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Title: ***An Ergonomic Assessment of the Assembly Line Unloading Workstation Located in the Finishing Division of Company XYZ***

The accompanying research report is submitted to the **University of Wisconsin-Stout**, **Graduate School** in partial completion of the requirements for the

Graduate Degree/ Major: MS Risk Control

Research Adviser: Dr. Brian J. Finder

Submission Term/Year: Fall, 2012

Number of Pages: 87

Style Manual Used: American Psychological Association, 6th edition

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Ralston, Jeremy P. ***An Ergonomic Assessment of the Assembly Line Unloading Workstation Located in the Finishing Division of Company XYZ***

Abstract

The presence of certain ergonomic stressors were placing Company XYZ's Finishing Division employees that engaged in manual material handling at the assembly line unloading workstation at risk of developing musculoskeletal disorders (MSD's). Additionally, those MDS's may lead to higher worker compensation insurance premium costs, increased employee illnesses and injuries, and an elevated personnel attrition rate. The purpose of this study was to determine if the presence of ergonomic stressors were placing the employees at an increased risk of developing MSD's as well as recommend various engineering and administrative controls which may potentially reduce or eliminate adverse conditions. As evidenced by the results from the Ergonomic Task Analysis Worksheet, the Revised NIOSH Lifting Equation, and the Liberty Mutual Manual Materials Handling Guidelines, it appears that high forces, awkward postures, and repetitive movements were present at this workstation. The recommended solutions proposed by this paper included engineering and administrative controls. One of the engineering controls recommended included the redesign of the workstation so as to elevate the shipping pallet to reduce the amount of spinal flexion experienced by the workers. The principal administrative control recommended was the implementation of a comprehensive ergonomic policy which includes a worker training program and task analysis procedures.

Acknowledgments

First and foremost, I would like to express my overwhelming gratitude to my wife, Melanie, my son, Jordan, and my daughter, Madelyn. Without your unwavering support and encouragement to me throughout the countless hours of studying, paper writing, and late-night classes I would not have been able to complete this major milestone in my professional and personal life. I am sincerely thankful for having such a wonderful family and I guarantee this will pay off for our future. I love you!

Second, I would like to extend my appreciation to the University of Wisconsin – Stout for preparing me to complete this project. The accommodating course schedules and quality instructors were instrumental in guiding me through my graduate studies.

Third, I would like to send a special thank you to Tim Wyer, the health and safety manager at the company where this research was conducted. Without your cooperation and assistance this study would not have been possible.

Last, but certainly not least, I would like to recognize the support and guidance of my research adviser, Dr. Brian Finder. Dr. Finder's vast knowledge and expertise of the field of ergonomics, as well as his words of wisdom and encouragement, were vital in motivating me throughout this process and continuing with my education.

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Chapter I: Introduction

Ergonomics is described by Dempsey, Wogalter, & Hancock (2002) as designing the interface of humans and machines to enhance performance. The principal objective of an ergonomic program within a business or industrial setting is to prevent workers from developing musculoskeletal disorders (MSD's). Organizations may limit its employees' risk of developing MSD's by reducing exposure to ergonomic stressors. The primary stressors, which may potentially lead to MSD's, include high forces, awkward postures, and repetitive movements (National Institute for Occupational Safety and Health [NIOSH], 1997). According to the United States Bureau of Labor Statistics (BLS) (2011), MSD's accounted for at least 30% of all non-fatal injuries and illnesses in the United States in 2010. Additionally, in 2010, the occupation classification which includes freight, stock, and material movers incurred the highest rate of injuries and illnesses as well as the second highest number of MSD's in the United States. Based on the extent of human-based losses that may be a result from improper design of the workplace, it would appear MSD's are a serious concern for employers as it relates to designing tasks for its workers.

It is reasonable to conclude that a primary cause of MSD's is frequently traced back to manual material handling (MMH) and related tasks. By its very nature, MMH exposes the worker to several of the ergonomic stressors which lead to MSD's. MMH is simply moving objects without the aid of a power assisted device, including, but is not limited to pushing, pulling, grasping, holding, carrying, lifting and manipulating items in the course of a work-related task. An organization's ability to develop and implement an ergonomics program with the overall intent to limit employee exposures to MMH is an important objective to reduce work-place injuries and increase efficiency (NIOSH, 2007).

There appears to be conclusive evidence that organizations who fail to control workplace injuries should reasonably expect to experience an increase in loss-related expenses. One of the areas for an organization's bottom line to be negatively affected is in its worker compensation (WC) insurance premiums. According to the State of Wisconsin's Department of Workforce Development (WIDWD) (n.d.), the 2011 WC rate for metal goods manufacturing was $8.05 per $100 of payroll. This means for every $100 the company pays to its employees for wage and benefit-related expenditures, an additional $8.05 is paid to the applicable insurance company in WC premium. This metal goods-based WC rate is significantly above the $5.41 average rate for all of Wisconsin's manufacturing industries. In 2001, the WC rate for metal goods manufacturing was $5.12 per $100 of payroll, while the average general manufacturing rate was $4.35. When comparing the 2001 and the 2011 WC rates for metal goods manufacturing, it appears that this business sector's WC rates are increasing in a manner which is outpacing general manufacturing. Because the overall WC premiums are adjusted by applying a modifier which is based on that specific organization's reported injuries, it is important for companies to be in constant control of its human-related losses.

Company XYZ is a producer and retailer of manufactured metal goods and related accessories. This company's 300,000+ square foot manufacturing and distribution facility is located in the upper Midwest region of the United States and employs approximately 340 full-time and part-time workers. Employees within this facility are directly involved in every step of the manufacturing process. These duties include unloading raw material from the delivery truck, cutting and bending steel tubing and plates, welding, placement of decals and stickers, packaging, and loading the products for delivery. A significant amount of the material handling is performed without the aid of equipment and thus must be completed manually.

At the final stage of the manufacturing process, the finished product must be removed from an overhead assembly line and packaged for shipping. After emerging from the powder coating process, the product is manually removed from the assembly line by a single worker, carried to a pallet, and then stacked to prepare such for shipping. The weight of each product ranges from 20 to 80 pounds, depending on the design specifications of the product being manufactured. Workers at the assembly line unloading workstation are typically engaged in this task for an eight hour period, do not perform alternate activities during the shift, and work at a rate of approximately six to seven pieces per minute. The substantial weight of the product, combined with exposure to repetitive motions and awkward postures are identified as the ergonomic stressors which are present at this workstation. While there are limited reports of injuries or MSD's from employees at the assembly line unloading workstation, a high turnover in staffing strongly suggests the presence of ergonomic stressors. Additionally, the rate of which the pieces are returned to the powder coating process due to chipped or scratched paint suggests a deficiency in the manual handling procedure of those products. Therefore, the current assembly line unloading workstation design in Company XYZ's Finishing Division is likely to be placing employees who perform manual material handling at risk of developing musculoskeletal disorders as well as exposing the company to higher worker compensation costs.

Purpose of the Study

The purpose of this study was to analyze the current design of the assembly line unloading workstation to determine the extent of ergonomic deficiencies and related effects in the Finishing Division of Company XYZ.

Goals of the Study

The goal of this study was to determine if conditions at the assembly line unloading workstation may lead to musculoskeletal disorders in Company XYZ's employees. This was accomplished by:

- Analyzing the assembly line unloading workstation by utilizing various ergonomic assessment tools.
- Reviewing the company's illness and injury records to determine the extent of reported musculoskeletal disorders.
- Reviewing the company's worker compensation and personnel records to determine insurance premium rates, medical payments, and employee turnover.

Assumptions of the Study

For the purposes of this study it was assumed that:

- Company XYZ collected and maintained accurate data regarding incidences of workplace illnesses and injuries, worker compensation records, and personnel attrition rates.
- Employees performed work-related tasks in a similar manner as when not being observed.

Background and Significance

An ergonomic analysis of the assembly line unloading workstation in the Finishing Division of Company XYZ was conducted as part of the company's new focus on reducing costs associated with work-related injuries and illnesses. This study possesses the potential to identify certain hazardous conditions which may contribute to workers developing MSD's. The presence of MSD's in workers could lead to reduced revenue for the company due to increased worker compensation claims, higher insurance premiums, reduced product quality, and increased rework. Additionally, an ergonomically-correct workstation may possess significant potential to increase worker efficiency and job satisfaction, which could reduce employee turnover due to the stressors which are likely to be occurring with the current task design.

Definition of Terms

Abduction. A movement of an extremity away from the body. (*Mosby's Dictionary of Complementary and Alternative Medicine*, 2005).

Adduction. A movement of an extremity toward the body. (*Mosby's Dictionary of Complementary and Alternative Medicine*, 2005).

Extension. A movement of a body part which increases the angle of a joint. (*Mosby's Dictionary of Complementary and Alternative Medicine,* 2005).

Flexion. A movement of a body part which decreases the angle of a joint. (*Mosby's Dictionary of Complementary and Alternative Medicine,* 2005).

Incident rate. A rate calculated using a formula to track the occurrence of illnesses and injuries. The formula is expressed as: total number of injuries and illnesses in one year, multiplied by 200,000, then divided by total number of hours worked by all employees in one year (OSHA, 2004a).

Musculoskeletal Disorders (MSD's). "Disease or syndrome attributed to abnormal formation of bones, muscles, ligaments, tendons, and/or other connective tissue" (*Cambridge Dictionary of Human Biology and Evolution,* 2005, para. 1).

Occupational Safety and Health Administration (OSHA) recordable. A workplace illness or injury that causes a worker's death, a loss of consciousness, time away from work, restricted/light duty, job transfer, and/or medical treatment beyond first aid (OSHA, 2004a).

Chapter II: Literature Review

The purpose of this study was to analyze conditions at the assembly line unloading workstation in Company XYZ's Finishing Division to determine if such posed an ergonomic risk to associated employees. The presence of manual material handling tasks, as well as other ergonomic stressors, is likely placing those employees at risk of developing MSD's. This chapter will review several major categories of MSD's, including the corresponding risk factors, as well as the direct and indirect impacts that such ailments may inflict on employees and organizations. Additionally, this chapter will discuss the definition, history, and objectives of modern-day ergonomic programs as well as highlight several effective systems currently in place at leading organizations. Finally, this chapter will review several ergonomic assessment tools and instrumentation devices which are available to analyze various tasks and thus determine the presence of certain conditions which may lead to MSD's, as well as discuss several specific methods organizations may employ to assist in limiting its employee's exposure to identified hazards.

Musculoskeletal Disorders

There appears to be sufficient evidence to conclude that the prevalence of work-related MSD's constitutes a significant percentage of all employee illnesses and injuries. As concluded by multiple studies, work-related MSD's are a common occurrence among employees in industrialized countries (Deeney& O'Sullivan, 2009; Nordander et al., 2009; Wang et al., 2009). Nordander et al. (2009) identified and described the symptoms of multiple MSD's, which are the most commonly reported injuries and illnesses among workers who are engaged in repetitive or constrained activities within industrialized nations. The symptoms experienced by workers who suffer from MSD's may vary greatly in severity, frequency, and location, however, there are several common characteristics which employers and employees should be aware. Workers suffering from MSD's may experience symptoms which include localized pain, stiffness and/or inflammation of the tissue surrounding a joint, and tenderness of the tendon at the point where it attaches to the skeleton. Several common forms of MSD's and associated symptoms, as identified by Nordander et al. (2009), include the following:

- Tension neck syndrome – discomfort, stiffness, and/or fatigue in the cervical region of the spine, including pain radiating to the rear of the skull.
- Cervical syndrome – pain radiating from the cervical area of the spine to the upper extremities which may be aggravated by movement; diminished feeling in the fingers and hands; reduced muscle strength throughout the upper extremities.
- Thoracic outlet syndrome – radiating pain or paresthesia (numbness, tingling, and/or prickling sensation) in the upper extremities throughout the ulnar nerve; extreme tenderness in the brachial plexus nerve bundle.
- Frozen shoulder – shoulder pain with increasing stiffness in the joint during a three to four month time span; reduced ability for shoulder abduction.
- Acromioclavicular syndrome – palpable tenderness of the tissue surrounding the shoulder joint; pain aggravated by shoulder adduction and outward rotation (with 90 degree abduction and flexed elbow).
- Carpal tunnel syndrome – numbness of the hand; paresthesia throughout the median nerve; decreased in hand grip strength.
- Ulnar nerve entrapment at the elbow and/or wrist – pain and paresthesia throughout the ulnar nerve over the cubital tunnel (elbow) and/or Guyon's tunnel (wrist); reduced ability to spread the fingers.

The term MSD's may be a generic phrase used in lieu of officially accepted medical conditions, however, it should be recognized as a serious and potentially costly problem confronting employers and employees.

Risk factors. The research indicates a majority of MSD's are attributed to three distinct risk factors, or ergonomic stressors. While each risk factor may be independently a source for developing a MSD's, the presence of multiple stressors potentially will enhance the likelihood of workers who experience ergonomic-related illnesses or injuries even further. NIOSH (1997), through the comprehensive review of several hundred scientific studies, recognized high forces, awkward postures, and repetitive movements as the primary hazardous conditions which may lead to workers developing MSD's. This study became the foundation for many ergonomic-related recommendations and is a source utilized by researchers to define the risks associated with adverse working conditions which potentially cause workers to develop MSD's.

Each of the major risk factors, for which the evidence identifies as presenting a high correlation of workers who engage in these activities to develop MSD's, are defined by the NIOSH (1997) study. High forces, while difficult to quantify due to the varying capabilities of each worker and the specific portion of the body utilized to complete the required work-related task, may be described as forceful or strenuous exertion. An awkward posture also depends on the particular body part engaged in the task. However, any activity that places the body in such a manner which is a moderate or extreme deviation from its neutral position is considered to be an awkward posture. Repetitive motions engage a part of the body in a frequent or cyclical motion, typically with a brief amount of time between cycles. The three previously discussed ergonomic risk factors are not an exhaustive list and there are other additional conditions, such as vibration exposure, extreme temperatures, as well as the worker's personal physical abilities, which could contribute to the prevalence of MSD's (NIOSH, 1997).

Even with the apparent ambiguity of medical testing and worker self-descriptions of physical symptoms, such methods continue to be the most reliable manner of describing the risks linked to developing MSD's. However, there are other less tangible manifestations of MSD-related symptoms which are reported by employees. According to Deeney & O'Sullivan (2009) and NIOSH (1997) psychosocial risk factors could manifest as physical symptoms of MSD's. The studies suggest that the perceived stress an employee experiences due to an imbalance between his or her personal abilities and the task requirements, the lack of job satisfaction, and the individual worker's personality characteristics may exacerbate MSD-related symptoms that are already present. Additionally, these psychosocial risk factors may be manifested as symptoms of MSD's, even when no ergonomic stressors were apparent. NIOSH (1997) identifies four plausible explanations for psychosocial factors which cause workers to experience MSD-related symptoms. First, and possibly the most reasonable, workers who are under a great deal of stress may experience an increased amount of tension which could potentially translate into muscle fatigue and therefore be expressed as a MSD symptom. Second, workers who previously acquired skills or knowledge, through ergonomic-based training or education, would be cognizant of MSD-related symptoms and therefore possess an increased likelihood to report a problem. Third, an initial physical injury with genuine pain may elicit a dysfunctional psychological response which causes the worker to continually experience chronic discomfort, even though the injury physically healed. Finally, changes in the actual work environment may cause simultaneous MSD-related symptoms and psychosocial stress due to physical and psychological demands of the new task. Psychosocial risk factors add another layer of complexity for employers to be aware of when attempting to design an ergonomic-based program that limits employee's exposure to conditions which are most likely to cause MSD's.

Costs of MSD's. An examination of the related literature reveals that the cost of MSD-related illnesses and injuries to business and industry is staggering. In the United States, from 2004 through 2010, MSD's accounted for approximately 30 percent of all reported, non-fatal injuries annually (BLS, 2011). The expense of MSD-related illnesses and injuries add up to a significant amount of money in direct medical costs and higher worker compensation (WC) premiums, as well as potentially leading to indirect losses such as employee absenteeism, worker turnover, and reduced productivity. The United States Bone and Joint Initiative (USBJI) (2011) estimated that in 2006, the costs to business and industry for direct MSD-related expenses such as medical care and WC payments were approximately $576 billion and the indirect costs associated with employee absenteeism, worker turnover, and reduced productivity were nearly $373 billion. This equates to over $949 billion dollars spent annually in the United States due to MSD-related illness and injuries.

A closer review of the data provided by the BLS (2011) of all non-fatal incidents finds the job classification, which includes material movers, experienced a consistently higher number of injuries and illnesses. The overall number of non-fatal injuries and illnesses in 2007 reached a staggering 80,000 individual cases in private industry. By 2010, the number of illnesses and injuries for the identical job classification dropped to slightly over 65,000 individual cases in private industry. While this indicates an overall reduction of work-related illness and injuries within the United States, it is still significantly higher than the next job classification, which includes nursing aides and orderlies, at slightly above 53,000 individual cases (BLS, 2011). Further analysis of the 2010 numbers reveals that the job classification which includes material movers is identified as experiencing the second highest number of reported MSD-related illnesses and injuries at approximately 23,400 cases. This is second only to nursing aids, orderlies and attendants which experienced approximately 27,000 reported MSD-related illness and injury cases during the same period. Within all job classifications, whether such were located in government and/or private industry, repetitive motion illnesses and injuries are reported as incurring the highest number of days away from work, at 24 days per incident (BLS, 2011). While the figures suggest that repetitive motion and MSD-related illnesses and injuries present a significant concern for all workers, regardless of job classification and occupational sector, this information is based solely on the data collected and does not include the number of unreported cases of human-based losses.

In addition to direct medical costs and the human-based losses related to MSD's, WC insurance is another expense incurred by organizations. WC insurance is mandated by state and federal statutes for all private business as well as local, state and federal governmental agencies. The State of Wisconsin Office of the Commissioner of Insurance (WIOCI) is the governmental agency charged with the oversight of the WC insurance program. According to the WIOCI (2012), WC insurance is the responsibility of employers and it is intended to provide financial assistance and medical services to employees who are injured while performing work-related duties. WC, in place since 1911, is meant to serve as the sole remedy for workers against the employer for injuries sustained while on the job. With few exceptions all organizations, private and public, are required to purchase WC insurance or self-insure to satisfy the legal requirements established by the state and federal laws (WIOCI, 2012). If an organization fails to obtain WC insurance, and are statutorily required to carry the coverage, it may be fined at least the cost of the premiums owed during the uninsured period. In addition to the fines levied, a company may be required to reimburse the WC program for all benefits paid out in the course of covering an injured employee (WIOCI, 2012). Therefore, regardless of the organization's philosophy towards establishing and maintaining a health and safety program, there is a minimum amount of coverage that is mandatory for employers to ensure the welfare of its workers.

WC insurance is structured in such a manner which may be a motivator for employers to be cognizant of and be proficient with controlling its work-related illnesses and injuries. The WC insurance premium rate for an organization is partially based on its industry classification, which is ultimately determined by the perceived risk associated with that type of business. Additionally, the State of Wisconsin's WC insurance program allows for organizations who maintain a lower-than-industry average of work-related illnesses and injuries an opportunity to experience a discount on its premiums through the experience rating plan (ERP) (WIOCI, 2012). An ERP uses the actual loss-based information from that specific organization to be applied to the WC rate as a modifier with the potential to decrease the company's insurance premium. Conversely, if the organization reports a higher-than-industry average of work-related illnesses and injuries, it potentially will be required to pay a significantly increased amount in WC insurance premiums (WIOCI, 2012). It would appear that an organization possesses the ability to decrease the financial burden of WC insurance premiums by recognizing and controlling work-related illnesses and injuries.

