APPENDIX F -- PIPEFITTING

F1. SHOP PIPE WELDER

Table F-1. Shop Pipe Welder (using positioners) RULA

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

Work Phase	Weld standing		Inspect weld		Adjust positioner		Change body positon		Get supplies	
	Spec	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***
Shoulder Extension/ Flexion	sl flex	2	neut	1	mod flx	3	neut	1	neut	1
Shoulder is Raised (+1)		0		0		0		0		0
Upper Arm Abducted (+1)		0		0		0		0		0
Arm supported, leaning (-1)		0		0		0		0		0
Elbow Extension/ Flexion	ext	1	ext	1	ext	1	neut	2	neut	2
Shoulder Abduction/ Adduction	neut	0	neut	0	neut	0	neut	0	neut	0
Shoulder Lateral/ Medial	neut	0	neut	0	neut	0	neut	0	neut	0
Wrist Extension/ Flexion	flx	2	neut	1	neut	1	neut	1	neut	1
Wrist Deviation	ulnar	1	neut	0		neut	0	neut	0	neut
Wrist Bent from Midline (+1)		0		0		0		0		0
Wrist Twist (1) In mid range or (2) End of range		1		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		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		1

Table F-1. Shop Pipe Welder (using positioners) RULA (continued)

Work Phase	Weld standing		Inspect weld		Adjust positioner		Change body positon		Get supplies	
	Spec	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***
Neck Extension/ Flexion	hyp flx	3	hyp flx	3	sl flx	2	sl flx	2	sl flx	2
Neck Twist (+1)		0		0		0		0		0
Neck Side-Bent (+1)		0		0		0		0		0
Trunk Extension/ Flexion	mod flx	3	sl flx	2	neut	1	neut	1	neut	1
Trunk Twist (+1)		0		0		0		0		0
Trunk Side Bend (+1)		0		0		0		0		0
Legs: If legs and feet are supported and balanced: (+1); If not: (+2)		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		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
Total RULA Score	**7**		**3**		**3**		**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 F-2. Shop Pipe Welder (using positioner) Strain Index

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

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 far right box.					
Rating Criterion	**% Maximal Strength**	**Borg 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**

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, and then dividing the measured duration of exertion by the total observation time and multiplying by 100. NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/minute multiplier should be set to 3.0			
Worksheet: % Duration of Exertion = 100 x duration of all exertions (sec) / Total observation time (sec) = 100 x 201 (sec)/419 (sec) = 48%	**Rating Criterion**	**Rating**	**Multiplier**
	< 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			**1.5**

3. Efforts per Minute: Measured by counting the number of exertions that occur during an observation period, and then dividing the number of exertions by the duration of the observation period, measured in minutes. NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/minute multiplier should be set to 3.0			
Worksheet: Efforts per Minute = number of exertions / total observation time (min) = 10/7 = 1.4, but task is static, set multiplier to 3.0	**Rating Criterion**	**Rating**	**Multiplier**
	< 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 F-2. Shop Pipe Welder (using positioner) Strain Index (continued)

4. Hand/Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position.						
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 done)	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.				
Rating Criterion	**Observed Pace/MTM Predicted Pace x 100%**	**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**

6. Duration of Task per Day: Either measured of obtained from plant personnel			
Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
Duration of Task per Day (hrs)	< or = 1 hr	1	0.25
= duration of task (hrs) +	1 –2 hrs	2	0.50
duration of task (hrs) + …	2 – 4 hrs	3	0.75
	4 – 8 hrs	4	1.00
= (estimate ~ 4- 8 hrs)	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**1.00**

Table F-2. Shop Pipe Welder (using positioner) Strain Index (continued)

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	**1.5 X**	**3.0 X**	**1.5 X**	**1.0 X**	**1.00**	**=**	**20.3**

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; and
-- SI Score of > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table F-3. Shop Pipe Welder (using positioner) UE CTD Checklist

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

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

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?		Y
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?		Y
4.2 Can the height of the work surface be adjusted?		Y
4.3 Can the location of the tool be adjusted?	N (height)	
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?		Y
6.4 Is the weight of the tool below 4 kg (9lbs)?		Y
6.5 Is the tool suspended?	N	
TOTAL	**8 (38%)**	**13 (62%)**

Table F-4. Shop Pipe Welder (using positioner) OWAS

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

Work Phase	Weld standing	Inspect weld	Adjust positioner	Change body positon	Get supplies
TOTAL Combination Posture Score	2	2	1	1	1
Common Posture Combinations (collapsed across work phases)					
Back	2	1	1		
Arms	1	1	1		
Legs	2	2	7		
Posture Repetition (% of working time)	62	21	18		
Back % of Working Time Score	2	1	1		
Arms % of Working Time Score	1	1	1		
Legs % of Working Time Score	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 F-4. Shop Pipe Welder (using positioner) OWAS (continued)

