	**non-neutral (*estimated, based on RULAs performed)**	**3**	**1.5**
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						**1.5**

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**Compared to MTM** (observed pace is divided by MTM's predicted pace and expressed as %)	**Perceived Speed**	**Rating**	**Multiplier**
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	**91 -100%**	**"normal" speed of motion**	**3**	**1.0**
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				**1.0**

Table 18. Sheetmetal Ductworker Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet: Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + ... = (estimate ~ 4-8 hrs)	**Rating Criterion**	**Rating**	**Multiplier**
	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
	4 - 8 hrs	**4**	**1.00**
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**1.00**

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**	=	**SI SCORE**
1.0 X	**2.0 X**	**0.5 X**	**1.5 X**	**1.0 X**	**1.00**		**1.50**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:
- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 19. Sheetmetal Ductworker UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders
(Lifshitz and Armstrong, 1986)

Date/ Time	**Facility**	**Area/Shop**	**Task**
5/08/00	Marinette	Shops Building (21)	Sheetmetal Ductwork

Risk Factors	**No**	**Yes**
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges	N	
1.2 Is the tool operating without vibration?	N	
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?		Y
1.4 Can the job be done without using gloves?		Y
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?	N	
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?		Y
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?		Y
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?		Y
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?		Y
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	N	
6.3 Is the handle of the tool made from material other than metal?		Y
6.4 Is the weight of the tool below 4 kg (9lbs)?		Y
6.5 Is the tool suspended?	N	
TOTAL	**12 (57%)**	**9 (43%)**

* "No" responses are indicative of conditions associated with the risk of CTD's

Table 20. Sheetmetal Ductworker OWAS

OWAS: OVAKO Work Analysis System
(Louhevaara and Suurnäkki, 1992)

Date/ Time	**Facility**	**Area/Shop**	**Task**
5/08/00	Marinette	Shops Building (21)	Sheetmetal Ductwork

Risk Factor	**Work Phase1 Hammer**	**Work Phase 2 Move Duct**	**Work Phase 3 Visually Inspect**	**Work Phase 4 Measure/ Inspect**	**Work Phase 5 Record Info**	**Work Phase 6 Rest**
TOTAL Combination Posture Score	**2**	**2**	**4**	**1**	**1**	**1**
Common Posture Combinations (collapsed across work phases)						
Back	2	1	4	3		
Arms	1	1	1	2		
Legs	3	2	5	2		
Posture Repetition (% of working time)	60	15	3	2		
Back % of Working Time Score	2	1	1	1		
Arms % of Working Time Score	1	1	1	1		
Legs % of Working Time Score	2	1	1	1		

ACTION CATEGORIES:
1 = no corrective measures
2 = corrective measures in the near future
3 = corrective measures as soon as possible
4 = corrective measures immediately

Table 20. Sheetmetal Ductworker OWAS (continued)

Risk Factor	**Work Phase1 Hammer**	**Work Phase 2 Move Duct**	**Work Phase 3 Visually Inspect**	**Work Phase 4 Measure/ Inspect**	**Work Phase 5 Record Info**	**Work Phase 6 Rest**
Posture						
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	2	2	4	3	1	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	1	2	1	1
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	3	3	5	2	2	2
Load/ Use of Force						
1 = weight or force needed is = or <10 kg (<22lbs)	1	1	1	1	1	1
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)						
3 = weight or force > 20 kg (>44 lbs)						
Phase Repetition						
% of working time (0,10,20,30,40,50,60,70,80,90,100)	51	9	3	2	12	3

Table 21. Sheetmetal Ductworker PLIBEL

PLIBEL Checklist
(Kemmlert, 1995)

Date/ Time	Facility	Area/Shop	Task
5/08/00	Marinette	Shops Building (21)	Sheetmetal Ductwork

Section I: Musculoskeletal Risk Factors

Methods of Application:

1) Find the injured body region, answer yes or no to corresponding questions
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	Body Regions				
	Neck, Shoulder, Upper Back	Elbows, Forearms Hands	Feet	Knees and Hips	Low Back
1: Is the walking surface uneven, sloping, slippery or nonresilient?			N	N	N
2: Is the space too limited for work movements or work materials?	N	N	N	N	N
3: Are tools and equipment unsuitably designed for the worker or the task?	N	N	N	N	N
4: Is the working height incorrectly adjusted?	N				N
5: Is the working chair poorly designed or incorrectly adjusted?	N				N
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	N				N
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table 21. Sheetmetal Ductworker PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	N				
c) severely twisted?	N				
d) extended backwards?	N				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	N				N
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	N				N
f) handling below knee length	N				N
g) handling above shoulder height	N				N
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	N	N			N
13: Is sustained work performed when one arm reaches forward or to the side without support?	N				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements beyond comfortable reaching distance?	N	N			
15: Is repeated or sustained manual work performed?					
a) weight of working materials or tools	Y	Y			
b) awkward grasping of working materials or tools	N	N			
16: Are there high demands on visual capacity?	N				
17: Repeated work, with forearm and hand, performed w/:					
a) twisting movements?		N			
b) forceful movements?		Y			
c) uncomfortable hand positions?		N			
d) switches or keyboards?		N			