Direct financial costs in the form of medical payments and higher WC insurance premiums are not the only expenses related to work-related MSD's. High employee turnover is a realistic expectation for organizations whose employees experience any of the ergonomic stressors previously mentioned. Regardless if personnel leave the workforce due directly to an injury or illness or if an employee resigns due to adverse working conditions, the expense associated with replacing that worker is comparable. According to the study conducted by O'Connell and Mei-Chuan (2007), in which the BLS was cited, the average direct cost to replace a manufacturing employee is slightly under $14,000. This figure does not account for the indirect costs associated with losing a worker due to lower morale, which may result in an increased burden on existing employees and the lost experience could potentially cause process inefficiency. The frequency of employee turnover is potentially an indicator for organization to be conscious of when tasks are analyzed to determine if workers are exposed to various ergonomic stressors.

History of Modern Ergonomics

Ergonomics is a term that may be defined differently by the general public as well as professionals within the health and safety field. The word "ergonomics" is a combination of the ancient Greek words *ergos* (meaning work) and *nomos* (meaning natural law) and based on one straightforward definition that is recognized for the purposes of this paper, it may be described simply as designing the interface of humans and machines to enhance performance (Dempsey, Wogalter, & Hancock, 2002). Christensen (1976) asserts there appears to be archeological evidence that pre-historic humans fashioned and used tools, such as stone blades and deer antlers, which were modified specifically so as to be easily wielded by hand or would enable the worker to efficiently complete a task. While ergonomics was present throughout human history, modern ergonomics did not emerge until the early and mid-twentieth century with the establishment of several professional ergonomic organizations and societies (Christensen, 1976; Galley, n.d.; Stanton & Stammers, 2008).

Throughout human history, the field of ergonomics evolved and was applied to workplace conditions utilizing methods which were dependent on the technological proficiency and needs of the organization. Christensen (1976) indicates that prior to the 1930's, the general focus of employers was on selecting employees to fit the task, however by the end of World War II, the United States government officially recognized the value in designing the task to accommodate the worker. In the 1940's and 1950's, the world witnessed a significant focus on ergonomics from both government and private industry. The United States Department of Defense established research facilities across many of its branches which were specializing in the development of ergonomic-based solutions. The International Ergonomics Association, a professional organization comprised of many individual federated and associated societies, was established in 1958 and focused on the physical welfare, productivity, and the psychological demands on workers (Galley, n.d.). As technology advances and with it the understanding of certain capabilities and limitations of the human body, the utilization of ergonomic solutions may play a vital role in an organization's ability to solve the problem of human-based losses.

Ergonomic Program Objectives

It would appear reasonable to assert that each business must realize its own specific objectives and reasons to establish and maintain an effective ergonomics program. However, regardless of specific goals and objectives, the main focus will predominantly be to reduce human-based losses and associated costs to the organization. The reduction of human-based losses may be accomplished by two approaches. First, by reducing direct and indirect costs associated with MSD's, such as medical payments and reduced production respectively. The second approach is to increase process efficiency by improving the interface between the worker and the task environment. A successful ergonomic program is one that is able to accomplish MSD-related illness and injury reduction while increasing worker efficiency.

An apparent leader in the employee health and safety field is 3M, which established an ergonomics program over 30 years ago and quickly recognized the benefits (3M, n.d.; Larson & Wick, 2012). 3M is a global technology-based company with at least 84,000 employees and over $30 billion in annual sales (3M, 2011). The 3M ergonomic program objectives are to improve the process efficiency, performance, health, and job satisfactions of employees while limiting the company's exposure to increased costs of work-related illnesses and injuries (3M, n.d.). In 1990, 3M compiled all relevant loss data and discovered that MSD's accounted for 39 percent of OSHA recordables, and 63 percent of all instances when workers were unable to immediately return to their duties after an injury or illness. After establishing and maintaining a quality ergonomics program, 3M noticed a steady decrease in the frequency and severity of reported MSD-related illnesses and injuries in 120 worksites across the world. Within a five year span from 2003 through 2008, 3M's domestically-based facilities experienced a reduction in the occurrence of ergonomic-related injuries and illnesses after implementation of this program. The study found the incident rate (frequency) decreased from approximately 1.8 to 1.2 and the days away (severity) decreased significantly from over 80 to slightly above 20 days away per injury or illness event (3M, n.d.). 3M anticipates consistent results in the reducing MSD-related injuries and illnesses as evidenced by its philosophy of continuous improvement. Based on the continuance of such a program, it is reasonable to assume that 3M values its ergonomic-based approach to decrease occurrences of MSD's within its organization.

Another leader in the employee health and safety field is Dow Chemical. According to its website, Dow (2011) is a worldwide organization with over 52,000 employees in 36 countries, and annual sales revenue exceeding $60 billion from its 5,000 products in the fields of agriculture, plastics, chemical, electronics, and advanced materials. In 1994, Dow embarked on a 10-year mission to reduce its reportable illness and injury rates by 90 percent. In order to assess the performance of this approach, OSHA commissioned a study of Dow's Six Sigma-based ergonomic program (OSHA, 2004b). Dow applied this system to its Dow Design and Construction (DDC) business unit in 2000. By using the Six Sigma-based approach to ergonomic risk reduction, results were immediately realized and the overall hazards were reduced by 63 percent within DDC. During the final two years of the 10-year mission, the number of ergonomic-based injuries, which required lost time or days away from work, dropped from 53 percent in 2001 to 30 percent in 2003. Dow invested significantly in the Six Sigma-based employee health and safety program for the DDC and by all indications, will continue to utilize this proven approach and expand such throughout the entire company.

Each organization will use a different human-based loss reduction approach depending on its specific set of circumstances. For example, an ergonomics program will differ greatly between an office setting with numerous computer workstations and a manufacturing facility which is engaged in manual material handling. The office ergonomic program may be simply limited to a workstation design system or basic ergonomic training for personnel which will promote efficient interface between the employee and the computer (Mahmud, Kenny, Zein, & Hassan, 2011). However, it would be reasonable for a manufacturing facility to establish a comprehensive ergonomics program which may include approaches to process redesign, utilizing power-assisted lifting devices, and/or instituting a physical training routine in an effort to reduce work-related MSD's (Hess & Hecker, 2003; Mallon, 2012; Nussbaum & Chaffin, 1999). Regardless of the specific ergonomic risk factors which are present within an organization, implementing and maintaining a quality system may reduce the employee's likelihood of developing MSD's.

In order for a company to initiate and continue an effective and ultimately advanced ergonomic program, several necessary traits must be present within the organization. The successes experienced by 3M may be attributed to the evolution of a microergonomic system, which focuses on solving individual problems, to a macroergonomics program that involves a strategic integration of ergonomics into other business objectives (Larson & Wick, 2012). Mallon (2012) proposes an organization in the early stages of developing an ergonomic program, described as the reactive phase, will be primarily concerned with ending the condition that caused the illness or injury and treating the worker's medical needs. The next evolution of the ergonomic program is the preventative phase, identified as the organization's attempt to fit the worker with the job or alter the employee's behavior in order to minimize MSD's. The proactive phase is one that organizations are involved in studying the risks of a task and attempt to modify the conditions in order to reduce the ergonomic stressors. Finally, Mallon (2012) recognizes several minimum requirements of an advanced ergonomic program which includes maintaining accurate records, utilizing a task assessment tool, implementing engineering controls based on workers' capabilities, establishing administrative rules to direct employee behavior, and, eventually as an ultimate goal, utilizing ergonomics-based information when designing the individual equipment, entire processes, or even in the planning a facility's layout. While it may not be practical for all organizations to immediately establish an ergonomics program at an advanced level, it is certainly feasible to initiate a system and strive to continually improve on the process.

Ergonomic Assessment Tools

There are a wide variety of qualitative, quantitative, and hybrid assessment tools available to assess an organization's ergonomic needs. Qualitative tools such as screening checklists and employee surveys are a subjective method of compiling preliminary information on potential ergonomic risks. Quantitative tools, similar to the NIOSH Revised Lifting Equation, utilize actual measurements to determine ergonomic risks and are reasonably objective in data analysis (NIOSH, 1994). Hybrid (qualitative and quantitative) assessment tools, equivalent to The Liberty Mutual Manual Materials Handling Guidelines and the Ergonomics Task Analysis Worksheet, use a combination of objective and subjective data gathering techniques to determine ergonomic risks. According to Village, Backman, & Lacaille, (2008) an organization should evaluate several criteria when determining which ergonomic assessment tool fits its needs, including the nature of the task being analyzed, proficiency of the evaluator, and capabilities of its workers.

The NIOSH Revised Lifting Equation is a formula which is based on a meta-analysis completed to further refine the current guidelines (NIOSH, 1994). This assessment method is designed to be applied to tasks with the intent on determining the maximum recommended weight an employee should be required to lift during the completion of a particular activity. The quantity is expressed as the recommended weight limit (RWL) which is factored by the equation RWL = LC x HM x VM x DM x AM x FM x CM. Additionally, the assessment tool will assist in determining the amount of stress the worker experiences while performing the task. This stress is expressed as the lifting index (LI) and it represents the ratio of the actual weight lifted (L) during the task and the RWL which is factored by completing the following equation LI = L / RWL. Research performed by Waters, Lu, Piacitelli, Werren, and Deddens (2011) indicated lifting-related tasks with a LI above 1.0 places workers engaged in such activities at an increased risk of developing a MSD-related illness or injury.

NIOSH (1994) established certain procedures for completing the lifting equation and that the data collection phase of the assessment must be conducted in a manner to ensure accurate measurements. Initially, the evaluator will establish if the activity is a single or multi-task lift. The multi-task version of the equation is utilized when a portion of the lifting activity varies significantly from other steps in the process. For the purposes of this study, only the single-task version of the equation will be reviewed for analyzing lifting-related activities. A review of the procedures for the single-task assessment version of the equation clarifies that a lifting activity is separated into two stages. Each phase is analyzed individually, obtaining two RWL and LI values for the single activity. The first phase of the analysis is conducted when the object is initially lifted and the equation is again applied to the second stage of the task when the item is placed upon the destination surface.

Initially, NIOSH (1994) instructs that the individual components of the equation must be defined. As previously stated, L represents the weight of the actual object lifted during the task. The load constant (LC) remains unchanged regardless of the task and is always expressed as a value of 51. H denotes the horizontal distance measurement of the hands in relation to the center point between the worker's ankles at the initial phase of the lift as well as at the end phase of the activity. The horizontal multiplier (HM) value is calculated by the following equation $HM = 10 / H$. V represents the vertical measurement of the hands in relation to the surface from which the object is lifted at the initial phase of the lift. The vertical multiplier (VM) is the product of the equation $VM = 1 – (.0075 |V - 30|)$. D represents a measurement value of vertical distance traveled by the object during the lift. The distance multiplier (DM) is calculated by the formula $DM = .82 + (1.8 / D)$. A represents the asymmetric angle measurement of spinal twisting the worker's body experiences during the lifting activity. The asymmetric multiplier (AM) is calculated by the formula AM = 1 – (.0032A). F represents the frequency of lifts per minute involved in the task. The frequency multiplier (FM) is a product of the frequency of the lifts, duration of the activity, and the V value which is determined by applying such to the NIOSH-supplied table. The coupling modifier (CM) is calculated by evaluating the hands' grip to the lifted object which is expressed as good, fair, or poor (definitions provided by NIOSH) and applying the results to the V value through a NIOSH-provided chart. Once all values of the components are ascertained, the equation is calculated by multiplying the numbers with each other in order to define the RWL. The RWL will then be applied to the formula to obtain the LI. Finally, the results will be interpreted and applied to the NIOSH-recommended standards to determine the level of risk an employee is exposed to while engaged in the lifting task.

In order to be as accurate as possible, the NIOSH Revised Lifting Equation assumes several optimal working conditions. The assumptions include lifting with two hands, task performance for eight hours or less, no seated or kneeling activities, not working in a restricted space, the lifted object is stable, there is no pushing, pulling or carrying involved in the task, no high speed (faster than 30 inches per second) lifting, and the work environment is between 66 and 79 degrees Fahrenheit (NIOSH, 1994). The NIOSH Revised Lifting Equation is a relatively complex tool and requires an experienced employee to ensure accurate results. Even with its limitations, the NIOSH Revised Lifting Equation may be a beneficial tool to an organization with regard to establishing certain guidelines for lifting-related tasks.

Another tool useful in analyzing tasks for adverse conditions which may lead to MSD's is The Liberty Mutual Manual Materials Handling Guidelines. This tool was developed by the Liberty Mutual Research Institute for Safety (LMRIS), which is commonly referred to as the Snook Tables after co-developer Stover Snook, to provide a guideline when determining the employee's ability to push, pull, lift, lower, and carry objects (LMRIS, 2004). The tables, which are separated by gender, help determine what percent of the population will likely be able to perform the activity being analyzed with the objective to assist in designing a task to accommodate the widest range of employees possible. According to the research Snook conducted and cited for development of these guidelines, up to two-thirds of low back injuries may be prevented by designing a workstation in order to provide that at least 75 percent of the female population completing the task falls within these recommendations (LMRIS, 2004). The Snook Tables are relatively simple to use, but a small amount of ergonomic training or experience is beneficial to effectively utilize this assessment tool.

There are a myriad of quick-analysis worksheets available for analyzing a task for ergonomic stressors, however several are more thorough and therefore provide a greater amount of assessment-orientated information. The Ergonomics Task Analysis Worksheet (ETAW) (see Appendix A) was developed by the Great American Insurance Company (GAIC) to assist organizations to identify and evaluate tasks for conditions which cause MSD's. The worksheet provides several sections, which correspond with the NIOSH-recognized risk factors that lead to MSD's and categorizes the conditions as ideal, warning level, and take action. The evaluator conducting the analysis is instructed to observe the task being performed (obtaining a video record for later playback and reference is recommended) and compare the conditions present to the provided descriptions. Once the task is analyzed, an action plan is recommended to be established for all conditions falling into the take action category. Additionally, the ETAW provides a section to record the type of control implemented and the cost associated with those solutions. The ETAW's comprehensive sections that identifies many of the ergonomic stressors which may lead workers to develop MSD-related illness and injuries, coupled with the simplicity of its operation, provides for a versatile and effective ergonomic assessment tool.

Utilizing various ergonomic assessment tools is only a partial step in analyzing a task for ergonomic stressors. Charlton & O'Brien (2002) recommend that in order to collect quantifiable information, employing certain instrumentation such as thermometers to measure temperature, goniometers to determine the angle of joints, and a tape measure to obtain linear dimensions is necessary. The goniometer is an effective device utilized to measure joint angles which are created during various motions of the human body (Kolber & Hanney, 2012). Additionally, Kociolek and Keir (2010) concluded that utilizing a digital video recording device to create still and motion pictures for review and playback during the task assessment phase is an efficient method to analyze conditions for ergonomic stressors. It is reasonable to conclude that when coupled with assessment tools, certain instrumentation is a valuable addition to the ergonomic task analysis process.

Ergonomic Illness/Injury Prevention Approaches

As previously stated, there appears to be sufficient evidence which proposes that an organization's ability to implement and manage an effective ergonomics program may reduce the prevalence of MSD's in the workplace and consequently, limit its exposure to increased expenses related to such. While there are numerous potential exposure hazards, types of MSD's, and assessment methods, many different approaches and methods are available to control the risks and reduce the potential for MSD-related illnesses and injuries. Engineering controls are such that alter the environment in a manner to reduce the worker's exposure to hazards, while administrative-based solutions attempt to alter employees' behavior to comply with established standards. Each organization may determine a course of action and develop a program specific to the needs and requirements based on its individual characteristics (Kennedy et al., 2010; Mallon, 2012). Discussed below are several ergonomic programs and approaches which, as the evidence indicates, are effective in reducing the hazards associated with MSD development.

With an overwhelming number of ergonomic programs and approaches which are available today, it is understandable that an organization may be unsure which ergonomic control methods are effective. A comprehensive study conducted by Kennedy et al. (2010) systematically reviewed over 15,000 articles and academic papers based on ergonomic prevention programs. During the course of the review, Kennedy et al, (2010) excluded all but 36 studies due to relevance and quality of the methodology used during the research. The remaining articles were analyzed for evidence where MSD prevention approaches were the most effective. The conclusions reached in this study indicated that workstation design (engineering controls) coupled with ergonomic training for workers (administrative solutions) were the most effective in producing a positive change in symptoms of MSD's (Kennedy et al., 2010). This study proposes that an ergonomically correct workstation, combined with providing the knowledge of safe and efficient work habits to employees, will provide the greatest results to reduce MSD-related symptoms.

There are a multitude of approaches utilized to control ergonomic stressors which may be present at a workstation. However, there are several methods commonly used when the presence of MMH handling is potentially exposing an organization's workers to MSD's. A particular engineering control, which may limit employees' exposure to MMH tasks, is the implementation of mechanical devices designed to assist the worker in lifting-related activities. However, evidence suggests that these devices possess unique characteristics which could potentially expose the employee to additional ergonomic stressors. The utilization of a power-assisted device to reduce the weight stress which is placed upon the worker may negatively impact the productivity of the workstation due to the extra time required to manipulate the controls. To negate the potential for reduced productivity, an automated system may be implemented to control the pacing of the task. The conditions present in an automated pacing system coupled with a power-assisted device, according to Nussbaum & Chaffin (1999), may expose the worker to ergonomic stressors associated with MSD's. The study conducted by Nussbaum & Chaffin (1999) concluded that an automated pacing system where workers utilize a material handling manipulator may pose similar adverse conditions as when no mechanical device is present. While the level of weight stress is reduced on the individual worker, the effect of an automated process places an increased amount of forces on the hands used to manipulate the device, as well as lateral and sheer forces on the spine in order for the employee to maintain the predetermined production pace. When the automated pacing system is replaced with a self-paced process, the evidence indicates a reduction in the MSD-related stressors (Nussbaum & Chaffin, 1999). If an organization's ergonomic program includes implementing power-assisted devices in its manual material handling tasks, it must resist the temptation to increase efficiency by establishing a pacing standard which may expose the worker to additional hazardous conditions.

A significant administrative solution which is associated with a successful ergonomics program is the inclusion of employees. Larsson & Nordholm (2008) assert employees view themselves as the primary individual responsible for MSD's and generally do not hold employers accountable. This attitude should be capitalized on by employers to foster engagement of the employee to participate in an ergonomic program. The evidence displays an organization that includes employees in the development and continued operation of an ergonomic program will improve the communication between management and staff, as well as provide for an effective approach to minimize the prevalence of MSD's (Boynton & Darragh, 2008; Laing et al., 2007; Wells, 2009). Employees could be considered one of the most valuable resources a company possesses to produce its products and services and such workers should be called upon to assist the organization in establishing programs with the intent of preventing MSD-related illness and injuries due to adverse working conditions.