Work Phase	Weld standing	Inspect weld	Adjust positioner	Change body positon	Get supplies
Posture					
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	2	2	1	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	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	2	2	2	7	7
Load/ Use of Force					
1 = weight or force needed is = or <10 kg (<22lbs) 2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs) 3 = weight or force > 20 kg (>44 lbs)	1	1	1	1	1
Phase Repetition					
% of working time (0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100)	48	14	21	14	4

Table F-5. Shop Pipe Welder (using positioner) PLIBEL

PLIBEL Checklist
Kemmlert (1995)

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?	N	N	N	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?			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 the 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 F-5. Shop Pipe Welder (using positioner) 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	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?	N	N			N
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? Notice factors of importance as:					
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?	Y				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		N			
b) forceful movements?		N			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table F-5. Shop Pipe Welder (using positioner) PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	10	4	0	0	4
PERCENTAGE	38.5	36.4	0	0	19
Section II: Environmental / Organizational Risk Factors (Modifying)					
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				

F2. SHIPBOARD PIPE WELDING

Table F-6. Pipe Welder #1 RULA

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

Work Phase	Deslag Kneeling		Arctime Standing		Deslag Standing		Change/ Fix Tool	
	Specific	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***	***Specific***	***RULA Score***
Shoulder Extension/ Flexion	sl flx	2	neut	1	sl flex	2	neut	1
Shoulder is Raised (+1)		0		0		0		0
Upper Arm Abducted (+1)		0		0		0		0
Arm supported, leaning (-1)		0		0		0		0
Elbow Extension/ Flexion	ext	1	flex	2	ext	1	flex	2
Shoulder Abduction/ Adduction	neut	0	neut	0	add	1	neut	0
Shoulder Lateral/ Medial	neut	0	neut	0	neut	0	neut	0
Wrist Extension/ Flexion	neut	1	flex	2	neut	1	neut	1
Wrist Deviation	rad	1	ulnar	1	rad	1	neut	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)		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)		1		2		0		0

Table F-6. Pipe Welder #1 RULA (continued)

Work Phase	Deslag Kneeling		Arctime Standing		Deslag Standing		Change/ Fix Tool	
	Specific	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*	*Specific*	*RULA Score*
Neck Extension/ Flexion	sl flex	2	neut	1	neut	1	sl flex	2
Neck Twist (+1)		1		0		0		0
Neck Side Bend (+1)		1		0		0		0
Trunk Extension/ Flexion	sl flex	2	flex	3	neut	1	neut	1
Trunk Twist (+1)		0		0		0		0
Trunk Side Bend (+1)		0		1		1		1
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)		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)		1		2		1		1
Total RULA Score	**3**		**7**		**2**		**3**	

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

Table F-7. Pipe Welder #2 RULA

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

Work Phase	Arctime		Deslag		Change, bend stick		Position body		Change tools		Use angle grinder	
	Spec	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***
Shoulder Extension/ Flexion	sl flex	2	mod flex	3	neut	1	neut	1	neut	1	sl flex	2
Shoulder is Raised (+1)		1		1		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	flx	2	neut	2	neut	2	neut	2	neut	2	neut	2
Shoulder Abduction/ Adduction	neut	0	neut	0	neut	0	neut	0	neut	0	add	1
Shoulder Lateral/ Medial	neut	0	neut	0	neut	0	neut	0	neut	0	mod med	1
Wrist Extension/ Flexion	neut	1	ext	2	neut	1	neut	1	neut	1	ext	2
Wrist Deviation	ul-nar	1	ul-nar	1	neut	0	neut	0	neut	0	ul-nar	1
Wrist Bent from Midline (+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 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		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)		2		1		0		0		1		2

Table F-7. Pipe Welder #2 RULA (continued)

Work Phase	Arctime		Deslag		Change, bend stick		Position body		Change tools		Use angle grinder	
	Spec	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***	***Spec***	***RULA Score***
Neck Extension/ Flexion	sl flx	2	ext	4	flx	3	ext	4	flx	3	sl flx	2
Neck Twist (+1)		0		1		0		0		0		0
Neck Side-Bent (+1)		0		0		0		0		0		0
Trunk Extension/ Flexion	neut	1	ext	1	neut	1	neut	1	sl flx	2	neut	1
Trunk Twist (+1)		0		0		0		0		0		0
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		0		0		0		1
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		2		1		0		1		2
Total RULA Score	**6**		**6**		**3**		**2**		**3**		**6**	

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

Table F-8. Pipe Welder #1 Strain Index

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

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 far right box.					
Rating Criterion	**% Maximal Strength**	**Borg 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**