Table 21. Sheetmetal Ductworker PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, Upper Back	**Elbows, Forearms, Hands**	**Feet**	**Knees and Hips**	**Low Back**
SUM	**4**	**3**	**0**	**0**	**1**
PERCENTAGE	**15.4**	**27.3**	**0**	**0**	**4.8**
Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores					
18: Is there no possibility to take breaks and pauses?	N				
19: Is there no possibility to choose order and type of work tasks or pace of work?	N				
20: Is the job performed under time demands or psychological stress?	N				
21:Can the work have unusual or expected situations?	N				
22: Are the following present?					
a) cold	N				
b) heat	N				
c) draft	N				
d) noise	Y				
e) troublesome visual conditions	N				
f) jerks, shakes, or vibration	Y				
Environmental / Organizational Risk Factors Score					
SUM	**2**				
PERCENTAGE	**20.0**				

A5. ASSEMBLY FITTER WITH COMEALONG

Table 22. Bow Assembly Shipfitter RULA

Rapid Upper Limb Assessment (RULA)
(Matamney and Corlett, 1993)

Date/ Time	**Facility**	**Area/Shop**	**Task**
5/08/00	Marinette	Module Assembly North	Bow Assembly Shipfitting

RULA: Posture Sampling Results

RULA Component	**Frame # 960 Torchcut**		**Frame # 480 Change Tool**		**Frame # 4020 Reposition**		**Frame # 6990 Inspect, set level**		**Frame # 11010 Attach/Adjust Comealong and Chains**		**Frame # 27390 Crank Comealong**	
	Spec	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***
Shoulder Extension/ Flexion	mod flx	3	sl flx	2	mod flex	3	sl flx	2	hyp flx	4	hyp flx	4
Shoulder is Raised (+1)		0		0		0		0		1		1
Upper Arm Abducted (+1)		0		0		0		0		0		0
Arm supported, leaning (-1)		-1		0		0		0		0		0
Elbow Extension/ Flexion	ext	1	ext	1	ext	1	ext	1	ext	1	ext	1
Shoulder Abduction/ Adduction	neut	0	neut	0	neut	0	neut	0	add	1	neut	0
Shoulder Lateral/ Medial* *not included in RULA analysis	neut	0	neut	0	neut	0	neut	0	mod med	0	lat	0
Wrist Extension/ Flexion	ext	2	neut	0	neut	0	flx	2	ext	2	flx	2
Wrist Deviation	ulnar	1	neut	0	neut	0	neut	0	ulnar	1	rad	1
		0		0		0		0		0		0
Wrist Twist (1) In mid range Or (2) End of range		1		1		1		1		1		1
Arm/Wrist Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		0		0		0		0		0		1
Arm and Wrist Force/ load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		1		1		1		1		1		3

Table 22. Bow Assembly Shipfitter RULA (continued)

RULA Component	**Frame # 80850 Torchcut**		**Frame # 5160 Change Tool**		**Frame # 12750 Reposition**		**Frame # 42270 Inspect, set level**		**Frame # 75510 Attach/ Adjust Comealong and Chains**		**Frame # 85529 Crank Comealong**	
	Spec	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***
Neck Extension/ Flexion	ext	4	sl flx	2	sl flx	2	mod flx	3	ext	4	ext	4
Neck Twist (+1)		0		0		0		1		0		0
Neck Side-Bent (+1)		0		0		0		1		0		0
Trunk Extension/ Flexion	mod flx	3	sl flx	2	sl flx	2	sl flx	2	neut	1	neut	1
Trunk Twist (+1)		0		0		0		0		0		0
Trunk Side Bend (+1)		1		0		0		1		0		0
Legs If legs and feet are supported and balanced: (+1); If not: (+2)		1		1		1		1		1		1
Neck, Trunk, and Leg Muscle Use Score If posture mainly static (I.e. held for longer than 10 minutes) or; If action repeatedly occurs 4 times per minute or more: (+ 1)		0		0		0		0		0		0
Neck, Trunk, and Leg Force/ Load Score If load less than 2 kg (intermittent): (+0) If 2kg to 10 kg (intermittent): (+1) If 2kg to 10 kg (static or repeated): (+2) If more than 10 kg load or repeated or shocks: (+3)		1		1		1		1		1		2
Total RULA Score	**5**		**3**		**3**		**4**		**6**		**6**	