By combining employee involvement and ergonomic training with the goal to reduce the prevalence and severity of MSD in the workplace, establishing a pre-shift stretching routine for personnel engaged in MMH is a reasonable administrative solution. The research conducted by Hess and Hecker (2003) asserts that a pre-shift stretching routine, consisting of specific criteria, may reduce the MSD-related symptoms experienced by employees. The research suggests that employing a stretching program which targets the specific area of the body exposed to ergonomic stressors as part of the work-related task is the most effective. Additionally, a preliminary warm-up routine consisting of aerobic activity, such as walking in place, prior to the stretching routine may be beneficial (Hess & Hecker, 2003). Not all types of stretching are recommended and only certain methods are suggested. For example, the ballistic technique, where the muscle is bounced while stretched, is not recommended and may cause injury. The preferred technique is the static stretching method and is safe and effective as well as simple to learn and perform. The pre-shift stretching routine is optimized when performed at least two or three days per week and coordinated by trained professionals. Each stretch, that targets the muscle group which is at the greatest risk of injury, should be held for 15 to 30 seconds and repeated three to four times (Hess & Hecker, 2003). A pre-shift stretching routine, which requires an up-front investment in time and resources, may benefit the organization in reduced occurrence and severity of work-related MSD's for employees who engage in MMH tasks.

Summary

There is sufficient evidence to indicate that quality ergonomic programs are an important part of an organization's attempt to limit its exposure to human-based losses due to the presence of MSD's within its workforce. With the increasing costs of healthcare and the pressure for an organization to continuously streamline its operating expenses, an effective ergonomics program may potentially be a vital method of reducing costs and increasing worker efficiency. Even the humanitarian point of view deserves consideration in developing an ergonomics program. In the increasingly competitive business world, the approach in which an organization sets itself apart from others by recognizing the importance of employee's health may lead to the attraction of higher quality personnel.

Hazardous conditions such as high forces, awkward postures, lengthy exposure time, and repetitive movements may lead to workers to develop MSD's. While there are a multitude of ergonomic assessment tools available, this paper highlighted the NIOSH Revised Lifting Equation, Snook Tables, and the ETAW as the methods that are effective and relatively easy to use. If these assessment tools are properly utilized in conjunction with accurate instrumentation and the high risk tasks identified, the controls implemented may reduce the occurrence of MSD's as well as potentially increase the efficiency of the workstation. When MSD's are reduced and the workstation efficiency is increased, it is reasonable to conclude the organization's loss-based expenses will decrease and its worker's efficiency will be enhanced.

Chapter III: Methodology

The purpose of this study was to analyze conditions at the assembly line unloading workstation in Company XYZ's Finishing Division to determine if such posed an ergonomic risk to associated employees. In order to collect a reasonably sufficient quantity of information, with the goal of determining the level of risk in relation to ergonomic stressors present at this workstation, several data collection methods and assessment tools were employed. This chapter will review the subject selection process, the instrumentation utilized for data collection, which assessment tools were employed, as well as outline the methods developed for administration of this analysis. Additionally, this chapter will discuss the limitations of this study.

Subject Selection and Description

The sample population of this study is limited to individuals tasked with removing a manufactured metal product from an overhead conveyor line and stacking such on a shipping pallet. The assembly line unloading workstation is divided into two substations which are staffed by one employee each and are supplied finished product from a single overhead conveyor line. For the purposes of this study, Substation A was designated as the first location to receive manufactured metal products from the overhead conveyor. Substation B was the second location to receive manufactured metal products from the overhead conveyor. The employees in the Finishing Division of Company XYZ alternate among several locations, including the assembly line unloading workstation. Workstation designations are typically assigned at the beginning of each shift based on the seniority of the workers. Due to the limited production capacity of this facility, only two workers were engaged in this activity during the data collection phase of this analysis. The worker located at Substation A was a 33 year-old male, approximately 160 pounds and five feet, ten inches tall. Substation B's worker was a 36 year-old male, approximately 210 pounds and five feet, 11 inches tall.

Instrumentation

In the initial stages of the ergonomic analysis of the assembly line unloading workstation, digital video, still photographic images, temperature readings, object mass, as well as linear and angular measurements were obtained by utilizing the following instrumentation:

- Digital camera and video recorder – devices used to capture still and moving images.
- Tape measure – a tool which measures linear distances.
- Infrared thermometer – a device which measures the level of thermal radiation produced by an object.
- Manual goniometer – a protractor-type tool which is used to determine the angle of the body's joints.
- Single axial force gauge – a device which measures the amount of force required to move or lift an object.

Ergonomic Assessment Tools

The second phase of data collection for this study involved the utilization of three ergonomic assessment tools to ascertain if the workstation contained adverse conditions which may potentially cause workers to develop MSD's. The ergonomic assessment tools utilized for this study were the Ergonomic Task Analysis Worksheet, the NIOSH Revised Lifting Equation, and the Snook Tables. The ETAW was utilized as a preliminary analysis to determine if adverse conditions were present within the assembly line unloading workstation and highlight those areas which may pose the highest risk associated with employees developing MSD's. Subsequently, the NIOSH Revised Lifting Equation was administered to determine the extent of risk associated with the task and established the recommended weight that the workers should be allowed to lift during the completion of this activity. Finally, the Snook Tables were utilized to highlight the adverse conditions present at the workstation by identifying the limited percentage of the human population that could safely complete the task. Additionally, the Snook Tables were utilized to establish a guideline for recommendations when redesigning the assembly line unloading workstation to accommodate a larger percentage of workers, while simultaneously decreasing the employee's exposure to adverse ergonomic conditions.

Data Collection Procedures

The following procedures were utilized to collect the necessary data for the purposes of an ergonomic analysis of the assembly line unloading workstation:

1) An appointment with Company XYZ's was coordinated with the safety and health manager, production supervisor, and human resources office to determine an appropriate time to conduct the study.
2) Approximately 30 minutes of video and 25 still photographs of the workstation were obtained from various angles of workers performing the task.
3) Workstation measurements were acquired on-site by utilizing a tape measure, an infrared thermometer, and a single axial force gauge. Linear measurements were documented in feet and inches, temperature readings were recorded in degrees Fahrenheit, and objects' mass were obtained in pounds.
4) The video and photographic images were reviewed to determine the workers' body positioning, joint angles, and task-cycle rates.
5) The data was applied to ETAW, NIOSH Revised Lifting Equation, and Snook Tables.

6) Several years of pertinent records were reviewed to obtain relevant information regarding worker compensation premium payments, medical claims, illness and injury reports, as well as employee staffing levels and attrition rates.

Video and photographic images collection procedures. The digital video recorder was affixed to the top of a five foot tripod and positioned at ground level approximately 25 feet from the assembly line unloading workstation in such a manner to include both substations within its unobstructed field of view. Still photographic images were manually obtained utilizing a digital camera from multiple angles and distances throughout various stages of the task.

Workstation measurement procedures. The workstation environmental conditions were obtained utilizing various instrumentations. Linear dimensions were acquired using a tape measure and recorded in feet and inches. Temperature readings were acquired by utilizing an infrared thermometer by aiming the laser at sample of three manufactured metal products approximately one second prior to a worker removing it from the overhead conveyor line. The temperature readings were recorded in degrees Fahrenheit. A single axial force gauge was utilized to obtain the mass of the manufactured metal product. The random sample of three manufactured metal products was removed from the assembly line and the weight of each piece recorded in pounds. A mean weight was determined from the samples of manufactured metal products and the average was utilized for all ergonomic-related calculations.

Ergonomic Task Analysis Worksheet procedures. The video and photographic images were reviewed and the conditions applied to the criteria included on the ETAW. Each section (repetition, posture, vibration, reach/proper height, force, static loading and fatigue, pressure/contact stress/repeated impacts, lifting and material handling, and environment) of the ETAW was completed in a manner consistent with the procedures described within the assessment tool. The results were utilized to determine if the conditions present at the workstation corresponded with the predetermined criteria in order to be classified at the ideal, warning level/monitor, or take action category. Only the conditions that corresponded to the warning level/monitor and take action sections of this assessment tool were analyzed for corrective solutions.

Revised NIOSH Lifting Equation procedures. Precise linear dimensions of the conditions present at the assembly line unloading workstation were acquired and recorded. The video and photographic images were reviewed to obtain measurements with regard to the asymmetric angle of spinal twisting as well as hand coupling conditions. Measurements were then applied to the NIOSH Lifting Equation in a manner consistent with the procedures as previously described in Chapter Two with the purpose of determining the RWL. The average weight of the manufactured metal product and the RWL were applied to the appropriate equation to determine the LI a manner consistent with the procedures previously described in Chapter Two.

Snook Tables procedures. Since the duties at the assembly line unloading workstation is primarily divided into three separate activities of an initial lifting phase, a carrying task, and a lowering action, three corresponding Snook Tables were utilized. Additionally, the tables are separated into a male (M) and a female (F) category. For the purposes of this study the flowing tables were utilized:

- Table 2F – Female population percentages for lifting tasks ending between knuckle and shoulder height (approximately 28 inches and above to no more than 53 inches).
- Table 2M – Male population percentages for lifting tasks ending between knuckle and shoulder height (approximately 31 inches and above to no more than 57 inches).

- Table 11F – Female population percentages for carrying tasks.
- Table 11M – Male population percentages for carrying tasks
- Table 5F – Female population percentages for lowering tasks beginning between knuckle and shoulder height (approximately 28 inches and above to no more than 53 inches).
- Table 5M – Male population percentages for lowering tasks beginning between knuckle and shoulder height (approximately 31 inches and above to no more than 57 inches).

Linear distances, cycle rates, body positioning and object's weight were applied to the table in a manner consistent with procedures described in the Liberty Mutual Manual Materials Handling Guidelines.

Document review procedures. Company XYZ's records were reviewed for relevant information regarding its WC insurance premiums, medical claims, illness and injury reports, as well as employee staffing levels and attrition rates. Four years of WC insurance premiums and direct medical payments were analyzed and compared with the State of Wisconsin's metal goods manufacturing industry averages. The OSHA 300 logs for the previous four years, or similar documentation, were reviewed and only the illness and injury reports which occurred at the assembly line unloading workstation were recorded. Four years of former Finishing Division employee files were reviewed to determine the worker attrition rate of those personnel.

Limitations

The following limitations were present throughout this study:

- Due to Company XYZ's industrial trade secrets and privacy concerns, no identifiable information regarding this organization, its employees, and the specific products manufactured was described.

- All of Company XYZ's loss-based data and personnel information was provided in a summary format and not obtained from the originating documents.
- Due to the organization's policy of worker task rotation, loss-based records and personnel attrition rates included employees within the entire Finishing Division of Company XYZ.
- The worker compensation premium rates identified were company-wide and not specifically attributed to the Finishing Division or assembly line unloading workstation.
- This ergonomic analysis is limited to the conditions present, including the workers and the specific metal manufactured product which was being unloaded, at the workstation during data collection phase of the study in early to late November of 2012.

Chapter IV: Results

The purpose of this study was to analyze conditions at the assembly line unloading workstation in Company XYZ's Finishing Division to determine if such posed an ergonomic risk to associated employees. In order to realize this purpose, the following three goals were established:

- Analyze the assembly line unloading workstation by utilizing various ergonomic assessment tools.
- Review the company's illness and injury records to determine the extent of reported musculoskeletal disorders.
- Review the company's worker compensation and personnel records to determine insurance premium rates, medical payments, and employee turnover.

This chapter will review the information obtained during the data gathering phase of this study. All information was obtained by utilizing the procedures outlined in Chapter III of this paper. The procedures included obtaining and reviewing video and still photographic images, acquiring workstation measurements, and applying the conditions to several ergonomic assessment tools. Additionally, several years of Company XYZ's loss-related records and personnel files were reviewed for relevant data.

General Workstation Description

The assembly line unloading workstation is located in the Finishing Division of Company XYZ. This workstation is the final step in the manufacturing procedure when workers manually remove the finished item from the overhead assembly line after it emerges from the powder coating process. The manufactured metal product is then manually stacked on a wooden pallet to prepare for shipping.

The workstation's floor was constructed of concrete which appeared to be free of obstructions or significant variations in elevation. A 48 by 60 inch anti-fatigue mat was located in-line with the conveyor at each of the two substations. Atmospheric temperature at the workstation was approximately 68 degrees Fahrenheit and the lighting appeared to be at an adequate level for completing the task. Each manufactured metal item weighed approximately 65.5 pounds (see Table 1), is constructed of 2.75 inch round steel tubing, measured 40.25 inches in length, and was coated in a glossy paint. A triangular steel plate was joined to each end of the manufactured metal product in a manner which places it perpendicular to the tube. The steel plate measured 16 inches at the widest end and tapers off to 2.75 inches at the point where it is attached to the tubing. At the wide end of each plate, the steel is bent at a 90 degree angle so to form a two-inch lip. Surface temperature of the manufactured metal products being removed at the assembly line unloading workstation ranged from 86.7 and 95.3 degrees Fahrenheit.

Both assembly line unloading substations were supplied manufactured metal products from a single overhead conveyor system at a constant rate of six to seven pieces per minute. The assembly line was a single-row, overhead conveyor system which was located approximately eight feet above ground level. Metal hooks were attached to the conveyor system in order to suspend a single manufactured metal product by one of the predrilled holes in the two-inch lip of the steel plate. Workers were unable to control the rate at which the manufactured metal products are supplied to the assembly line unloading workstation. An emergency shutoff switch was located approximately 25 feet from substation A and was easily accessible. As the manufactured metal product approached the assembly line unloading workstation, the worker occupying Substation A manually removed the item in such a manner which allowed several pieces to reach Substation B. Each manufactured metal product must travel an additional 15 feet to arrive at Substation B. Both workers typically performed the task at a pace which was faster than the conveyor provided the manufactured metal product. This caused a need for the workers to walk an even further distance to remove the product from the assembly line and return to the shipping pallet.

Once removed from the overhead conveyor, the manufactured metal product was then placed on a wooden pallet to prepare the item for shipping. Both substations were equipped with an automatic machine which wrapped the fully loaded shipping pallet with plastic. Each fully loaded pallet contained 20 manufactured metal items, stacked in four rows of five pieces. A single five-inch high wooden shipping pallet was located on a three-inch thick rotating platform. The rotating platform was used by the automatic wrapping machine to spin the loaded pallet while the plastic was fed from the roller. No type of caging or guarding was present at the automatic wrapping machine. After the wrapping was complete, a powered industrial truck removed the fully loaded shipping pallet. The worker then placed a new shipping pallet on the automatic wrapping machine platform to repeat the process. The entire process is repeated approximately every seven minutes. Slight deviations of procedures were observed, depending on the distance workers walked to retrieve the manufactured metal product and the number of rows of product on the shipping pallet. However, the following descriptions are a generally accurate depiction of the procedures at each substation.

Table 1

Manufactured Metal Product Weights

Sample	Sample #1	Sample #2	Sample #3	Average
Weight	65.5	65.5	65.5	65.5

Substation A Task Description

The worker, while wearing cotton gloves with a non-slip coating, approached the assembly line until his body was approximately six to eight inches from the suspended manufactured metal product. He flexed his lumbar region of the spine approximately 10 degrees while simultaneously reaching with both arms to grasp the product. His right shoulder flexed to approximately 30 degrees while the right elbow was flexed to 50 degrees. The right forearm and wrist maintained a neutral position as the hand utilized a wide grip to grasp the manufactured metal product at a position approximately eight to 10 inches below the top of the object. His left shoulder remained in a neutral position while the elbow flexed to approximately 160 degrees. The worker's left forearm rotated to a fully supinated posture while the wrist was extended to 45 degrees as the worker grasped the two-inch lip of the steel plate. He lifted the manufactured metal product approximately four to five inches until the item disengaged from the hook.

Once the manufactured metal product was free from the hook, the worker rotated the item to a horizontal position. The worker's right shoulder was in a neutral posture and the elbow flexed at 90 degrees while the corresponding forearm was rotated to a fully supinated position, supporting the product. His left hand remained gripping the two-inch lip at the end of the product which caused the worker's shoulder to abduct from the body by approximately 30 degrees. The worker then walked approximately seven to 15 feet until he reached the shipping pallet. As the worker approached the pallet, he stepped up on the three-inch platform and positioned himself directly in front of the pallet. The worker flexed both knees to approximately 150 degrees while simultaneously flexing the lumbar region of the spine to 50 degrees. He flexed both shoulders to approximately 90 degrees and fully extended the elbows to place the manufactured metal product upon the shipping pallet. This process is then repeated until the shipping pallet is fully loaded.

Substation B Task Description

The worker, while wearing cotton gloves with a non-slip coating, approached the manufactured metal product until his body was approximately four to six inches from the item. His spine maintained an upright posture while he reached out with both arms to grasp the product. The worker's right shoulder flexed to approximately 20 degrees while the elbow flexed to 70 degrees. His right forearm and wrist maintained a neutral position as the hand utilized a wide grip to grasp the manufactured metal product at a position approximately eight inches below the top of the object. The worker's left shoulder remained in a neutral position while the elbow flexed to approximately 160 degrees. His left forearm rotated to a supinated posture and the wrist was extended to 45 degrees as the worker grasped the two-inch lip of the steel plate. The worker lifted the manufactured metal product approximately four to five inches until the item disengaged from the hook.

Once the manufactured metal product was free from the hook, the worker rotated the item to a semi-horizontal position. His right shoulder remained in a neutral posture and the elbow flexed at 90 degrees while the corresponding forearm was rotated to a partial-supinated posture, supporting the product. The worker's left hand remained gripping the two-inch lip at the end of the product and the left shoulder was positioned in a neutral posture. His left elbow was flexed to 120 degrees and the corresponding forearm was in a supinated position. The worker then walked approximately 7 to 15 feet until he reached the shipping pallet. As the worker approached the pallet, he stepped up on the three-inch platform and positioned himself directly in front of the pallet. The worker flexed both knees to approximately 135 degrees while flexing the lumbar region of the spine to 90 degrees. He flexed both shoulders to approximately 90 degrees and fully extended the elbows to place the manufactured metal product upon the shipping pallet. The process is then repeated until the shipping pallet is fully loaded.

Ergonomic Analysis of the Workstation

The video and still images were reviewed and the measurements evaluated in order to analyze workstation conditions with the intent to identify the possible presence of ergonomic stressors. Each of the ergonomic assessment tools were utilized in a manner consistent with the methodology outlined in Chapter Three. First, the Ergonomic Task Analysis Worksheet (ETAW) was completed as a preliminary assessment to highlight the most severe conditions which may cause workers to develop MSD's. Second, the NIOSH Revised Lifting Equation was applied to determine the recommended weight limit (RWL) and the lifting index (LI) associated with the task. Third, the Snook Tables were utilized to identify what percentage of the human population could reasonably be expected to complete this task in a safe manner. The following information is a result of these assessment tools.

Ergonomic Task Analysis Worksheet results. The ETAW identified conditions which corresponded to the criteria in the ideal, warning level/monitor, and take action sections. Conditions at both substations were individually applied to the ETAW and results for each were analyzed. An analysis of both completed ETAW's (see Appendix B) revealed that Substation A and Substation B contained identical conditions which may be likely to cause workers to develop MSD's. The conditions which corresponded to the most severe risk (take action) section are:

- Repetition (1B)
- Hand Posture (5B)
- Wrist Posture (6A and 6B)

- Reach (9A, 9C, 10A, 10B, and 10C)
- Force (11B, 12B, 13A, 13B, 14B, and 16B)
- Static Loading (19B)
- Pressure/Contact Stress/Repeated Impacts (20B)
- Lifting and Material Handling (21B)
- Environment (24B)

The conditions which correspond to the moderate risk (Warning Level/Monitor) section are:

- Reach (9D)
- Force (17A)
- Static Loading (18A)
- Environment (27A, 29A, and 30A)

Revised NIOSH Lifting Equation results. The Revised NIOSH Lifting Equation was utilized to calculate the RWL and LI. Each of the two substations of the assembly line unloading workstation was analyzed separately (see Appendix C). It appears the RWL is considerably less than the actual weight of the object lifted and the LI is significantly greater than the target value of 1.0 for both substations (see Table 2).