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, and then dividing the measured duration of exertion by the total observation time and multiplying by 100. NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/minute multiplier should be set to 3.0			
Worksheet: % Duration of Exertion = 100 x duration of all exertions (sec) / Total observation time (sec) = 100 x 152 (sec)/620 (sec) = 25%	**Rating Criterion**	**Rating**	**Multiplier**
	< 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, and then dividing the number of exertions by the duration of the observation period, measured in minutes. NOTE: If duration of exertion is 100% (as with some static tasks), then efforts/minute multiplier should be set to 3.0			
Worksheet: Efforts per Minute = number of exertions / total observation time (min) = 9/10.33 = 0.87, but somewhat static tasks, set multiplier to 1.0	**Rating Criterion**	**Rating**	**Multiplier**
	< 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 F-8. Pipe Welder #1 Strain Index (continued)

4. Hand/Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position.						
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	3	1.5
Bad	41 – 55 degrees	31 – 50 degrees	21 – 25 degrees	marked deviation (*estimated, based on RULAs done)	4	2.0
Very Bad	> 60 degrees	> 50 degrees	> 25 degrees	near extreme	5	3.0
Hand/Wrist Posture Multiplier						**2.0**

5. Speed of Work: An estimate of how fast the worker is working.				
Rating Criterion	**Observed Pace/MTM Predicted Pace x 100%**	**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**

6. Duration of Task per Day: Either measured of obtained from plant personnel			
Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
Duration of Task per Day (hrs)	< or = 1 hr	1	0.25
= duration of task (hrs) +	1 –2 hrs	2	0.50
duration of task (hrs) + …	2 – 4 hrs	3	0.75
	4 – 8 hrs	4	1.00
= (estimate ~ 4- 8 hrs)	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**1.00**

Table F-8. Pipe Welder #1 Strain Index (continued)

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**	**1.0 X**	**2.0 X**	**1.0 X**	**1.00**	**=**	**6.0**

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; and
-- SI Score of > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table F-9. Pipe Welder #2 Strain Index

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

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 far right box.					
Rating Criterion	**% Maximal Strength**	**Borg 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**

2. Duration of Exertion (% of cycle): Calculated by measuring the duration of all exertions during an observation period, and then dividing the measured duration of exertion by the total observation time and multiplying by 100. 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 1310 (sec)/1677 (sec) = 78%	< 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, and then dividing the number of exertions by the duration of the observation period, measured in minutes. 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) = 61/28 = 2.2	< 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 F-9. Pipe Welder #2 Strain Index (continued)

4. Hand/Wrist Posture: An estimate of the position of the hand or wrist relative to neutral position.						
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 done)	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.				
Rating Criterion	**Observed Pace/MTM Predicted Pace x 100%**	**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**

6. Duration of Task per Day: Either measured of obtained from plant personnel			
Worksheet:	**Rating Criterion**	**Rating**	**Multiplier**
Duration of Task per Day (hrs)	< or = 1 hr	1	0.25
= duration of task (hrs) +	1 –2 hrs	2	0.50
duration of task (hrs) + …	2 – 4 hrs	3	0.75
	4 – 8 hrs	4	1.00
= (estimate ~ 2 - 4 hrs)	> or = 8 hrs	5	1.50
Duration of Task per Day Multiplier			**0.75**

Table F-9. Pipe Welder #2 Strain Index (continued)

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**	**0.5 X**	**1.5 X**	**1.0 X**	**0.75**	**=**	**3.4**

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; and
-- SI Score of > 60 is correlated to an Incidence Rate of about 130 DUE injuries per 100 FTE.

Table F-10. Pipe Welder #1 UE CTD Checklist

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

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

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?	N	
2. Force		
2.1 Does the job require exerting less than 4.5 kg (10lb) 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?		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)?		Y (welding)
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 (9lb)?		Y
6.5 Is the tool suspended?	N	
TOTAL	**13 (62%)**	**8 (38%)**

Table F-11. Pipe Welder #2 UE CTD Checklist

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

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

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	Y
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?	N	
6.2 Is the span of the tool's handle between 5 and 7 cm (2-2 3/4 inches)?	N	Y (grinder)
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	**16 (67%)**	**8 (33%)**

Table F-12. Pipe Welder #1 OWAS

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

Work Phase	Deslag Kneeling	Arctime Standing	Deslag Standing	Change/ Fix Tool
TOTAL Combination Posture Score	2	2	1	1
Common Posture Combinations (collapsed across work phases)				
Back	2	2	1	
Arms	1	1	1	
Legs	6	2	2	
Posture Repetition (% of working time)	5	15	26	
Back % of Working Time Score	1	1	1	
Arms % of Working Time Score	1	1	1	
Legs % of Working Time Score	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 F-12. Pipe Welder #1 OWAS (continued)