1 or 2 = Acceptable
3 or 4 = Investigate Further
5 or 6 = Investigate Further and Change Soon
7 = Investigate and Change Immediately

Table 23. Bow Assembly Shipfitter Strain Index

Strain Index: Distal Upper Extremity Disorders Risk Assessment
(Moore and Garg, 1995)

Date/ Time	**Facility**	**Area/Shop**	**Task**
5/08/00	Marinette	Module Assembly North	Bow Assembly Shipfitting

1. Intensity of Exertion: An estimate of the strength required to perform the task one time. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**% MS** (percentage of maximal strength)	**Borg Scale** (Compare to Borg Cr-10 Scale)	**Perceived Effort**	**Rating**	**Multiplier**
Light	< 10%	< or = 2	barely noticeable or relaxed effort	1	1.0
Somewhat hard	**10 - 29%**	**3**	**noticeable or definite effort**	**2**	**3.0**
Hard	30 - 49%	4 - 5	obvious effort; unchanged facial expression	3	6.0
Very Hard	50 - 79%	6 - 7	substantial effort; changes to facial expression	4	9.0
Near Maximal	> or = 80%	> 7	uses shoulder or trunk to generate force	5	13.0
Intensity of Exertion Multiplier					**3.0**

Table 23. Bow Assembly Shipfitter Strain Index (continued)

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, then dividing the measured duration of exertion by the total observation time and multiplying by 100. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box.*NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0

Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
% Duration of Exertion = 100 x duration of all exertions (sec) / Total observation time (sec) = 100 x 301 (sec)/ 1311 (sec) = 23	< 10	1	0.5
	10 - 29	**2**	**1.0**
	30 - 49	3	1.5
	50 -79	4	2.0
	> or = 80	5	3.0
Duration of Exertion Multiplier			**1.0**

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, then dividing the number of exertions by the duration of the observation period, measured in minutes. Use the worksheet below and mark the appropriate rating according to the rating criterion, then fill in the corresponding multiplier in the bottom far right box. *NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/ minute multiplier should be set to 3.0

Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
Efforts per Minute = number of exertions / total observation time (min) = 38/22 = 1.7	**< 4**	**1**	**0.5**
	4 - 8	2	1.0
	9 -14	3	1.5
	15 -19	4	2.0
	> or = 20	5	3.0
Efforts per Minute Multiplier			**0.5**

Table 23. Bow Assembly Shipfitter Strain Index (continued)

4. Hand/ Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position. Mark the rating after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**Wrist Extension**	**Wrist Flexion**	**Ulnar Deviation**	**Perceived Posture**	**Rating**	**Multiplier**
Very Good	0 -10 degrees	0 - 5 degrees	0 - 10 degrees	perfectly neutral	1	1.0
Good	11 - 25 degrees	6 - 15 degrees	11 -15 degrees	near neutral	2	1.0
Fair	**26 -40 degrees**	**16 - 30 degrees**	**16 - 20 degrees**	**non-neutral (*estimated, based on RULAs performed)**	**3**	**1.5**
Bad	41 - 55 degrees	31 - 50 degrees	21 -25 degrees	marked deviation	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/ Wrist Posture Multiplier						**1.5**

5. Speed of Work: An estimate of how fast the worker is working. Mark the rating on the far right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.

Rating Criterion	**Compared to MTM** (observed pace is divided by MTM's predicted pace and expressed as %)	**Perceived Speed**	**Rating**	**Multiplier**
Very Slow	< or = 80%	extremely relaxed pace	1	1.0
Slow	81 - 90%	"taking one's own time"	2	1.0
Fair	**91 -100%**	**"normal" speed of motion**	**3**	**1.0**
Fast	101-115%	rushed, but able to keep up	4	1.5
Very Fast	> 115%	rushed, barely or unable to keep up	5	2.0
Speed of Work Multiplier				**1.0**

Table 23. Bow Assembly Shipfitter Strain Index (continued)