Table 2

RWL and LI for Substation A and Substation B

Revised NIOSH Lifting Equation	Substation A		Substation B	
	Phase I (Lift)	Phase II (Lower)	Phase I (Lift)	Phase II (Lower)
RWL	7.2	4.7	8.2	4.7
LI	9.2	14.0	8.0	13.9

Snook Tables results. The Snook Tables were utilized to determine what percentage of the human population could reasonably be expected to complete this task in a safe manner. A review of the completed Snook Tables (see Appendix D) suggests that a significant portion of the population is unable to perform the task at the assembly line unloading workstation. According to the results, only 16 to 48 percent of males would be expected to complete the task safely. Additionally, the results indicate that less than 10 percent of females are expected to be able to perform any portion of this task safely (see Table 3).

Table 3

Percentages of the Human Population that Could Perform the Task Safely

Snook Tables	Substation A		Substation B	
	Male	Female	Male	Female
Table 2 (Lift)	38%	< 10%	38%	< 10%
Table 11 (Carry)	22% - 49%	< 10%	22% - 49%	< 10%
Table 5 (Lower)	16% - 29%	< 10%	16% - 29%	< 10%

Document Review

Several years of records were reviewed to obtain the worker compensation (WC) insurance premium rates for Company XYZ. These rates are expressed in number of dollars per $100 of payroll and benefits paid to employees. This indicates for every $100 the company pays to its employees for wage and benefit-related expenditures, an additional amount is paid to the applicable insurance company in WC premium. In Table 4, several years of Company XYZ's WC premium rates (including the experience modifier) were compared to that of the average metal good manufacturing (MGM) business located in the State of Wisconsin (WIDWD, n.d.).

While 2008's WC rate was significantly higher than the others, 2009 through 2011's seems to be consistent with the average MGM business.

Table 4

Comparison of the WC Premium Rates for the Average Wisconsin MGM Business and Company XYZ

WC Premium Rates	2008	2009	2010	2011
Average Wisconsin MGM Business	$8.41	$8.41	$8.68	$8.05
Company XYZ Experience Modifier	1.59	1.02	1.01	.95
Company XYZ WC Premium Rate	$13.37	$8.58	$8.77	$7.65

Additionally, direct loss-related data for the employees engaging in duties at the assembly line unloading workstation were reviewed. From 2008 through 2011 assembly line unloading workstation employees experienced a total of six (see Table 5) OSHA Recordable illnesses and/or injuries. The six injuries and/or illnesses resulted in $7,784 of direct costs that were paid by the WC insurance. While there was a minor WC payout in years 2008 and 2010, there were several significant payments in 2008, 2010, and 2011. Three of the six incidents resulted in $6,589 in payments, which translates into that half on the illnesses and injuries were responsible for approximately 85 percent of the WC payouts for the years 2008 through 2011. The nature of each illness and injury were not reviewed for the purposes of this study.

Table 5

Worker Compensation Payouts for Years 2008 Through 2011.

	2008	2009	2010	2011
Injury #1 Cost	$120	$834	$240	$1,173.31
Injury #2 Cost	$2,211.51	-	$3,205.58	-
Total Cost	$2,331.51	$834	$3,445.58	$1,173.31

Finally, the personnel files of previous employees of Company XYZ's Finishing Division were reviewed to establish the attrition rate of associated workers. The number of Finishing Division employees was compared with the amount of workers that voluntarily resigned from the company or transferred to another department (see Table 6). It appears Company XYZ increased its staffing levels in 2011, while at the same time as experiencing a reducing in its attrition rate. However, for years 2008 through 2010, the attrition rate was at significant levels from15 to 30 percent turnover. This information does not include involuntary terminations or temporary, limited-term project hires. Specific reasons for the employees' voluntary resignations or transfers were not recorded.

Table 6

Finishing Division Employee Attrition Rate.

	2008	2009	2010	2011
Number of Employees	23	20	26	34
Employees Quit or Transferred	7	3	7	2
Attrition Rate	30.4%	15%	27%	6%

Chapter V: Conclusions and Recommendations

The purpose of this study was to analyze conditions at the assembly line unloading workstation in Company XYZ's Finishing Division to determine if such posed an ergonomic risk to associated employees. Initially, this study established three goals to accomplish in order to determine the risk associated with the assembly line unloading workstation. These goals were to evaluate the workstation for ergonomic stressors, review the company's illness/injury records, and analyze appropriate personnel records. Second, a comprehensive literature review was conducted to gather relevant information regarding ergonomics, manual material handling, and musculoskeletal disorders. Additionally, the literature review provided information on various assessment tools and methods available to analyze workstations for ergonomic stressors. Third, a worksite survey was completed at Company XYZ's Finishing Division utilizing several data collection methods and instrumentations. Finally, the data gathered during the survey was applied to the ergonomic assessment tools and analyzed for conditions which may cause workers to develop MSD's. The remainder of this chapter will discuss conclusions which may be drawn from the collected data as well as provide possible solutions in order to reduce the probability of employees being exposed to conditions which may lead to the development of MSD's.

Conclusions

Based upon the analysis of the various ergonomic assessment tools as well as a review of the associated literature, it is reasonable to conclude there are conditions present at the assembly line unloading workstation which are placing workers at a risk of developing MSD's. This conclusion is based on the following data gathered during a worksite survey:

- According to the Ergonomic Task Analysis Worksheet, 25 workplace conditions met the criteria to be classified as warning level/monitor or take action. Further analysis of the

ETAW revealed these conditions to be primarily (21 out of 25 conditions) related to the presence of extreme forces, deviated postures, and high repetition.

- The Revised NIOSH Lifting Equation recommended the maximum weight a worker should be allowed to lift, while completing a task similar to the assembly line unloading workstation, is between six and seven pounds. While the products manufactured by Company XYZ can vary greatly in weight, they are all above the recommended limit as proposed by this assessment tool. The results indicate that the phase which poses the highest amount of risk is the lowering portion of the task. The extent of the risk associated with the lowering portion task can be evidenced by the lifting index, which was factored to be 13.7 and 14 for Substation A and Substation B respectively.
- The results from the Liberty Mutual Manual Materials Handling Guidelines (Snook Tables) indicated that less than 10 percent of the female population are able to perform the task safely. Additionally, the results also indicate only 16 to 49 percent of males could be able to perform this task safely. However, the 49 percent number is slightly misleading as this represents only the number of males who could perform the carry portion of the task safely. Once again, the analysis reveals that the lowering portion of the task is the highest risk for which only 16 to 29 percent of males could perform the job safely.
- During the worksite survey phase of the task, it was observed the anti-fatigue mats were not utilized in a manner for which they were intended. The workers did not maintain a consistent position on the mat to gain an appreciable level of benefit. Additionally, the mats were placed directly in the path of the workers while walking to remove a

manufactured metal product from the conveyor. This presented a possible tripping hazard due to the slight change in elevation of the walking surface.

- The gloves being utilized by the workers provided minimal cut and force protection from the edge of the lip located on the manufactured metal product's steel plate.
- The illness and injury records of Company XYZ revealed that over the course of four years, the assembly line unloading workstation produced six injuries and caused over $7,700 in WC payments. While this amount represents money paid by the insurance and not a direct payment by Company XYZ, it affects overall expenses by increasing the cost of the WC premium. A reduction in the dollar amount paid by WC insurance may have a positive effect by reducing the overall premium paid by Company XYZ.
- Insurance records indicate that Company XYZ's WC premium rate was significantly above that of the state's average metal goods manufacturing businesses in 2008. In the following years, 2009 through 2011, the WC premium rate remained consistent with the state average. While the rates that were referenced applied to the entire facility, losses incurred at the assembly line unloading workstation contribute to this number and mitigating MSD's related to this task may potentially reduce the company's overall WC premium.
- The personnel turnover rate indicates that the Finishing Division experienced an average attrition rate of approximately 20 percent from the years 2008 through 2011. When utilizing the $14,000 expense figure cited by O'Connell and Mei-Chuan (2007) as the price to replace a manufacturing employee, the financial burden of replacing those 19 workers, which voluntarily resigned or transferred out of the Finishing Division, can be

estimated to cost Company XYZ approximately $266,000 over those corresponding four years.

All three primary ergonomic risk factors, as previously discussed in this paper, were present at the assembly line unloading workstation. Those primary risk factors, as well as the associated activities, are listed as follows:

- High forces, due to the weight of the manufactured metal product.
- Awkward posture, due to adverse body positioning (spinal flexion; shoulder flexion, extension, abduction).
- High repetition, due to the worker's completing six to seven task cycles per minute.

Additionally, the following conditions present at the assembly line unloading workstation may also increase the risk to employees are listed as follows:

- Duration, due to the workers performing this task for an entire eight-hour shift.
- Sharp edges, due to the worker utilizing the 90 degree lip present on the manufactured metal product to lift/carry the object.
- The worker standing/walking on concrete for an entire shift without the benefit of an anti-fatigue mat.
- The worker could be struck by the unguarded automatic wrapping machine while in operation.

Recommendations

It is recognized that Company XYZ is in the business of manufacturing a metal product and certain aspects of this process may inherently pose a risk to employees. However, it is reasonable to conclude that there are certain aspects of this task that may be modified to reduce the worker's overall exposure to potentially harmful conditions, therefore, providing a safer work environment and possibly increasing the workstation's efficiency. Therefore, the following recommendations are proposed with the intention of improving the conditions which would effectively reduce or possibly eliminate certain ergonomic stressors which are placing workers at a risk of developing MSD's:

- Establish and communicate a comprehensive ergonomics program which demonstrates the Company XYZ's commitment to a safe and healthy workplace. The ergonomic program, at a minimum should include the following:
    - Top management support expressed by adequately funding reasonable ergonomic initiatives.
    - Employee involvement through basic ergonomic training and establishing a process for recommending improvements.
    - Create an assessment process to identify ergonomic hazards associated with each task.
    - Maintain accurate ergonomic-based program records such as trainings, losses-related data, recommendations, and accomplishments.
- Raise the wooden shipping pallet to approximately the employee's waist height. This would significantly reduce the amount of awkward postures the worker must perform during the lowering portion of the task. It is recommended to utilize a powered adjustable scissor lift-type device as the pallet's surface may be optimized to accommodate multiple workers' heights. Additionally, by utilizing a self-adjusting scissor-lift, the work surface may be raised or lowered as needed when stacking multiple rows of the manufactured metal product on the shipping pallet.

- Add an additional employee to each substation to reduce the number of task cycles the worker is required to perform. Additionally, the extra worker would be available to utilize a two-person lift on heavy objects.
- Establish an employee rotation schedule which limits the worker's time at this workstation to no more than four hours per day.
- Instruct the workers on basic ergonomics. This training may include MSD warning signs as well as the optimal body postures and lifting/lowering procedures.
- Establish a short (approximately 10 minutes) pre-shift stretching routine to allow proper warm-up of the worker's muscles.
- Institute guidelines which state the workers are not to approach the conveyor to remove the manufactured metal product until it arrives at the corresponding substation. This will reduce the distance the worker must travel while carrying the heavy load.
- Supply each worker with a pair of gloves with a non-slip coating as well as extra padding, similar to the Youngstown Mechanic's Glove. This will protect the worker's hands from the pressure caused by the hard edge of the manufactured metal product's lip and from any residual heat retained by the product after emerging from the powder coating process. The non-slip coating will provide extra grip for the worker when handling the manufactured metal product.
- Remove the anti-fatigue mat from the workstation and supply each worker with an anti-fatigue overshoe similar to the Ergomates Soles. This will provide the benefits of an anti-fatigue mat while allowing the worker increased mobility at the workstation.

Recommendations for Additional Research

This analysis was limited to the specific conditions present at this workstation. Additional analysis may be beneficial to Company XYZ to provide greater detail regarding other solutions. The areas of additional research may include:

- Possible implementation of a powered assisted lifting device to reduce the load weight of the manufacture metal product.
- Redesign of the entire conveyor system which would allow the workers to control the rate that the products are supplied to the assembly line unloading workstation, without impacting amount of time the product is exposed to the powder coating process.
- Possible implementation of a robotic device which could automate the process to remove the manufactured metal product from the assembly line and stack the item on a shipping pallet.
- Design an enclosure for the automatic wrapping machine so as to prevent workers from being struck by the spinning load while the unit is in operation.

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Appendix A: Blank Ergonomic Task Analysis Worksheet

Ergonomics Task Analysis Worksheet

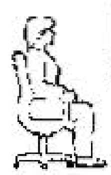
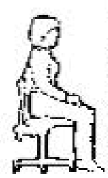
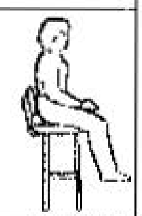
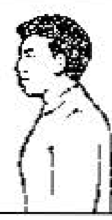
Directions: **The Ergonomics Task Analysis Worksheet** provides a method for identifying, evaluating, and eliminating/controlling ergonomic risk factors. Observe several task cycles prior to making notes or drawing conclusions. Score each risk factor (ideal, warning level, or take action) that most resembles the task you are analyzing. Once you have completed the worksheet, create an Action Plan (how to control or eliminate the risk factor), focusing on tasks from the "Take Action" column first. It is often helpful to videotape the job to facilitate a more detailed review and action plan.

Repetition

NIOSH defines a repetitive task as one with a task cycle time of less than 30 seconds or performed for prolonged periods, such as an 8 hour shift.

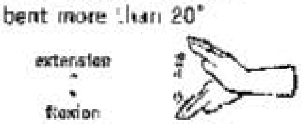
Ideal	Warning Level - Monitor	Take Action
1. No repetitive hand or arm motions	1A. Repetitive hand or arm motions with cycle times of 30-60 seconds	1B. Repetitive hand or arm motions with cycle times of less than 30 seconds

Posture

Ideal	Warning Level - Monitor	Take Action
Standing 2. Knees are straight, but not locked. Back is upright and straight. No twisting, reaching or bending. (See reaching) 	**Standing** 2A. Knees partly bent. 	**Standing** 2B. Squatting > 3 hrs/day  2B. Kneeling > 3 hrs/day  2B. Using a foot pedal 
Sitting 3. Back and legs supported by comfortable chair. Feet are flat on floor or foot rest. 	**Sitting** 3A. Back is only partially supported or feet are not flat. 	**Sitting** 3B. Little support for legs and back. Feet do not touch floor. 
Head/Neck 4. Head and neck are upright and straight 	**Head/Neck** 4A. Bent forward less than 20° 	**Head/Neck** 4A. Bent forward more than 20° > 3 hrs/day 

Posture (continued)

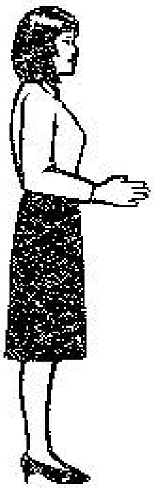
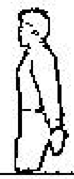
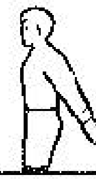
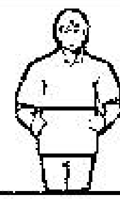
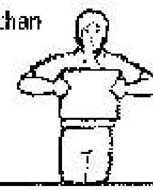
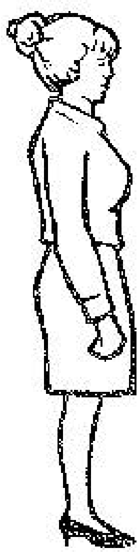
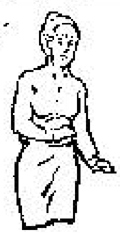
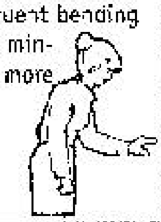
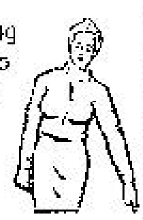
Ideal	Warning Level - Monitor	Take Action
Head/Neck 4. Head and neck are upright and straight 	**Head/Neck** 4B. Bent back less than 10° 	**Head/Neck** 4B. Bent back more than 10° 
	4C. Bent sideways less than 20° 	4C. Bent sideways more than 20° 
	4D. Twisting neck less than 20° 	4D. Twisting neck more than 20° 

Ideal	Warning Level - Monitor	Take Action
Hands 5. Palms are vertical (handshake position) 	**Hands** 5A. Hands rotate less than 20° 	**Hands** 5A. Hands rotate more than 20° 
Wrists 6. Wrists are straight 	**Wrists** 6A. Wrists are bent between 5 and 30 times per minute and bent less than 20° 	**Wrists** 6A. Wrists are bent more than 30 times per minute or bent more than 20° 
	6B. Wrists move sideways between 5 and 30 times per minute and less than 20° 	6B. Wrists move sideways more than 30 times per minute or more than 20° 

Vibration (Check with tool manufacturer for recommendations or warnings.)

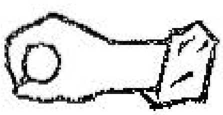
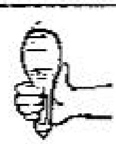
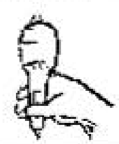
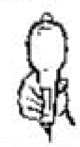
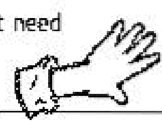
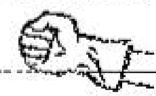
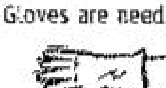
Ideal	Warning Level - Monitor	Take Action
7. No hand or arm vibration	7A. Occasional hand or arm vibration	7B. Constant hand or arm vibration
8. No whole body vibration	8A. Occasional whole body vibration	8B. Constant whole body vibration

Reach/Proper Height

Ideal	Warning Level - Monitor	Take Action
9. Work should be performed at 90˚ or slightly above or below elbow level 	9A. Arms forward up to 45˚ or frequently maintained outside of the ideal position > 4 hrs/day 	9A. Arms forward more than 45˚ or constantly maintained outside of the ideal position > 3 hrs/day 
	9B. Arms back up to 20˚ and no more than 2-4 times per minute > 4 hrs/day 	9B. Arms back more than 20˚ or more than 4 times per minute > 3 hrs/day 
	9C. Elbows bent up to 25% above or below the ideal position > 4 hrs/day 	9C. Elbows bent more than 25% above or below the ideal position > 3 hrs/day 
	9D. Elbows up to 45˚ away from body > 4 hrs/day 	9D. Elbows more than 45˚ away from body > 3 hrs/day 
10. No twisting, reaching or bending 	10A. Twisting up to 45˚ or frequent twisting (2-4 times per minute) 	10A. Twisting more than 45˚ or highly repetitive twisting (more than 4 times per minute) 
	10B. Bending/reaching forward up to 45˚, frequent bending (2-4 times per minute) or > 30% more than 4 hours per day without support 	10B. Bending/reaching forwarc more than 45˚, highly repetitive bending (more than 4 times per minute) or more than 2 hours per day without support 
	10C. Bending/reaching to the side up to 20˚ or frequent bending (2-4 times per minute) 	10C. Bending/reaching to the side more than 20˚ or highly repetitive bending to the side (more than 4 times per minute) 

Force

Force is the amount of physical effort required to do a task or maintain control of the tools or equipment. Effort depends on the weight of the object, type of grip, object dimensions, type of activity, slipperiness of the object and duration of the task.