Work Phase	Deslag Kneeling	Arctime Standing	Deslag Standing	Change/ Fix 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	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
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	2	2	2
Load/ Use of Force				
1 = weight or force needed is = or <10 kg (<22lb) 2 = weight or force > 10 but < 20kg (>22lb < 44 lb) 3 = weight or force > 20 kg (>44 lb)	1	1	1	1
Phase Repetition				
% of working time (0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100)	5	15	5	21

Table F-13. Pipe Welder #2 OWAS

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

Work Phase	Position stick holder	Arctime	Deslag	Change, bend stick	Position body	Change tools	Grind O/H w/ electric offset	Resting, change over to wire
TOTAL Combination Posture Score	1	1	2	1	1	2	1	1
Common Posture Combinations (collapsed across work phases)								
Back	1	1	2	1	1			
Arms	2	1	2	1	3			
Legs	3	7	2	2	2			
Posture Repetition (% of working time)	14	27	18	13	15			
Back % of Working Time Score	1	1	1	1	1			
Arms % of Working Time Score	1	1	1	1	1			
Legs % of Working Time Score	1	1	1	1	1			
ACTION CATEGORIES: 1 = No corrective measures 2 = Corrective measures in near future 3 = Corrective measures as soon as possible 4 = Corrective measures immediately								

Table F-13. Pipe Welder #2 OWAS (continued)

Work Phase	Position stick holder	Arctime	Deslag	Change, bend stick	Position body	Change tools	Grind O/H w/ electric offset	Resting, change over to wire
Posture								
Back 1 = straight 2 = bent forward, backward 3 = twisted or bent sideways 4 = bent and twisted or bent forward and sideways	1	1	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	2	2	2	1	1	1	3	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	2, 3	2	2	7	7	2	7
Load/ Use of Force								
1 = weight or force needed is = or <10 kg (<22lbs) 2 = weight or force > 10 but < 20kg (>22lbs < 44 lbs) 3 = weight or force > 20 kg (>44 lbs)	1	1	1	1	1	1	2	1
Phase Repetition								
% of working time (0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100)	2	12	18	13	12	5	15	15

Table F-14. Pipe Welder #1 PLIBEL

PLIBEL Checklist
Kemmlert (1995)

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, Forearm, 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?	Y	Y	Y	Y	Y
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/a				n/a
6: If work performed standing, is there no possibility to sit and rest?			Y	Y	Y
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?	Y				Y
d) severely twisted?	N				N

Table F-14. Pipe Welder #1 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?	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?	Y				
14: Is there a repetition of:					
a) similar work movements?	Y	Y			
b) similar work movements past comfortable reaching distance?	N	N			
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?	Y				
17: Is repeated work, with forearm and hand, performed with:					
a) twisting movements?		Y			
b) forceful movements?		N			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table F-14. Pipe Welder #1 PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, Upper Back	Elbows, Forearm, Hands	Feet	Knees and Hips	Low Back
SUM	9	5	2	2	4
PERCENTAGE	34.6	45.4	25	25	19.0
Section II: Environmental / Organizational Risk Factors (Modifying)					
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	Y				
Environmental / Organizational Risk Factors Score					
SUM	4				
PERCENTAGE	40.0				

Table F-15. Pipe Welder #2 PLIBEL

PLIBEL Checklist
Kemmlert (1995)

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?	N				N
6: If work performed standing, is there no possibility to sit and rest?			Y	Y	Y
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..			Y	Y	Y
b) repeated jumps, prolonged squatting or kneeling?			N	N	N
c) one leg being used more often in supporting the body?			Y	Y	Y
9: Is repeated or sustained work performed when the back is:					
a) mildly flexed forward?	N				N
b) severely flexed forward?	N				N
c) bent sideways or mildly twisted?	N				N
d) severely twisted?	N				N

Table F-15. Pipe Welder #2 PLIBEL (continued)

10: Is repeated/sustained work performed with neck:					
a) flexed forward?	N				
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	N				N
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	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?	Y				
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? Notice factors of importance as:					
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, performed with:					
a) twisting movements?		N			
b) forceful movements?		N			
c) uncomfortable hand positions?		Y			
d) switches or keyboards?		N			

Table F-15. Pipe Welder #2 PLIBEL (continued)

Musculoskeletal Risk Factors Scores					
	Neck, Shoulder, and Upper Back	Elbows, Forearms, and Hands	Feet	Knees and Hips	Low Back
SUM	9	5	4	4	8
PERCENTAGE	34.6	45.5	50.0	50.0	38.1
Section II: Environmental / Organizational Risk Factors (Modifying)					
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	N				
Environmental / Organizational Risk Factors Score					
SUM	5				
PERCENTAGE	50.0				