6. Duration of Task per Day: Either measured or obtained from plant personnel. Mark the rating on the right after using the guidelines below, then fill in the corresponding multiplier in the bottom far right box.			
Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
Duration of Task per Day (hrs) = duration of task (hrs) + duration of task (hrs) + ... = (estimate ~ 4-8 hrs)	< or = 1 hrs	1	0.25
	1 - 2 hrs	2	0.50
	2 - 4 hrs	3	0.75
	4 - 8 hrs	**4**	**1.00**
	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**1.00**

7. Calculate the Strain Index (SI) Score: Insert the multiplier values for each of the six task variables into the spaces below, then multiply them all together.							
Intensity of Exertion	**Duration of Exertion**	**Efforts per Minute**	**Hand/ Wrist Posture**	**Speed of Work**	**Duration of Task**	=	**SI SCORE**
3.0 X	**1.0 X**	**0.5 X**	**1.5 X**	**1.0 X**	**1.00**		**2.25**

SI Scores are used to predict Incidence Rates of Distal Upper Extremity injuries per 100 FTE:
- SI Score < 5 is correlated to an Incidence Rate of about 2 DUE injuries per 100 FTE;
- SI Score of between 5-30 is correlated to an Incidence Rate of about 77 DUE injuries per 100 FTE;
- SI Score of between 31-60 is correlated to an Incidence Rate of about 106 DUE injuries per 100 FTE;
- SI Score > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table 24. Bow Assembly Shipfitter UE CTD Checklist

Michigan Checklist for Upper Extremity Cumulative Trauma Disorders

Lifshitz and Armstrong (1986)

Date/ Time	**Facility**	**Area/Shop**	**Task**
5/08/00	Marinette	Module Assembly North	Bow Assembly Shipfitting

Risk Factors	**No**	**Yes**
1. Physical Stress		
1.1 Can the job be done without hand/ wrist contact with sharp edges		Y
1.2 Is the tool operating without vibration?		Y
1.3 Are the worker's hands exposed to temperature >21degrees C (70 degrees F)?		Y
1.4 Can the job be done without using gloves?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lbs) of force?	N	
2.2 Can the job be done without using finger pinch grip?		Y
3. Posture		
3.1 Can the job be done without flexion or extension of the wrist?	N	
3.2 Can the tool be used without flexion or extension of the wrist?	N	
3.3 Can the job be done without deviating the wrist from side to side?	N	
3.4 Can the tool be used without deviating the wrist from side to side?	N	
3.5 Can the worker be seated while performing the job?		Y
3.6 Can the job be done without "clothes wringing" motion?		Y
4. Workstation Hardware		
4.1 Can the orientation of the work surface be adjusted?	N	
4.2 Can the height of the work surface be adjusted?	N	
4.3 Can the location of the tool be adjusted?	N	
5. Repetitiveness		
5.1 Is the cycle time longer than 30 seconds?	N	
6. Tool Design		
6.1 Are the thumb and finger slightly overlapped in a closed grip?		Y
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?		
6.3 Is the handle of the tool made from material other than metal?	N	
6.4 Is the weight of the tool below 4 kg (9lbs)?	N	
6.5 Is the tool suspended?	N	
TOTAL	**13 (65%)**	**7 (35%)**

* "No" responses are indicative of conditions associated with the risk of CTD's

Table 25. Bow Assembly Shipfitter OWAS

OWAS: OVAKO Work Analysis System
(Louhevaara and Suurnäkki, 1992)

Date/ Time	**Facility**	**Area/Shop**	**Task**
5/08/00	Marinette	Module Assembly North	Bow Assembly Shipfitting

Risk Factor	**Work Phase1 Torchcut**	**Work Phase 2 Change Tool**	**Work Phase 3 Repo-sition**	**Work Phase 4 Inspect, set level**	**Work Phase 5 Attach/ Adjust Come-along and Chains**	**Work Phase 6 Crank Come-along**
TOTAL Combination Posture Score	**2**	**1**	**1**	**2**	**1**	**1**
Common Posture Combinations (collapsed across work phases)						
Back	2	1	1	1		
Arms	1	1	1	3		
Legs	1	1	7	2		
Posture Repetition (% of working time)	49	2	29	17		
Back % of Working Time Score	2	1	1	1		
Arms % of Working Time Score	1	1	1	1		
Legs % of Working Time Score	1	1	1	1		

ACTION CATEGORIES:
1 = no corrective measures
2 = corrective measures in the near future
3 = corrective measures as soon as possible
4 = corrective measures immediately

Table 25. Bow Assembly Shipfitter OWAS (continued)