Ideal	Warning Level - Monitor	Take Action
11. Objects lifted by hand weigh less than 1 pound	11A. Objects lifted by hand weigh less than 1 pound and frequent lifting (no more than 20 times an hour)	11B. Objects lifted by hand weigh more than 1 pound or highly repetitive lifting (more than 20 times an hour)
12. Objects lifted by the back weigh less than 5 pounds	12A. Objects lifted by the back weigh between 5 and 25 pounds or frequent lifting (no more than 20 times/hour)	12B. Objects lifted by the back weigh more than 25 pounds or highly repetitive lifting (more than 20 times/hour)
Duration 13. No pinch grip used. Fingers and thumb comfortably fit around tool or object 	**Duration** 13A. Moderate pinch grip or pinch grip with less than 2 pounds of force 	**Duration** 13A. Severe pinch grip or pinch grip used with greater than 2 pounds of force 
	13B. Grip is slightly too wide 	13B. Grip is extremely wide 
14. Power grip used with little to no force.	14A. Power grip used with less than 10 pounds of force. Forearm rotation force is less than 5 pounds	14B. Power grip used with more than 10 pounds of force. Forearm rotation force is more than 5 pounds
15. Entire hand controls trigger 	15A. Thumb activated control 	15B. Finger(s) activated control 
16. Tools or objects have handles that are rounded	16A. Awkward handles	16B. Handles, tools or objects that concentrate force or have no handles
	16A. Tools with awkward handles 	16B. Handles that concentrate force 
	Choose One	
	16A. Objects with awkward handles 	16B. Objects with no handles 
Slipperiness 17. Gloves do not need to be worn at any time 	**Slipperiness** 17A. Gloves are needed but fit well 	**Slipperiness** 17B. Gloves are needed but fit poorly 

Static Loading and Fatigue

Static loading refers to staying in the same position for prolonged periods. Tasks that use the same muscles or motions for long durations (6 seconds or more at one time) and repetitively (more than 50% repetition) increase the likelihood of fatigue.

Ideal	Warning Level - Monitor	Take Action
Duration 18. Constant position, tool or object is held less than 6 seconds	**Duration** 18A. Constant position, tool or object is held 6 to 10 seconds	**Duration** 18B. Constant position, tool or object is held more than 10 seconds
Repetition 19. Less than 25% of the task is repetitive	**Repetition** 19A. 25% to 50% of the task is repetitive	**Repetition** 19B. More than 50% of the task is repetitive

Pressure/Contact Stress/Repeated Impacts

Refers to pressure or contact from tools or equipment handles with narrow width that create local pressure. It also applies to sharp corners of desks or counter tops. Impact refers to the use of hands, knees, foot, etc. as a hammer. *(Related to Force Conditions in item 16.)*

Ideal	Warning Level - Monitor	Take Action
20. No contact or impact stress: tools, objects, or workstation do not press against hands or body	20A. Occasional and minimal pressure or impact on hands or body. Hand, knee or other body part used as hammer less than 2 hours/day	20B. Constant pressure or impact on hands or body. Hand, knee or other body part used as hammer more than 2 hours/day

Lifting and Materials Handling

Ideal	Warning Level - Monitor	Take Action
21. No lifting or lowering of materials (see also Force for weights of objects handled)	21A. Occasional lifting and/or lowering (no more than 20 times per hour)	21B. Constant lifting and/or lowering (more than 20 times per hour)
Push/Pull 22. No pushing or pulling of carts or materials	**Push/Pull** 22A. Pushing or pulling 10-50 carts per shift	**Push/Pull** 22B. Pushing or pulling more than 50 carts per shift
23. Slight force is required to push or pull carts or materials. Pushing is preferred over pulling objects.	23A. Moderate force is required to push or pull carts or materials.	23B. High force is required to push or pull materials.

Environment

Ideal	Warning Level – Monitor	Take Action
Work Pace 24. Worker has adequate control over work pace.	**Work Pace** 24A. Worker has some control over work pace.	**Work Pace** 24B. Worker has no control over work pace.
Lighting 25. The lighting is adequate for the task.	**Lighting** 25A. The lighting is slightly too bright or too dark for the task.	**Lighting** 25B. The lighting is significantly too bright or too dark for the task.
Temperature 26. The temperature is comfortable.	**Temperature** 26A. The temperature is slightly too cold or too hot.	**Temperature** 26B. The temperature is significantly too cold or too hot.
Noise 27. The work area is quiet.	**Noise** 27A. The work area is slightly noisy.	**Noise** 27B. The work area is significantly noisy (too noisy to carry on a conversation).
Floor Surface 28. The flooring provides good traction. 29. The flooring is sufficiently padded to relieve stress on back and legs. 30. Floor mats are provided to relieve stress on back and legs. Employee can alternate between sitting and standing.	**Floor Surface** 28A. The flooring is slightly slippery. 29A. The flooring contributes slight stress to the back and legs. 30A. Standing 0-50% of time without floor mats or other means to relieve stress on back and legs.	**Floor Surface** 28B. The flooring is moderately to extremely slippery. 29B. The flooring contributes moderate to extreme stress to the back and legs. 30B. Standing more than 50% of time without floor mats or other means to relieve stress on back and legs.

Comments: ____

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Note: The levels provided above are standard practices which have been accepted or established by NIOSH, OSHA, ANSII and other related organizations.

Summary Worksheet Date ______

Condition	Ideal	Warning Level	Take Action
Repetition			
1. No repetitive hand or arm motions. (*Monitor* if repetitive cycle every 30-60 seconds; *take action* if repetitive cycle of less than 30 seconds.)	1	1A	1B
Posture			
2. Standing, with knees straight but not locked. (*Monitor* if standing with knees partially bent; *take action* if using a foot pedal or squatting or kneeling more than 3 hours/day.)	2	2A	2B
3. Sitting, back and legs comfortably supported, feet flat on floor/floor rest. (*Monitor* if back partially supported or feet not flat on floor; *take action* if little support for back and legs, feet not touching floor.)	3	3A	3B
4. Head and neck are upright and straight. (*Monitor* if head and neck are bent forward < 20°; *take action* if >20° >3 hours/day.)	4	4A	4A
Head and neck are bent back. (*Monitor* if ≤ 10°; *take action* if >10°.)	4	4B	4B
Head and neck are bent sideways. (*Monitor* if ≤ 20°; *take action* if >20°.)	4	4C	4C
Head and neck are twisting. (*Monitor* if < 20°; *take action* if >20°.)	4	4D	4D
5. Hands (palms) are vertical. (*Monitor* if hands rotate < 20°; *take action* if hands rotate >20°.)	5	5A	5B
6. Wrists are straight. (*Monitor* if wrists are bent, extension/flexion, < 20° for 5-30 times/minute; *take action* if bent >20° or >30 times/minute.)	6	6A	6A
Wrists move sideways, ulnar/radial. (*Monitor* if < 20° and 5-30 times/minute; *take action* if bent >20° or >30 times/minute.)	6	6B	6B
Vibration			
7. No hand or arm vibration. (*Monitor* if occasional; *take action* if constant.)	7	7A	7B
8. No whole body vibration. (*Monitor* if occasional; *take action* if constant.)	8	8A	8B
Reach			
9. Arms positioned at elbow level. (*Monitor* if up to 45° or frequently out of ideal position for more than 4 hours/day; *take action* if arms are forward >45° or constantly out of ideal position >3 hours/day.)	9	9A	9A
Arms back. (*Monitor* if arms back up to 20° between 2-4 times/minute for more than 4 hours/day; *take action* if arms back >20° or >4 times/minute for more than 3 hours/day.)	9	9B	9B
Elbows bent upward. (*Monitor* if elbows bent up to 25% above or below ideal position >4 hours/day; *take action* if bent upward >25% above or below ideal position >3 hours/day.)	9	9C	9C
Elbows away from body. (*Monitor* if elbows are up to 45° away from body >4 hours/day; *take action* if elbows are >45° away from body >3 hours/day.)	9	9D	9D
10. No twisting, reaching or bending, twisting/repetitive. (*Monitor* if twisting up to 45° or 2-4 times/minute; *take action* if >45° or >4 times/minute.)	10	10A	10A
Reaching/bending forward. (*Monitor* if bending/reaching forward up to 45° or 2-4 times/minute or >30° for >4 hrs/day w/out support; *take action* if >45° or >4 times/minute or >2 hrs/day w/out support.)	10	10B	10B
Reaching/bending to the side. (*Monitor* if up to 20° or 2-4 times/minute; *take action* if >20° or >4 times/minute.)	10	10C	10C
Force			
11. Objects lifted by hand weigh less than one pound. (*Monitor* if objects weighing < 1 lb. are lifted up to 20 times/hour; *take action* if objects weigh >1 lb. or lifting occurs >20 times/hour.)	11	11A	11B
12. Objects lifted by the back weigh less than 5 pounds. (*Monitor* if objects weigh 5-25 lbs. or lifting occurs up to 20 times/hour; *take action* if objects weigh >25 lbs. or lifting occurs >20 times/hour.)	12	12A	12B
13. No pinch grip used. (*Monitor* use of pinch grip with < 2 lbs. of force; *take action* if pinch grip with >2 lbs. of force is used.)	13	13A	13A
Wide pinch grip used. (*Monitor* if slightly too wide; *take action* if extremely wide.)	13	13B	13B
14. Power grip used with no force. (*Monitor* if power grip with < 10 lbs. force is used and forearm rotation force is < 5lbs.; *take action* if power grip with >10 lbs. force is used and forearm rotation force is >5 lbs.)	14	14A	14B
15. Entire hand controls trigger. (*Monitor* if thumb controls; *take action* if finger[s] control.)	15	15A	15B
16. Tools or objects have rounded, padded handles. (*Monitor* if handles are awkward; *take action* if there are no handles or handles concentrate force.)	16	16A	16B
17. Gloves do not need to be worn at any time. (*Monitor* if gloves are needed but fit well; *take action* if gloves fit poorly.)	17	17A	17B
Static Loading and Fatigue			
18. Constant position, tool or object is held less than 6 seconds. (*Monitor* if held between 6-10 seconds; *take action* if held >10 seconds.)	18	18A	18B
19. Less than 25% of the task is repetitive. (*Monitor* if 25-50% repetitive; *take action* if >50% repetitive.)	19	19A	19B
Pressure/Contact Stress/Repeated Impacts			
20. No contact/impact stress. (*Monitor* if occasional pressure or body part is used as hammer < 2 hours/day; *take action* if constant pressure or body part is used as hammer >2 hours/day.)	20	20A	20B

Summary Worksheet

Date ________________

Condition	Ideal	Warning Level	Take Action
Lifting and Materials Handling			
21. No lifting or lowering of materials. (*Monitor* if occasional and/or no more than 20 times/hour; *take action* if constant and/or greater than 20 times/hour)	21	21A	21B
22. No pushing or pulling of materials. (*Monitor* if pushing/pulling 10-50 carts/shift; *take action* if pushing/pulling more than 50 carts/shift.)	22	22A	22B
23. Slight force is required to push or pull materials. (*Monitor* if moderate force is required; *take action* if high force is required.)	23	23A	23B
Environment			
24. Worker has adequate control over workplace. (*Monitor* if worker has some control; *take action* if worker has no control.)	24	24A	24B
25. Lighting is adequate for the task. (*Monitor* if slightly too dark or bright; *take action* if significantly too dark or bright.)	25	25A	25B
26. Temperature is comfortable. (*Monitor* if slightly too cold or hot; *take action* if significantly too cold or hot.)	26	26A	26B
27. Work area is quiet. (*Monitor* if slightly too noisy; *take action* if significantly too noisy.)	27	27A	27B
28. Flooring provides good traction. (*Monitor* if flooring is slightly slippery; *take action* if moderately to extremely slippery.)	28	28A	28B
29. Flooring is sufficiently padded to relieve stress on back and legs. (*Monitor* if slight stress to back and legs; *take action* if moderately to extreme stress.)	29	29A	29B
30. Floor mats are provided. Employee can alternate between sitting and standing. (*Monitor* if employee is standing up to 50% of shift without floor mats or other stress relief for back and legs; *take action* if standing >50% of shift without floor mats or other relief for back and legs.	30	30A	30B

Action Plan

Today's date: ________________ Date Solution to be Completed ________________

Location/Department: ________________

Job/Task Title: ________________

Evaluator: ________________

Describe MSD in previous 24 months: ________________

____

Task: ________________

Summary of Problem: ________________

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Alternative Solution and Costs: ________________

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Recommended Solution: 1) Engineering ________________

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2) Administrative: ________________

____

3) Use of personal protective equipment ________________

____

Date Solution Actually Completed: ________________ Actual Cost: ________________

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Appendix B: The Completed Ergonomic Task Analysis Worksheet (Substation A & B)

Summary Worksheet Substation A

Date 11/5/12

Condition	Ideal	Warning Level	Take Action
Repetition			
1. No repetitive hand or arm motions. (*Monitor* if repetitive cycle every 30-60 seconds; *take action* if repetitive cycle of less than 30 seconds.)	1	1A	1B
Posture			
2. Standing, with knees straight but not locked. (*Monitor* if standing with knees partially bent; *take action* if using a foot pedal or squatting or kneeling more than 3 hours/day.)	2	2A	2B
3. Sitting, back and legs comfortably supported, feet flat on floor/floor rest. (*Monitor* if back partially supported or feet not flat on floor; *take action* if little support for back and legs, feet not touching floor.)	3	3A	3B
4. Head and neck are upright and straight. (*Monitor* if head and neck are bent forward < 20°; *take action* if >20° >3 hours/day.)	4	4A	4A
Head and neck are bent back. (*Monitor* if < 10°; *take action* if >10°.)	4	4B	4B
Head and neck are bent sideways. (*Monitor* if < 20°; *take action* if >20°.)	4	4C	4C
Head and neck are twisting. (*Monitor* if < 20°; *take action* if >20°.)	4	4D	4D
5. Hands (palms) are vertical. (*Monitor* if hands rotate < 20°; *take action* if hands rotate >20°.)	5	5A	5B
6. Wrists are straight. (*Monitor* if wrists are bent, extension/flexion, < 20° for 5-30 times/minute; *take action* if bent >20° or >30 times/minute.)	6	6A	6A
Wrists move sideways, ulnar/radial. (*Monitor* if < 20° and 5-30 times/minute; *take action* if bent >20° or >30 times/minute.)	6	6B	6B
Vibration			
7. No hand or arm vibration. (*Monitor* if occasional; *take action* if constant.)	7	7A	7B
8. No whole body vibration. (*Monitor* if occasional; *take action* if constant.)	8	8A	8B
Reach			
9. Arms positioned at elbow level. (*Monitor* if up to 45° or frequently out of ideal position for more than 4 hours/day. *take action* if arms are forward >45° or constantly out of ideal position >3 hours/day.)	9	9A	9A
Arms back. (*Monitor* if arms back up to 20° between 2-4 times/minute for more than 4 hours/day; *take action* if arms back >20° or >4 times/minute for more than 3 hours/day.)	9	9B	9B
Elbows bent upward. (*Monitor* if elbows bent up to 35% above or below ideal position >4 hours/day; *take action* if bent upward >35% above or below ideal position >3 hours/day.)	9	9C	9C
Elbows away from body. (*Monitor* if elbows are up to 45° away from body >4 hours/day; *take action* if elbows are >45° away from body >3 hours/day.)	9	9D	9D
10. No twisting, reaching or bending, twisting/repetitive. (*Monitor* if twisting up to 45° or 2-4 times/minute; *take action* if >45° or >4 times/minute.)	10	10A	10A
Reaching/bending forward. (*Monitor* if bending/reaching forward up to 45° or 2-4 times/minute or >30° for >4 hrs/day w/out support; *take action* if >45° or >4 times/minute or >2 hrs/day w/out support.)	10	10B	10B
Reaching/bending to the side. (*Monitor* if up to 20° or 2-4 times/minute; *take action* if >20° or >4 times/minute.)	10	10C	10C
Force			
11. Objects lifted by hand weigh less than one pound. (*Monitor* if objects weighing < 1 lb. are lifted up to 20 times/hour; *take action* if objects weigh >1 lb. or lifting occurs >20 times/hour.)	11	11A	11B
12. Objects lifted by the back weigh less than 5 pounds. (*Monitor* if objects weigh 5-25 lbs. or lifting occurs up to 20 times/hour; *take action* if objects weigh >25 lbs. or lifting occurs >20 times/hour.)	12	12A	12B
13. No pinch grip used. (*Monitor* use of pinch grip with < 2 lbs. of force; *take action* if pinch grip with >2 lbs. of force is used.)	13	13A	13A
Wide pinch grip used. (*Monitor* if slightly too wide; *take action* if extremely wide.)	13	13B	13B
14. Power grip used with no force. (*Monitor* if power grip with < 10 lbs. force is used and forearm rotation force is < 5lbs.; *take action* if power grip with >10 lbs. force is used and forearm rotation force is >5 lbs.)	14	14A	14B
15. Entire hand controls trigger. (*Monitor* if thumb controls; *take action* if finger(s) control.)	15	15A	15B
16. Tools or objects have rounded, padded handles. (*Monitor* if handles are awkward; *take action* if there are no handles or handles concentrate force.)	16	16A	16B
17. Gloves do not need to be worn at any time. (*Monitor* if gloves are needed but fit well; *take action* if gloves fit poorly.)	17	17A	17B
Static Loading and Fatigue			
18. Constant position, tool or object is held less than 6 seconds. (*Monitor* if held between 6-10 seconds; *take action* if held >10 seconds.)	18	18A	18B
19. Less than 25% of the task is repetitive. (*Monitor* if 25-50% repetitive; *take action* if >50% repetitive.)	19	19A	19B
Pressure/Contact Stress/Repeated Impacts			
20. No contact/impact stress (*Monitor* if occasional pressure or body part is used as hammer < 2 hours/day; *take action* if constant pressure or body part is used as hammer >2 hours/day.)	20	20A	20B

Summary Worksheet Substation A Date 11/8/12

Condition	Ideal	Warning Level	Take Action
Lifting and Materials Handling			
21. No lifting or lowering of materials. (*Monitor* if occasional and/or no more than 20 times/hour; *take action* if constant and/or greater than 20 times/hour.	21	21A	(21B)
22. No pushing or pulling of materials. (*Monitor* if pushing/pulling 10-50 carts/shift; *take action* if pushing/pulling more than 50 carts/shift.)	(22)	22A	22B
23. Slight force is required to push or pull materials. (*Monitor* if moderate force is required; *take action* if high force is required.)	(23)	23A	23B
Environment			
24. Worker has adequate control over workplace. (*Monitor* if worker has some control; *take action* if worker has no control.)	24	24A	(24B)
25. Lighting is adequate for the task. (*Monitor* if slightly too dark or bright; *take action* if significantly too dark or bright.)	(25)	25A	25B
26. Temperature is comfortable. (*Monitor* if slightly too cold or hot; *take action* if significantly too cold or hot.)	(26)	26A	26B
27. Work area is quiet. (*Monitor* if slightly too noisy; *take action* if significantly too noisy.)	27	(27A)	27B
28. Flooring provides good traction. (*Monitor* if flooring is slightly slippery; *take action* if moderately to extremely slippery.)	(28)	28A	28B
29. Flooring is sufficiently padded to relieve stress on back and legs. (*Monitor* if slight stress to back and legs; *take action* if moderately to extreme stress.)	29	(29A)	29B
30. Floor mats are provided. Employee can alternate between sitting and standing. (*Monitor* if employee is standing up to 50% of shift without floor mats or other stress relief for back and legs; *take action* if standing >50% of shift without floor mats or other relief for back and legs.	30	(30A)	30B

Action Plan

Today's date: ______________ Date Solution to be Completed ______________________

Location/Department: ____

Job/Task Title: ____

Evaluator: ____

Describe MSD in previous 24 months: ____

____

Task: ____

Summary of Problem: ____

____

Alternative Solution and Costs: ____

____

Recommended Solution: 1) Engineering ____

____

2) Administrative: ____

____

3) Use of personal protective equipment ____

____

Date Solution Actually Completed: ______________ Actual Cost: ______________

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Summary Worksheet Substation B

Date 11/8/12

Condition	Ideal	Warning Level	Take Action
Repetition			
1. No repetitive hand or arm motions. (*Monitor* if repetitive cycle every 30-60 seconds; *take action* if repetitive cycle of less than 30 seconds.)	1	1A	**1B**
Posture			
2. Standing, with knees straight but not locked. (*Monitor* if standing with knees partially bent; *take action* if using a foot pedal or squatting or kneeling more than 3 hours/day.)	**2**	2A	2B
3. Sitting, back and legs comfortably supported, feet flat on floor/floor rest. (*Monitor* if back partially supported or feet not flat on floor; *take action* if little support for back and legs, feet not touching floor.)	**3**	3A	3B
4. Head and neck are upright and straight. (*Monitor* if head and neck are bent forward < 20°; *take action* if >20° >3 hours/day.)	**4**	4A	4A
Head and neck are bent back. (*Monitor* if < 10°; *take action* if >10°.)	**4**	4B	4B
Head and neck are bent sideways. (*Monitor* if < 20°; *take action* if >20°.)	**4**	4C	4C
Head and neck are twisting. (*Monitor* if < 20°; *take action* if >20°.)	**4**	4D	4D
5. Hands (palms) are vertical. (*Monitor* if hands rotate < 20°; *take action* if hands rotate >20°.)	5	5A	**5B**
6. Wrists are straight. (*Monitor* if wrists are bent, extension/flexion, < 20° for 5-30 times/minute; *take action* if bent >20° or >30 times/minute.)	6	6A	**6A**
Wrists move sideways, ulnar/radial. (*Monitor* if < 20° and 5-30 times/minute; *take action* if bent >20° or >30 times/minute.)	6	6B	**6B**
Vibration			
7. No hand or arm vibration. (*Monitor* if occasional; *take action* if constant.)	**7**	7A	7B
8. No whole body vibration. (*Monitor* if occasional; *take action* if constant.)	**8**	8A	8B
Reach			
9. Arms positioned at elbow level. (*Monitor* if up to 45° or frequently out of ideal position for more than 4 hours/day; *take action* if arms are forward >45° or constantly out of ideal position >3 hours/day.)	9	9A	**9A**
Arms back. (*Monitor* if arms back up to 20° between 2-4 times/minute for more than 4 hours/day; *take action* if arms back >20° or >4 times/minute for more than 3 hours/day.)	**9**	9B	9B
Elbows bent upward. (*Monitor* if elbows bent up to 25% above or below ideal position >4 hours/day; *take action* if bent upward >25% above or below ideal position >3 hours/day.)	9	9C	**9C**
Elbows away from body. (*Monitor* if elbows are up to 45° away from body >4 hours/day; *take action* if elbows are >45° away from body >3 hours/day.)	9	**9D**	9D
10. No twisting, reaching or bending, twisting/repetitive. (*Monitor* if twisting up to 45° or 2-4 times/minute; *take action* if >45° or >4 times/minute.)	10	10A	**10A**
Reaching/bending forward. (*Monitor* if bending/reaching forward up to 45° or 2-4 times/minute or >30° for >4 hrs/day w/out support; *take action* if >45° or >4 times/minute or >2 hrs/day w/out support.)	10	10B	**10B**
Reaching/bending to the side. (*Monitor* if up to 20° or 2-4 times/minute; *take action* if >20° or >4 times/minute.)	10	10C	**10C**
Force			
11. Objects lifted by hand weigh less than one pound. (*Monitor* if objects weighing < 1 lb. are lifted up to 20 times/hour; *take action* if objects weigh >1 lb. or lifting occurs >20 times/hour.)	11	11A	**11B**
12. Objects lifted by the back weigh less than 5 pounds. (*Monitor* if objects weigh 5-25 lbs. or lifting occurs up to 20 times/hour; *take action* if objects weigh >25 lbs. or lifting occurs >20 times/hour.)	12	12A	**12B**
13. No pinch grip used. (*Monitor* use of pinch grip with < 2 lbs. of force; *take action* if pinch grip with >2 lbs. of force is used.)	13	13A	**13A**
Wide pinch grip used. (*Monitor* if slightly too wide; *take action* if extremely wide.)	13	13B	**13B**
14. Power grip used with no force. (*Monitor* if power grip with < 10 lbs. force is used and forearm rotation force is < 5 lbs.; *take action* if power grip with >10 lbs. force is used and forearm rotation force is >5 lbs.)	14	14A	**14B**
15. Entire hand controls trigger. (*Monitor* if thumb controls; *take action* if finger(s) control.)	**15**	15A	15B
16. Tools or objects have rounded, padded handles. (*Monitor* if handles are awkward; *take action* if there are no handles or handles concentrate force.)	16	16A	**16B**
17. Gloves do not need to be worn at any time. (*Monitor* if gloves are needed but fit well; *take action* if gloves fit poorly.)	17	**17A**	17B
Static Loading and Fatigue			
18. Constant position, tool or object is held less than 6 seconds. (*Monitor* if held between 6-10 seconds; *take action* if held >10 seconds.)	18	**18A**	18B
19. Less than 25% of the task is repetitive. (*Monitor* if 25-50% repetitive; *take action* if >50% repetitive.)	19	19A	**19B**
Pressure/Contact Stress/Repeated Impacts			
20. No contact/impact stress. (*Monitor* if occasional pressure or body part is used as hammer < 2 hours/day; *take action* if constant pressure or body part is used as hammer >2 hours/day.)	20	20A	**20B**

Summary Worksheet Substation B

Date 11/8/12

Condition	Ideal	Warning Level	Take Action
Lifting and Materials Handling			
21. No lifting or lowering of materials. (*Monitor* if occasional and/or no more than 20 times/hour; *take action* if constant and/or greater than 20 times/hour.)	21	21A	21B
22. No pushing or pulling of materials. (*Monitor* if pushing/pulling 10-50 carts/shift; *take action* if pushing/pulling more than 50 carts/shift.)	22	22A	22B
23. Slight force is required to push or pull materials. (*Monitor* if moderate force is required; *take action* if high force is required.)	23	23A	23B
Environment			
24. Worker has adequate control over workplace. (*Monitor* if worker has some control; *take action* if worker has no control.)	24	24A	24B
25. Lighting is adequate for the task. (*Monitor* if slightly too dark or bright; *take action* if significantly too dark or bright.)	25	25A	25B
26. Temperature is comfortable. (*Monitor* if slightly too cold or hot; *take action* if significantly too cold or hot.)	26	26A	26B
27. Work area is quiet. (*Monitor* if slightly too noisy; *take action* if significantly too noisy.)	27	27A	27B
28. Flooring provides good traction. (*Monitor* if flooring is slightly slippery; *take action* if moderately to extremely slippery.)	28	28A	28B
29. Flooring is sufficiently padded to relieve stress on back and legs. (*Monitor* if slight stress to back and legs; *take action* if moderately to extreme stress.)	29	29A	29B
30. Floor mats are provided. Employee can alternate between sitting and standing. (*Monitor* if employee is standing up to 50% of shift without floor mats or other stress relief for back and legs; *take action* if standing >50% of shift without floor mats or other relief for back and legs.	30	30A	30B

Action Plan

Today's date: ____________ Date Solution to be Completed ____________

Location/Department: ____________

Job/Task Title: ____________

Evaluator: ____________

Describe MSD in previous 24 months: ____________

____

Task: ____________

Summary of Problem: ____________

____

Alternative Solution and Costs: ____________

____

Recommended Solution: 1) Engineering ____________

____

2) Administrative: ____________

____

3) Use of personal protective equipment ____________

____

Date Solution Actually Completed: ____________ Actual Cost: ____________

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Appendix C: The Completed Revised NIOSH Lifting Equation (Substation A & B)

JOB ANALYSIS WORKSHEET

DEPARTMENT: Finishing Div.
JOB TITLE: Assembly Line Unloading
ANALYST'S NAME: Ralston
DATE: 11/8/12
JOB DESCRIPTION: Substation A Phase 1 (Lift)

STEP 1. Measure and record task variables

Object Weight (lbs)		Hand Location (in)				Vertical Distance (in)	Asymmetric Angle (degrees)		Frequency Rate lifts/min	Duration (HRS)	Object Coupling
		Origin		Dest.			Origin	Destination			
L (AVG.)	L (Max.)	H	V	H	V	D	A	A	F		C
65.5	65.5	12	50	6	44	6	0	0	7	8	Poor

STEP 2. Determine the multipliers and compute the RWL's

RWL = LC × HM × VM × DM × AM × FM × CM

ORIGIN RWL = 51 × .83 × .85 × 1 × 1 × .22 × .90 = 7.2 Lbs

DESTINATION RWL = 51 × _ × _ × _ × _ × _ × _ = _ Lbs

STEP 3. Compute the LIFTING INDEX

ORIGIN LIFTING INDEX = OBJECT WEIGHT (L) / RWL = 65.5 / 7.2 = 9.2

DESTINATION LIFTING INDEX = OBJECT WEIGHT (L) / RWL = _ = _

Single Task Job Analysis Worksheet

JOB ANALYSIS WORKSHEET

DEPARTMENT: Finishing Div
JOB TITLE: Assembly Line Unloading
ANALYST'S NAME: Ralston
DATE: 11/8/12
JOB DESCRIPTION: Substation A Phase 2 (lower)

STEP 1. Measure and record task variables

Object Weight (lbs)		Hand Location (in)				Vertical Distance (in)	Asymmetric Angle (degrees)		Frequency Rate lifts/min	Duration (HRS)	Object Coupling
		Origin		Dest			Origin	Destination			
L (AVG.)	L (Max.)	H	V	H	V	D	A	A	F		C
65.5	65.5	6	44	16	10	34	0	0	7	8	Poor

STEP 2. Determine the multipliers and compute the RWL's

RWL = LC × HM × VM × DM × AM × FM × CM

ORIGIN RWL = 51 × 1 × .90 × .87 × 1 × .22 × .90 = 4.7 Lbs

DESTINATION RWL = 51 × _ × _ × _ × _ × _ × _ = _ Lbs

STEP 3. Compute the LIFTING INDEX

ORIGIN LIFTING INDEX = OBJECT WEIGHT (L) / RWL = 65.5 / 4.7 = 14

DESTINATION LIFTING INDEX = OBJECT WEIGHT (L) / RWL = _ = _

Single Task Job Analysis Worksheet

JOB ANALYSIS WORKSHEET

DEPARTMENT Finishing Div.
JOB TITLE Assembly line unloading
ANALYST'S NAME Ralston
DATE 11/8/12

JOB DESCRIPTION Substation B Phase 1 (lift)

STEP 1. Measure and record task variables

Object Weight (lbs)		Hand Location (in)				Vertical Distance (in)	Asymmetric Angle (degrees)		Frequency Rate lifts/min	Duration (HRS)	Object Coupling
		Origin		Dest.			Origin	Destination			
L (AVG.)	L (Max.)	H	V	H	V	D	A	A	F		C
65.5	65.5	10	53	6	42	9	0	0	7	8	Poor

STEP 2. Determine the multipliers and compute the RWL's

RWL = LC × HM × VM × DM × AM × FM × CM

ORIGIN RWL = 51 × 1 × .83 × .98 × 1 × .22 × .90 = 8.2 Lbs

DESTINATION RWL = 51 × ___ × ___ × ___ × ___ × ___ × ___ = ___ Lbs

STEP 3. Compute the LIFTING INDEX

ORIGIN LIFTING INDEX = OBJECT WEIGHT (L) / RWL = 65.5 / 8.2 = 8

DESTINATION LIFTING INDEX = OBJECT WEIGHT (L) / RWL = ___ = ___

Single Task Job Analysis Worksheet

JOB ANALYSIS WORKSHEET

DEPARTMENT Finishing Div.
JOB TITLE Assembly Line Unloading
ANALYST'S NAME Ralston
DATE 11/8/12

JOB DESCRIPTION Substation B Phase 2 (lower)

STEP 1. Measure and record task variables

Object Weight (lbs)		Hand Location (in)				Vertical Distance (in)	Asymmetric Angle (degrees)		Frequency Rate lifts/min	Duration (HRS)	Object Coupling
		Origin		Dest.			Origin	Destination			
L (AVG.)	L (Max.)	H	V	H	V	D	A	A	F		C
65.5	65.5	6	42	16	10	32	0	0	7	8	Poor

STEP 2. Determine the multipliers and compute the RWL's

RWL = LC × HM × VM × DM × AM × FM × CM

ORIGIN RWL = 51 × 1 × .91 × .88 × 1 × .22 × .90 = 4.7 Lbs

DESTINATION RWL = 51 × ___ × ___ × ___ × ___ × ___ × ___ = ___ Lbs

STEP 3. Compute the LIFTING INDEX

ORIGIN LIFTING INDEX = OBJECT WEIGHT (L) / RWL = 65.5 / 4.7 = 13.9

DESTINATION LIFTING INDEX = OBJECT WEIGHT (L) / RWL = ___ = ___

Single Task Job Analysis Worksheet

Appendix D: The Completed Snook Tables (Substation A & B)

Substation A

Liberty Mutual Manual Materials Handling Guidelines

TABLE 2M - MALE POPULATION PERCENTAGES FOR LIFTING TASKS

ENDING BETWEEN KNUCKLE AND SHOULDER HEIGHT (≥31" AND ≤67")

OBJECT WEIGHT (POUNDS)	LIFTING DISTANCE (INCHES)	7 INCHES 15s	30 s	1m	5m	8h	10 INCHES 15s	30 s	1m	5m	8h	15 INCHES 15s	30 s	1m	5m	8h
88	30	-	-	-	-	12	-	-	-	-	-	-	-	-	-	-
	20	-	-	-	-	25	-	-	-	-	12	-	-	-	-	-
	10	-	-	16	21	40	-	-	-	-	30	-	-	-	-	-
92	30	-	-	-	-	16	-	-	-	-	-	-	-	-	-	-
	20	-	-	-	-	30	-	-	-	-	10	-	-	-	-	-
	10	-	-	20	25	52	-	-	-	13	36	-	-	-	-	-
88	30					21	-	-	-	-	-	-	-	-	-	-
	20	-	-	-	13	36	-	-	-	-	21	-	-	-	-	-
	10	-	11	25	32	57	-	-	12	17	42	-	-	-	-	13
84	30	-	-	-	-	27	-	-	-	-	13	-	-	-	-	-
	20	-	-	12	17	42	-	-	-	-	26	-	-	-	-	-
	10	-	15	31	38	63	-	-	17	22	48	-	-	-	-	17
80	30	-	-	-	11	33	-	-	-	-	18	-	-	-	-	-
	20	-	-	17	23	49	-	-	-	11	32	-	-	-	-	-
	10	12	20	38	44	58			22	28	54	-	-	-	-	23
76	30	-	-	11	18	40	-	-	-	-	24	-	-	-	-	-
	20	-	-	23	29	55	-	-	11	15	39	-	-	-	-	11
	10	17	26	45	51	72	-	13	29	35	60	-	-	-	-	25
72	30	-	-	16	21	47	-	-	-	-	31	-	-	-	-	-
	20	-	14	30	35	61	-	-	16	21	47	-	-	-	-	18
	10	23	33	52	59	77	11	19	36	42	66	-	-	-	13	36
68	30	-	11	22	28	54	-	-	-	15	39	-	-	-	-	11
	20	12	20	37	44	67	-	-	22	28	54	-	-	-	-	23
	10	30	41	59	64	81	16	25	43	50	72	-	-	14	19	44
64	30	12	17	30	36	61	-	-	10	21	47	-	-	-	-	10
	20	18	27	45	57	73	-	14	28	38	61	-	-	-	-	30
	10	39	49	65	70	84	23	33	51	57	77	-	-	20	26	52
60	30	19	28	38	45	68	-	12	23	29	55	-	-	-	-	24
	20	25	35	54	63	78	13	20	38	44	68	-	-	-	15	39
	10	47	57	72	76	87	31	42	59	64	81	-	13	28	34	60
56	30	26	32	48	54	74	13	19	32	38	63	-	-	-	-	32
	20	34	45	62	67	83	20	29	47	53	74	-	-	17	22	48
	10	58	65	77	81	+	41	51	67	71	85	13	20	37	44	67
52	30	38	43	57	63	80	21	28	41	48	70	-	-	13	17	42
	20	44	54	69	74	89	28	39	56	62	80	-	11	25	31	57
	10	64	72	82	85	+	50	60	73	77	88	20	29	47	53	74
48	30	46	54	68	71	85	31	38	52	58	77	-	11	21	27	53
	20	54	63	76	80	+	39	49	65	70	84	12	19	36	42	66
	10	72	78	86	88	+	60	68	80	83	+	30	40	57	63	80
44	30	57	64	74	78	88	42	50	62	67	83	14	19	32	38	63
	20	64	72	82	85	+	51	60	74	77	86	20	29	47	53	74
	10	79	84	+	+	+	69	76	85	87	+	42	51	67	71	86
40	30	68	72	81	84	+	55	61	72	76	87	24	31	44	51	72
	20	73	78	87	89	+	62	70	81	84	+	32	42	59	64	81
	10	85	88	+	+	+	77	82	89	+	+	54	65	75	79	89
36	30	77	81	87	89	+	68	72	80	83	+	38	45	58	63	80
	20	81	85	+	+	+	72	78	88	88	+	46	56	70	74	87
	10	89	+	+	+	+	84	88	+	+	+	68	73	82	85	+
32	30	84	87	+	+	+	77	81	86	88	+	53	60	70	74	87
	20	87	+	+	+	+	81	85	-	+	-	61	69	79	83	-
	10	+	+	+	+	+	59	+	-	+	+	76	82	88	+	-
28	30	+	+	+	+	+	65	88	+	+	+	80	73	81	84	
	20	+	+	+	+	+	88	+	+	+	+	74	79	87	88	+
	10	+	+	+	+	+	+	+	+	+	+	85	88	+	+	+

+ = GREATER THAN 90%   - = LESS THAN 10%

Substation A

Liberty Mutual Manual Materials Handling Guidelines

TABLE 2F - FEMALE POPULATION PERCENTAGES FOR LIFTING TASKS

ENDING BETWEEN KNUCKLE AND SHOULDER HEIGHT (≥28" AND ≤ 53")