Risk Factor	**Work Phase1 Torchcut**	**Work Phase 2 Change Tool**	**Work Phase 3 Repo-sition**	**Work Phase 4 Inspect, set level**	**Work Phase 5 Attach/ Adjust Come-along and Chains**	**Work Phase 6 Crank Come-along**
Posture						
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	2	1	1	2	1	1
Arms 1 = both arms are below shoulder level 2 = one arm is at or above shoulder level 3 = both arms are at or above shoulder level	1	1	1	1	3	3
Legs 1 = sitting 2 = standing with both legs straight 3 = standing with the weight on one straight leg 4 = standing or squatting with both knees bent 5 = standing or squatting with one knee bent 6 = kneeling on one or both knees 7 = walking or moving	1	1	7	1,7	2	2
Load/ Use of Force						
1 = weight or force needed is = or <10 kg (<22lbs)	1	1	1	1	1	2
2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs)						
3 = weight or force > 20 kg (>44 lbs)						
Phase Repetition						
% of working time (0,10,20,30,40,50,60,70,80,90,100)	4	2	29	45	14	3

Table 26. Bow Assembly Shipfitter PLIBEL

PLIBEL Checklist
(Kemmlert, 1995)

Date/ Time	**Facility**	**Area/Shop**	**Task**
5/08/00	Marinette	Module Assembly North	Bow Assembly Shipfitting

Section I: Musculoskeletal Risk Factors

Methods of Application:

1) Find the injured body region, answer yes or no to corresponding questions
2) Answer questions, score potential body regions for injury risk

Musculoskeletal Risk Factor Questions	**Body Regions**				
	Neck, Shoulder, Upper Back	**Elbows, Forearms Hands**	**Feet**	**Knees and Hips**	**Low Back**
1: Is the walking surface uneven, sloping, slippery or nonresilient?			Y	Y	Y
2: Is the space too limited for work movements or work materials?	Y	Y	Y	Y	Y
3: Are tools and equipment unsuitably designed for the worker or the task?	Y	Y	Y	Y	Y
4: Is the working height incorrectly adjusted?	Y				Y
5: Is the working chair poorly designed or incorrectly adjusted?	n/a				n/a
6: If work performed standing, is there no possibility to sit and rest?			N	N	N
7: Is fatiguing foot pedal work performed?			N	N	
8: Is fatiguing leg work performed? e.g. ...					
a) repeated stepping up on stool, step etc..			N	N	N
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			N	N	N
9: Is repeated or sustained work performed when back is:					
a) mildly flexed forward?	Y				Y
b) severely flexed forward?	Y				Y
c) bent sideways or mildly twisted?	Y				Y
d) severely twisted?	N				N

Table 26. Bow Assembly Shipfitter PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	Y				
b) bent sideways or mildly twisted?	Y				
c) severely twisted?	N				
d) extended backwards?	Y				
11: Are loads lifted manually? Note important factors:					
a) periods of repetitive lifting	N				N
b) weight of load	N				N
c) awkward grasping of load	Y				Y
d) awkward location of load at onset or end of lifting	N				N
e) handling beyond forearm length	N				N
f) handling below knee length	N				N
g) handling above shoulder height	Y				Y
12: Is repeated, sustained or uncomfortable carrying, pushing or pulling of loads performed?	Y	Y			Y
13: Is sustained work performed when one arm reaches forward or to the side without support?	N				
14: Is there a repetition of:					
a) similar work movements?	N	N			
b) similar work movements beyond comfortable reaching distance?	Y	Y			
15: Is repeated or sustained manual work performed?					
a) weight of working materials or tools	N	N			
b) awkward grasping of working materials or tools	Y	Y			
16: Are there high demands on visual capacity?	N				
17: Repeated work, with forearm and hand, performed w/:					
a) twisting movements?		N			
b) forceful movements?		Y			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table 26. Bow Assembly Shipfitter PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, Upper Back	**Elbows, Forearms, Hands**	**Feet**	**Knees and Hips**	**Low Back**
SUM	**14**	**7**	**3**	**3**	**10**
PERCENTAGE	**53.8**	**63.6**	**37.5**	**37.5**	**47.6**

Section II: Environmental / Organizational Risk Factors (Modifying) Answer below questions, use to modify interpretation of musculoskeletal scores	
18: Is there no possibility to take breaks and pauses?	N
19: Is there no possibility to choose order and type of work tasks or pace of work?	N
20: Is the job performed under time demands or psychological stress?	N
21:Can the work have unusual or expected situations?	N
22: Are the following present?	
a) cold	N
b) heat	Y
c) draft	N
d) noise	Y
e) troublesome visual conditions	Y
f) jerks, shakes, or vibration	N
Environmental / Organizational Risk Factors Score	
SUM	**3**
PERCENTAGE	**30.0**