HAND DISTANCE		7 INCHES					10 INCHES					15 INCHES				
OBJECT WEIGHT (POUNDS)	FREQUENCY ONE LIFT EVERY / LIFTING DISTANCE (INCHES)	15s	30 s	1m	5m	8h	15s	30 s	1m	5m	8h	15s	30 s	1m	5m	8h
59	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
56	30	-	-	-	-	-		-	-	-	-	-	-	-	-	-
	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10	-	-	-	-	15	-	-	-	-	-	-	-	-	-	-
53	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	20	-	-	-	-	11	-	-	-	-	-	-	-	-	-	-
	10	-	-	-	-	21	-	-	-	-	-	-	-	-	-	-
50	30	-	-	-		-	-	-	-	-	-	-	-	-	-	-
	20	-	-	-	-	17	-	-	-	-	-	-	-	-	-	-
	10	-	-	-	-	29	-	-	-	-	14	-	-	-	-	-
47	30	-	-	-	-	12	-	-	-	-	-	-	-	-	-	-
	20	-	-	-	-	24	-	-	-	-	11	-	-	-	-	-
	10	-	-	-	-	38	-	-	-	-	21	-	-	-	-	-
44	30	-	-	-	-	19	-	-	-	-	-	-	-	-	-	-
	20	-	-	-	-	34	-	-	-	-	17	-	-	-	-	-
	10	-	-	-	15	48	-	-	-	-	30	-	-	-	-	-
41	30	-	-	-	-	29	-	-	-	-	14	-	-	-	-	-
	20		-	-	12	44	-	-	-	-	26	-	-	-	-	-
	10	-	-	14	23	58	-	-	-	-	41	-	-	-	-	-
38	30	-	-	-	-	40	-	-	-	-	22	-	-	-	-	-
	20		-	12	21	56	-	-	-	-	38	-	-	-	-	-
	10	-	-	23	34	38	-	-	-	18	52	-	-	-	-	17
35	30	-	-	-	6	52	-	-	-	-	34	-	-	-	-	-
	20	-	14	22	32	66	-	-	-	16	50	-	-	-	-	16
	10	11	16	35	47	76	-	-	18	29	63	-	-	-	-	28
32	30	-	-	23	30	54	-	-	-	15	48	-	-	-	-	14
	20	20	25	34	46	76	-	11	16	28	62	-	-	-	-	28
	10	20	30	49	60	83	-	14	31	42	73	-	-	-	11	42
29	30	12	16	33	45	75	-	-	17	27	61	-	-	-	-	27
	20	34	38	49	60	83	18	22	31	43	74	-	-	-	11	42
	10	34	45	62	71	80	18	27	46	56	82	-	-	13	22	56
26	30	25	33	50	60	84	11	17	32	43	74	-	-	-	11	43
	20	50	55	84	73	89	32	38	47	58	83	-	-	14	23	58
	10	60	60	75	81	+	33	43	51	70	88	-	12	26	37	70
23	30	43	52	69	74	+	20	34	50	67	84	-	-	16	26	60
	20	66	70	77	83	+	51	56	64	73	89	17	21	30	41	73
	10	67	74	84	88	+	51	61	75	81	+	16	26	44	55	81
20	30	62	70	80	85	+	46	54	68	76	+	14	20	35	46	76
	20	80	83	87	+	+	69	73	79	84	+	37	41	51	61	84
	10	80	85	+	+	+	69	76	85	89	+	37	47	64	72	89
17	30	79	84	+	+	+	68	74	83	88	+	35	44	59	68	87
	20	+	+	+	-	+	85	86	58	+	+	60	64	71	79	+
	10	+	+	+	+	+	84	86	+	+	+	61	69	80	85	+
14	30	+	+	+	+	+	85	88	+	+	+	83	70	80	85	+
	20	+	+	+	+	+	+	+	+	+	+	80	83	87	+	+
	10	+	+	+	+	+	+	+	+	+	+	81	85	+	+	+
11	30	+	+	+	+	+	+	+	+	+	+	86	88	+	+	+
	20	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	10	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
8	30	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	20	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	10	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

+ = GREATER THAN 90% - = LESS THAN 10%

Substation A

Liberty Mutual Manual Materials Handling Guidelines

TABLE 11M - MALE POPULATION PERCENTAGES FOR CARRYING TASKS

CARRYING DISTANCE		7 FEET					14 FEET					28 FEET				
FREQUENCY ONE CARRY EVERY		15s	30 s	1m	5m	8h	15s	30 s	1m	5m	8h	15s	30 s	1m	5m	8h
OBJECT WEIGHT (POUNDS)	HAND HEIGHT (INCHES)															
99	43	-	-	-	18	50	-	-	-	-	36	-	-	-	-	22
	33	-	11	22	36	67	-	-	11	21	54	-	-	-	15	47
94	43	-	-	12	23	56	-	-	-	12	42	-	-	-	-	28
	33	-	15	26	42	71	-	-	15	27	60	-	-	11	20	53
89	43	-	-	17	29	62	-	-	-	17	49	-	-	-	-	34
	33	14	20	35	49	75	-	-	21	34	65	-	15	16	26	59
85	43	-	-	22	35	66	-	-	11	21	54	-	-	-	-	40
	33	18	25	40	54	78	-	-	26	39	70	-	19	20	32	64
81	43	-	14	27	41	70	-	-	15	27	60	-	-	-	14	46
	33	23	31	46	59	81	-	13	31	45	73	11	24	25	36	68
77	43	13	19	33	47	74	-	-	20	33	65	-	-	-	19	52
	33	29	37	52	64	84	-	17	38	51	77	15	30	31	44	73
73	43	18	25	40	53	78	-	-	26	39	69	-	13	14	25	58
	33	35	44	58	69	86	11	23	44	57	80	21	37	38	50	76
69	43	24	32	46	59	81	-	13	32	46	74	-	18	19	31	63
	33	42	50	64	74	88	16	29	51	63	83	27	44	45	57	80
65	43	31	39	53	65	84	-	19	40	53	78	-	25	26	38	69
	33	49	57	69	78	+	22	37	58	69	86	34	51	52	63	83
61	43	39	47	60	71	87	13	26	47	60	82	16	32	34	46	74
	33	57	64	74	82	+	29	44	64	74	88	42	58	59	69	86
57	43	47	55	67	76	89	19	34	55	67	85	23	41	42	54	79
	33	64	70	79	85	+	37	52	70	78	+	50	65	66	74	88
53	43	56	62	73	80	+	27	43	63	73	88	31	50	51	62	83
	33	70	75	83	88	+	46	60	76	83	+	56	71	72	79	+
49	43	64	70	78	84	+	37	52	70	78	+	41	58	59	69	86
	33	76	80	86	+	+	55	66	81	86	+	66	77	78	83	+
45	43	71	76	83	88	+	47	61	76	83	+	51	67	68	76	89
	33	81	85	89	+	+	64	75	85	88	+	73	82	82	87	+
41	43	78	82	87	+	+	58	70	82	87	+	61	74	75	82	+
	33	86	88	+	+	+	72	81	88	+	+	80	86	87	+	+
36	43	85	87	+	+	+	70	79	88	+	+	73	82	83	87	+
	33	+	+	+	+	+	81	87	+	+	+	86	+	+	+	+
31	43	+	+	+	+	+	81	87	+	+	+	82	89	89	+	+
	33	+	+	+	+	+	88	+	+	+	+	+	+	+	+	+

+ = GREATER THAN 90% - = LESS THAN 10%

Substation A

Liberty Mutual Manual Materials Handling Guidelines

TABLE 11F - FEMALE POPULATION PERCENTAGES FOR CARRYING TASKS

OBJECT WEIGHT (POUNDS)	HAND HEIGHT (INCHES)	7 FEET 15s	7 FEET 30 s	7 FEET 1m	7 FEET 5m	7 FEET 8h	14 FEET 15s	14 FEET 30 s	14 FEET 1m	14 FEET 5m	14 FEET 8h	28 FEET 15s	28 FEET 30 s	28 FEET 1m	28 FEET 5m	28 FEET 8h
73	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	31	-	-	-	-	21	-	-	-	-	-	-	-	-	-	-
70	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	31	-	-	-	-	28	-	-	-	-	70	-	-	-	-	12
67	40	-	-	-	-	15	-	-	-	-	13	-	-	-	-	-
	31	-	-	-	-	36	-	-	-	-	21	-	-	-	-	18
64	40	-	-	-	-	22	-	-	-	-	19	-	-	-	-	-
	31	-	-	-	-	45	-	-	-	-	29	-	-	-	-	25
61	40	-	-	-	-	30	-	-	-	-	27	-	-	-	-	13
	31	-	-	-	-	54	-	-	-	-	38	-	-	-	-	34
58	40	-	-	-	-	40	-	-	-	-	36	-	-	-	-	20
	31	-	-	-	11	63	-	-	-	-	47	-	-	-	-	43
55	40	-	-	-	-	50	-	-	-	-	48	-	-	-	-	29
	31	-	-	14	18	71	-	-	-	-	57	-	-	-	-	54
52	40	-	-	-	-	60	-	-	-	-	57	-	-	-	-	39
	31	-	14	22	27	79	-	-	11	14	67	-	-	-	12	63
49	40	-	-	13	17	70	-	-	11	14	67	-	-	-	-	51
	31	18	22	33	39	85	-	-	18	23	75	-	15	15	20	73
46	40	-	15	22	27	78	-	-	19	24	76	-	-	-	11	62
	31	28	34	45	51	89	-	-	29	34	82	12	25	25	30	80
43	40	17	23	34	40	85	-	-	31	36	83	-	15	15	20	73
	31	41	47	58	63	+	-	13	42	47	88	22	37	37	43	86
40	40	29	36	48	54	+	-	15	44	50	89	18	27	27	32	81
	31	55	60	70	74	+	-	23	55	61	+	35	51	51	57	+
37	40	44	51	62	67	+	11	27	59	64	+	31	41	41	47	88
	31	68	72	80	83	+	19	38	69	73	+	50	65	65	70	+
34	40	60	66	75	79	+	23	43	72	76	+	47	57	57	63	+
	31	79	82	87	89	+	34	54	60	83	+	65	77	77	61	+
31	40	74	79	85	87	+	40	60	83	86	+	64	72	72	76	+
	31	88	+	+	+	+	51	70	88	+	+	78	86	86	88	+
28	40	85	88	+	+	+	59	76	+	+	+	78	84	84	86	+
	31	+	+	+	+	+	69	82	+	+	+	87	+	+	+	+
25	40	+	+	+	+	+	77	87	+	+	+	88	+	+	+	+
	31	+	+	+	+	+	83	+	+	+	+	+	+	+	+	+

+ = GREATER THAN 90% - = LESS THAN 10%

Substation A

Liberty Mutual Manual Materials Handling Guidelines

TABLE 5M - MALE POPULATION PERCENTAGES FOR LOWERING TASKS

BEGINNING BETWEEN KNUCKLE AND SHOULDER HEIGHT (≥31" AND ≤57")

HAND DISTANCE		7 INCHES					10 INCHES					15 INCHES				
OBJECT WEIGHT (POUNDS)	LOWERING DISTANCE (INCHES) / FREQUENCY ONE LOWER EVERY	15s	30 s	1m	5m	8h	15s	30 s	1m	5m	8h	15s	30 s	1m	5m	8h
76	30	15	17	20	36	62	-	-	-	22	49	-	-	-	-	20
	20	21	25	33	51	73	-	13	19	36	62					34
	10	41	46	54	68	83	27	31	39	56	76	-	-	12	27	54
72	30	19	21	24	41	66	-	-	12	28	54	-	-	-	-	25
	20	28	30	38	55	76	14	17	24	41	66	-	-	-	14	39
	10	46	50	58	71	85	32	35	44	60	79	-	11	16	31	56
69	30	24	25	29	47	70	12	13	16	32	59	-	-	-	-	30
	20	31	35	44	60	79	18	21	29	46	70	-	-	-	18	44
	10	51	56	63	75	87	37	41	49	64	81	12	14	20	37	63
66	30	29	31	36	52	74	16	17	21	37	63			-	11	35
	20	36	41	49	64	81	22	28	34	51	73	-		-	22	50
	10	56	60	67	78	89	42	47	54	69	84	15	18	25	42	67
63	30	34	36	41	57	77	21	22	26	43	66	-	-	-	15	41
	20	42	47	55	69	84	28	32	40	57	77	-	-	13	28	55
	10	61	65	71	81	+	48	52	59	72	86	20	29	31	48	71
60	30	40	43	47	62	80	20	28	32	48	72	-	-	-	20	47
	20	48	52	60	73	88	34	39	48	62	80	-	12	18	34	60
	10	68	69	75	83	+	54	59	64	76	86	25	29	37	54	75
57	30	47	49	53	67	83	32	34	38	55	76	-	-	12	26	53
	20	54	58	65	76	88	40	44	52	67	83	14	17	23	40	65
	10	71	73	78	86	+	59	63	69	79	89	32	35	43	59	78
54	30	53	56	59	72	85	39	41	45	61	79	13	14	16	32	59
	20	60	64	70	80	+	47	51	58	71	85	19	22	29	47	70
	10	75	77	81	88	+	65	68	74	82	+	38	42	50	65	82
51	30	60	61	65	76	88	46	48	52	66	82	18	20	22	39	65
	20	66	69	74	83	+	53	57	64	76	88	25	29	36	53	76
	10	79	81	84	+	+	70	73	78	85	+	45	49	56	70	84
48	30	66	67	70	80	+	53	55	58	72	85	25	26	29	47	70
	20	71	74	79	86	+	60	64	70	80	+	32	36	44	60	78
	10	82	84	87	+	+	75	77	81	88	+	53	56	63	75	87
45	30	71	73	75	83	+	60	62	65	78	88	32	34	37	54	75
	20	76	78	82	88	+	67	70	75	83	+	40	44	52	68	82
	10	85	87	89	+	+	79	81	84	+	+	60	63	69	79	89
42	30	76	78	80	87	+	67	68	71	81	+	41	43	46	62	80
	20	80	82	86	+	+	72	75	79	86	+	49	53	59	72	86
	10	88	89	+	+	+	83	85	87	+	+	67	68	74	83	+
39	30	81	82	84	89	+	73	74	77	85	+	50	52	55	69	84
	20	84	85	88	+	+	78	80	83	89	+	57	61	67	78	86
	10	+	+	+	+	+	86	88	+	+	+	73	75	79	86	+
36	30	85	86	87	+	+	79	80	82	88	+	50	61	63	75	87
	20	88	89	+	+	+	82	84	87	+	+	65	68	73	82	+
	10	+	+	+	+	+	89	+	+	+	+	78	80	84	89	+
33	30	88	89	+	+	+	84	84	88	+	+	68	69	71	81	+
	20	+	+	+	+	+	86	88	+	+	+	73	75	79	88	+
	10	+	+	+	+	+	+	+	+	+	+	83	85	87	+	+
30	30	+	+	+	+	+	88	88	89	+	+	75	78	78	85	+
	20	+	+	+	+	+	+	+	+	+	+	80	81	84	+	+
	10	+	+	+	+	+	+	+	+	+	+	87	89	+	+	+
27	30	+	+	+	+	+	+	+	+	+	+	82	83	84	89	+
	20	+	+	+	+	+	+	+	+	+	+	85	86	89	+	+
	10	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
24	30	+	+	+	+	+	+	+	+	+	+	87	88	89	+	+
	20	+	+	+	+	+	+	+	+	+	+	89	+	+	+	+
	10	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

+ = GREATER THAN 90% - = LESS THAN 10%+

Substation A

Liberty Mutual Manual Materials Handling Guidelines

TABLE 5F - FEMALE POPULATION PERCENTAGES FOR LOWERING TASKS

BEGINNING BETWEEN KNUCKLE AND SHOULDER HEIGHTS (≥28" AND ≤53")

OBJECT WEIGHT (POUNDS)	LOWERING DISTANCE (INCHES)	7 INCHES 15s	7 INCHES 30 s	7 INCHES 1m	7 INCHES 5m	7 INCHES 8h	10 INCHES 15s	10 INCHES 30 s	10 INCHES 1m	10 INCHES 5m	10 INCHES 8h	15 INCHES 15s	15 INCHES 30 s	15 INCHES 1m	15 INCHES 5m	15 INCHES 8h
51	30	-	-	-	-	25	-	-	-	-	-	-	-	-	-	-
	20	-	-	-	-	43	-	-	-	-	23	-	-	-	-	-
	10	-	-	-	21	56	-	-	-	-	36	-	-	-	-	-
48	30	-	-	-	-	36		-	-	-	17	-	-	-	-	-
	20	-	-	-	17	53	-	-	-	-	33	-	-	-	-	-
	10	-	-	-	30	67	-	-	-	14	49	-	-	-	-	12
45	30	-	-	-	12	46	-	-	-	-	28	-	-	-	-	-
	20	-	-	-	26	63	-	-	-	-	44	-	-	-	-	-
	10	-	-	11	41	75	-	-	-	22	59	-	-	-	-	20
42	30	-	-	-	17	54	-	-	-	-	33	-	-	-	-	-
	20	-	-	-	33	60	-	-	-	15	51	-	-	-	-	14
	10	-	-	15	49	79	-	-	-	29	65	-	-	-	-	27
41	30	-	-	-	24	61	-	-	-	-	41	-	-	-	-	-
	20	-	-	-	41	75	-	-	-	22	59	-	-	-	-	20
	10	-	-	22	57	83	-	-	-	37	72	-	-	-	-	35
39	30	-	-	-	32	68	-	-	-	14	50	-	-	-	-	13
	20	-	11	16	49	80	-			29	66	-	-	-	-	27
	10	-	14	28	64	87	-	-	13	45	77	-	-	-	-	43
37	30	-	-	-	40	74	-	-	-	21	58	-	-	-	-	20
	20	14	16	23	58	84	-	-	-	38	72	-	-	-	-	36
	10	14	21	38	71	+	-	-	19	54	82	-	-	-	18	52
35	30	-	-	16	50	80	-	-	-	30	66	-	-	-	-	28
	20	21	24	31	60	88	-	-	14	47	78	-	-	-	11	45
	10	21	30	47	77	+	-	13	27	62	86	-	-	-	23	61
33	30	-	13	24	59	85	-	-	-	39	74	-	-	-	-	37
	20	29	33	41	73	+	13	16	22	57	83	-	-	-	18	55
	10	30	39	57	82	+	13	21	37	70	89	-	-	-	33	69
31	30	14	20	34	68	89	-	-	16	50	80	-	-	-	13	48
	20	40	44	52	80	+	21	24	31	66	88	-	-	-	27	64
	10	40	50	66	87	+	21	30	47	77	+	-	-	12	43	76
29	30	23	30	45	76	+	-	14	25	60	85	-	-	-	22	58
	20	51	55	62	85	+	31	35	43	74	+	-	-	-	38	73
	10	51	60	74	+	+	32	41	56	83	+	-	-	20	54	82
27	30	34	42	57	82	+	16	23	37	70	89	-	-	-	33	69
	20	62	65	71	89	+	43	47	54	81	+	-	12	16	50	80
	10	62	70	81	+	+	44	53	68	88	+	-	16	30	65	87
25	30	47	56	68	88	+	27	35	50	79	+	-	-	13	46	77
	20	72	75	80	+	+	58	59	66	87	+	18	21	27	62	86
	10	72	79	87	+	+	58	65	77	+	+	19	27	43	74	+
23	30	80	87	77	+	+	41	49	63	85	+	-	13	24	59	86
	20	81	83	88	+	+	68	71	76	+	+	31	34	41	73	+
	10	81	86	+	+	+	68	75	84	+	+	31	40	57	82	+
21	30	72	78	85	+	+	56	63	74	+	+	19	25	39	71	+
	20	87	89	+	+	+	78	80	84	+	+	46	50	56	82	+
	10	88	+	+	+	+	78	83	+	+	+	46	55	70	89	+
18	30	86	89	+	+	+	76	81	87	+	+	43	50	63	86	+
	20	+	+	+	+	+	89	+	+	+	+	69	72	70	+	+
	10	+	+	+	+	+	89	+	+	+	+	70	76	85	+	+
15	30	+	+	+	+	+	+	+	+	+	+	70	76	83	+	+
	20	+	+	+	+	+	+	+	+	+	+	86	88	+	+	+
	10	+	+	+	+	+	+	+	+	+	+	87	+	+	+	+
12	30	+	+	+	+	+	+	+	+	+	+	88	+	+	+	+
	20	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	10	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

+ = GREATER THAN 90% - = LESS THAN 10%

Substation B

Liberty Mutual Manual Materials Handling Guidelines

TABLE 2M - MALE POPULATION PERCENTAGES FOR LIFTING TASKS

ENDING BETWEEN KNUCKLE AND SHOULDER HEIGHT (≥31" AND ≤57")

HAND DISTANCE		7 INCHES					10 INCHES					15 INCHES				
FREQUENCY ONE LIFT EVERY		15s	30 s	1m	5m	8h	15s	30 s	1m	5m	8h	15s	30 s	1m	5m	8h
OBJECT WEIGHT (POUNDS)	LIFTING DISTANCE (INCHES)															
96	30	-	-	-	-	12	-	-	-	-	-	-	-	-	-	-
	20	-	-	-	-	25	-	-	-	-	12	-	-	-	-	-
	10	-	-	16	21	46	-	-	-	-	30	-	-	-	-	-
92	30	-	-	-	-	16		-	-	-	-	-	-	-	-	-
	20	-	-	-	-	30	-	-	-	-	16	-	-	-	-	-
	10	-	-	20	26	52	-	-	-	13	36	-	-	-	-	-
88	30	-	-	-	-	21	-	-	-	-	-	-	-	-	-	-
	20	-	-	-	13	36	-	-	-	-	21	-	-	-	-	-
	10	-	11	25	32	57	-	-	12	17	42	-	-	-	-	13
84	30	-	-	-	-	27	-	-	-	-	13	-	-	-	-	-
	20	-	-	12	17	42	-	-	-	-	26	-	-	-	-	-
	10	-	15	31	38	63	-	-	17	22	48	-	-	-	-	17
80	30	-	-	-	11	33	-	-	-	-	18	-	-	-	-	-
	20	-	-	17	23	49	-	-	-	11	32	-	-	-	-	-
	10	12	20	38	44	68	-	-	22	28	54	-	-	-	-	23
76	30	-	-	11	16	40	-	-	-	-	24	-	-	-	-	-
	20	-	-	23	29	55	-	-	11	15	39	-	-	-	-	11
	10	17	26	45	51	72	-	13	29	35	60	-	-	-	-	29
72	30	-	-	16	21	47	-	-	-	-	31	-	-	-	-	-
	20	-	14	30	36	61	-	-	16	21	47	-	-	-	-	16
	10	23	33	52	58	77	11	19	36	42	66	-	-	-	13	36
68	30	-	11	22	28	54	-	-	-	15	39	-	-	-	-	11
	20	12	20	37	44	67	-	-	22	28	54	-	-	-	-	23
	10	30	41	59	64	81	16	25	43	50	72	-	-	14	19	44
64	30	12	17	30	36	61	-	-	16	21	47	-	-	-	-	16
	20	18	27	45	52	73	-	14	29	36	61	-	-	-	-	30
	10	38	49	65	70	84	23	33	51	57	77	-	-	20	26	52
60	30	18	25	38	45	68	-	12	23	29	55	-	-	-	-	24
	20	25	35	54	60	78	13	20	38	44	68	-	-	-	15	39
	10	47	57	72	76	87	31	42	59	64	81	-	13	28	34	60
56	30	26	33	48	54	74	13	19	32	38	63	-	-	-	-	32
	20	34	45	62	67	83	20	29	47	53	74	-	-	17	22	48
	10	56	65	77	81	+	41	51	67	71	85	13	20	37	44	67
52	30	36	43	57	63	80	21	28	41	48	70	-	-	13	17	42
	20	44	54	69	74	86	28	39	56	62	80	-	11	25	31	57
	10	64	72	82	85	+	50	60	73	77	88	20	29	47	53	74
48	30	46	54	66	71	85	31	38	52	58	77	-	11	21	27	53
	20	54	63	76	80	+	39	49	65	70	84	12	19	36	42	66
	10	72	78	86	88	+	60	68	80	83	+	30	40	57	63	80
44	30	57	64	74	78	88	42	50	62	67	83	14	19	32	38	63
	20	64	72	82	85	+	51	60	74	77	88	20	29	47	53	74
	10	79	84	+	+	+	69	76	85	87	+	42	51	67	71	85
40	30	68	73	81	84	+	55	61	72	76	87	24	31	44	51	72
	20	73	79	87	89	+	62	70	81	84	+	32	42	59	64	81
	10	85	88	+	+	+	77	82	89	+	+	54	63	75	79	89
36	30	77	81	87	89	+	66	72	80	83	+	38	45	58	63	80
	20	81	85	+	+	+	72	78	86	88	+	46	56	70	74	87
	10	89	+	+	+	+	84	88	+	+	+	66	73	82	85	+
32	30	84	87	+	+	+	77	81	86	88	+	53	60	70	74	87
	20	87	+	+	+	+	81	85	+	+	+	61	69	79	83	+
	10	+	+	+	+	+	89	+	+	+	+	76	82	88	+	+
28	30	+	+	+	+	+	85	88	+	+	+	68	73	81	84	+
	20	+	+	+	+	+	88	+	+	+	+	74	79	87	89	+
	10	+	+	+	+	+	+	+	+	+	+	85	88	+	+	+

+ = GREATER THAN 90% - = LESS THAN 10%

Substation B

Liberty Mutual Manual Materials Handling Guidelines

TABLE 2F - FEMALE POPULATION PERCENTAGES FOR LIFTING TASKS

ENDING BETWEEN KNUCKLE AND SHOULDER HEIGHT (≥28" AND ≤ 53")

HAND DISTANCE		7 INCHES					10 INCHES					15 INCHES				
FREQUENCY ONE LIFT EVERY		15s	30 s	1m	5m	8h	15s	30 s	1m	5m	8h	15s	30 s	1m	5m	8h
OBJECT WEIGHT (POUNDS)	LIFTING DISTANCE (INCHES)															
59	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
56	30	-	-	-	-	-		-	-	-	-	-	-	-	-	-
	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10	-	-	-	-	15	-	-	-	-	-	-	-	-	-	-
53	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	20	-	-	-	-	11	-	-	-	-	-	-	-	-	-	-
	10	-	-	-	-	21	-	-	-	-	-	-	-	-	-	-
50	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	20	-	-	-	-	17	-	-	-	-	-	-	-	-	-	-
	10	-	-	-	-	29	-	-	-	-	14	-	-	-	-	-
47	30	-	-	-	-	12	-	-	-	-	-	-	-	-	-	-
	20	-	-	-	-	24	-	-	-	-	11	-	-	-	-	-
	10	-	-	-	-	38	-	-	-	-	21	-	-	-	-	-
44	30	-	-	-	-	19	-	-	-	-	-	-	-	-	-	-
	20	-	-	-	-	34	-	-	-	-	17	-	-	-	-	-
	10	-	-	-	15	48	-	-	-	-	30	-	-	-	-	-
41	30	-	-	-	-	29	-	-	-	-	14	-	-	-	-	-
	20		-	-	12	44	-	-	-	-	26	-	-	-	-	-
	10	-	-	14	23	58	-	-	-	-	41	-	-	-	-	-
38	30	-	-	-	-	40	-	-	-	-	22	-	-	-	-	-
	20	-	-	12	21	56	-	-	-	-	38	-	-	-	-	-
	10	-	-	23	34	68	-	-	-	18	52	-	-	-	-	17
35	30	-	-	-	18	52	-	-	-	-	34	-	-	-	-	-
	20	-	14	22	32	66	-	-	-	16	50	-	-	-	-	16
	10	11	18	35	47	76	-	-	18	29	63	-	-	-	-	28
32	30	-	-	20	30	64	-	-	-	15	48	-	-	-	-	14
	20	20	25	34	46	76	-	11	18	28	62	-	-	-	-	28
	10	20	30	49	60	83	-	14	31	42	73	-	-	-	11	42
29	30	12	18	33	45	75	-	-	17	27	61	-	-	-	-	27
	20	34	39	49	60	83	18	22	31	43	74	-	-	-	11	42
	10	34	45	62	71	89	18	27	45	56	82	-	-	13	22	56
26	30	25	33	50	60	84	11	17	32	43	74	-	-	-	11	43
	20	50	55	64	73	89	32	38	47	58	83	-	-	14	23	58
	10	50	60	75	81	+	33	43	61	70	88	-	12	26	37	70
23	30	43	52	66	74	+	25	34	50	61	84	-	-	16	26	60
	20	66	70	77	83	+	51	56	64	73	89	17	21	30	41	73
	10	67	74	84	88	+	51	61	75	81	+	18	26	44	55	81
20	30	62	70	80	85	+	46	54	68	76	+	14	20	35	46	76
	20	80	83	87	+	+	69	73	79	84	+	37	41	51	61	84
	10	80	85	+	+	+	69	76	85	89	+	37	47	64	72	89
17	30	79	84	+	+	+	68	74	83	88	+	35	44	59	68	87
	20	+	+	+	+	+	83	86	89	+	+	60	64	71	79	+
	10	+	+	+	+	+	84	88	+	+	+	61	69	80	85	+
14	30	+	+	+	+	+	85	88	+	+	+	63	70	80	85	+
	20	+	+	+	+	+	+	+	+	+	+	80	83	87	+	+
	10	+	+	+	+	+	+	+	+	+	+	81	85	+	+	+
11	30	+	+	+	+	+	+	+	+	+	+	85	88	+	+	+
	20	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	10	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
8	30	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	20	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	10	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

+ = GREATER THAN 90%   - = LESS THAN 10%

Substation B

Liberty Mutual Manual Materials Handling Guidelines

TABLE 11M - MALE POPULATION PERCENTAGES FOR CARRYING TASKS

CARRYING DISTANCE		7 FEET					14 FEET					28 FEET				
FREQUENCY ONE CARRY EVERY		15s	30 s	1m	5m	8h	15s	30 s	1m	5m	8h	15s	30 s	1m	5m	8h
OBJECT WEIGHT (POUNDS)	**HAND HEIGHT (INCHES)**															
99	43	-	-	-	18	50	-	-	-	-	36	-	-	-	-	22
	33	-	11	22	36	67	-	-	11	21	54	-	-	-	15	47
94	43	-	-	12	23	56	-	-	-	12	42	-	-	-	-	28
	33	-	15	28	42	71	-	-	15	27	60	-	-	11	20	53
89	43	-	-	17	29	62	-	-	-	17	49	-	-	-	-	34
	33	14	20	35	49	75	-	-	21	34	65	-	15	16	26	59
85	43	-	-	22	35	66	-	-	11	21	54	-	-	-	-	40
	33	18	25	40	54	78	-	-	26	39	70	-	19	20	32	64
81	43	-	14	27	41	70	-	-	15	27	60	-	-	-	14	46
	33	23	31	46	59	81	-	13	31	45	73	11	24	25	38	68
77	43	13	19	33	47	74	-	-	20	33	65	-	-	-	19	52
	33	29	37	52	64	84	-	17	38	51	77	15	30	31	44	73
73	43	18	25	40	53	78	-	-	26	39	69	-	13	14	25	58
	33	35	44	58	69	86	11	23	44	57	80	21	37	38	50	76
69	43	24	32	46	59	81	-	13	32	46	74	-	18	19	31	63
	33	42	50	64	74	88	16	29	51	63	83	27	44	45	57	80
65	43	31	39	53	65	84	-	19	40	53	78	-	25	26	38	69
	33	49	57	69	78	+	22	37	58	69	86	34	51	52	63	83
61	43	39	47	60	71	87	13	26	47	60	82	16	32	34	46	74
	33	57	64	74	82	+	29	44	64	74	88	42	58	59	69	86
57	43	47	55	67	76	89	19	34	55	67	85	23	41	42	54	79
	33	64	70	79	85	+	37	52	70	78	+	50	65	66	74	88
53	43	56	62	73	80	+	27	43	63	73	88	31	50	51	62	83
	33	70	75	83	88	+	46	60	76	83	+	58	71	72	79	+
49	43	64	70	78	84	+	37	52	70	78	+	41	58	59	69	86
	33	76	80	86	+	+	55	68	81	86	+	66	77	78	83	+
45	43	71	76	83	88	+	47	61	76	83	+	51	67	68	76	89
	33	81	85	89	+	+	64	75	85	89	+	73	82	82	87	+
41	43	78	82	87	+	+	58	70	82	87	+	61	74	75	82	+
	33	86	88	+	+	+	72	81	88	+	+	80	86	87	+	+
36	43	85	87	+	+	+	70	79	88	+	+	73	82	83	87	+
	33	+	+	+	+	+	81	87	+	+	+	86	+	+	+	+
31	43	+	+	+	+	+	81	87	+	+	+	82	89	89	+	+
	33	+	+	+	+	+	88	+	+	+	+	+	+	+	+	+

+ = GREATER THAN 90% - = LESS THAN 10%

Substation B

Liberty Mutual Manual Materials Handling Guidelines

TABLE 11F - FEMALE POPULATION PERCENTAGES FOR CARRYING TASKS

CARRYING DISTANCE		7 FEET					14 FEET					28 FEET				
FREQUENCY ONE CARRY EVERY		15s	30 s	1m	5m	8h	15s	30 s	1m	5m	8h	15s	30 s	1m	5m	8h
OBJECT WEIGHT (POUNDS)	HAND HEIGHT (INCHES)															
73	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	31	-	-	-	-	21	-	-	-	-	-	-	-	-	-	-
70	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	31	-	-	-	-	28	-	-	-	-	70	-	-	-	-	12
67	40	-	-	-	-	15	-	-	-	-	13	-	-	-	-	-
	31	-	-	-	-	36	-	-	-	-	21	-	-	-	-	18
64	40	-	-	-	-	22	-	-	-	-	19	-	-	-	-	-
	31	-	-	-	-	45	-	-	-	-	29	-	-	-	-	25
61	40	-	-	-	-	30	-	-	-	-	27	-	-	-	-	13
	31	-	-	-	-	54	-	-	-	-	38	-	-	-	-	34
58	40	-	-	-	-	40	-	-	-	-	36	-	-	-	-	20
	31	-	-	-	11	63	-	-	-	-	47	-	-	-	-	43
55	40	-	-	-	-	50	-	-	-	-	46	-	-	-	-	29
	31	-	-	14	18	71	-	-	-	-	57	-	-	-	-	54
52	40	-	-	-	-	60	-	-	-	-	57	-	-	-	-	39
	31	-	14	22	27	79	-	-	11	14	67	-	-	-	12	63
49	40	-	-	13	17	70	-	-	11	14	67	-	-	-	-	51
	31	18	22	33	39	85	-	-	18	23	75	-	15	15	20	73
46	40	-	13	22	27	78	-	-	19	24	76	-	-	-	11	62
	31	28	34	45	51	89	-	-	29	34	82	12	25	25	30	80
43	40	17	23	34	40	85	-	-	31	36	83	-	15	15	20	73
	31	41	47	58	63	+	-	13	42	47	88	22	37	37	43	86
40	40	29	36	48	54	+	-	15	44	50	89	18	27	27	32	81
	31	55	60	70	74	+	-	23	55	61	+	35	51	51	57	+
37	40	44	51	62	67	+	11	27	59	64	+	31	41	41	47	88
	31	68	72	80	83	+	19	38	69	73	+	50	65	65	70	+
34	40	60	66	75	79	+	23	43	72	76	+	47	57	57	63	+
	31	79	82	87	89	+	34	54	80	83	+	65	77	77	81	+
31	40	74	79	85	87	+	40	60	83	86	+	64	72	72	76	+
	31	88	+	+	+	+	51	70	88	+	+	78	86	86	88	+
28	40	85	88	+	+	+	59	76	+	+	+	78	84	84	86	+
	31	+	+	+	+	+	69	82	+	+	+	87	+	+	+	+
25	40	+	+	+	+	+	77	87	+	+	+	88	+	+	+	+
	31	+	+	+	+	+	83	+	+	+	+	+	+	+	+	+

+ = GREATER THAN 90%   - = LESS THAN 10%

Substation B

Liberty Mutual Manual Materials Handling Guidelines

TABLE 5M - MALE POPULATION PERCENTAGES FOR LOWERING TASKS

BEGINNING BETWEEN KNUCKLE AND SHOULDER HEIGHT (≥31" AND ≤57")

HAND DISTANCE		7 INCHES					10 INCHES					15 INCHES				
FREQUENCY ONE LOWER EVERY		15s	30 s	1m	5m	8h	15s	30 s	1m	5m	8h	15s	30 s	1m	5m	8h
OBJECT WEIGHT (POUNDS)	LOWERING DISTANCE (INCHES)															
75	30	15	17	20	36	62	-	-	-	22	49	-	-	-	-	20
	20	21	25	33	51	73	-	13	19	36	62	-	-	-	-	34
	10	41	46	54	68	83	27	31	39	56	76	-	-	12	27	54
72	30	19	21	24	41	66	-	-	12	26	54	-	-	-	-	25
	20	26	30	38	55	76	14	17	24	41	66	-	-	-	14	39
	10	46	50	58	71	85	32	36	44	60	79	-	11	16	31	58
69	30	24	25	29	47	70	12	13	16	32	59	-	-	-	-	30
	20	31	35	44	60	79	18	21	29	46	70	-	-	-	18	44
	10	51	55	63	75	87	37	41	49	64	81	12	14	20	37	63
66	30	29	31	35	52	74	16	17	21	37	63	-	-	-	11	35
	20	36	41	49	64	81	22	26	34	51	73	-	-	-	22	50
	10	56	60	67	78	89	42	47	54	69	84	15	18	25	42	67
63	30	34	36	41	57	77	21	22	26	43	68	-	-	-	15	41
	20	42	47	55	69	84	28	32	40	57	77	-	-	13	28	55
	10	61	65	71	81	+	48	52	59	72	86	20	23	31	48	71
60	30	40	43	47	62	80	26	28	32	49	72	-	-	-	20	47
	20	48	52	60	73	86	34	38	46	62	80	-	12	18	34	60
	10	68	69	75	83	+	54	58	64	76	88	25	29	37	54	75
57	30	47	49	53	67	83	32	34	38	55	76	-	-	12	26	53
	20	54	58	65	76	88	40	44	52	67	83	14	17	23	40	65
	10	71	73	78	86	+	59	63	69	79	89	32	35	43	59	78
54	30	53	55	59	72	85	39	41	45	61	79	13	14	16	32	59
	20	60	64	70	80	+	47	51	58	71	85	19	22	29	47	70
	10	75	77	81	88	+	65	68	74	82	+	38	42	50	65	82
51	30	60	61	65	76	88	46	48	52	66	82	18	20	22	39	65
	20	66	69	74	83	+	53	57	64	76	88	25	29	36	53	75
	10	79	81	84	+	+	70	73	78	85	+	45	49	56	70	84
48	30	66	67	70	80	+	53	55	58	72	85	25	26	29	47	70
	20	71	74	79	86	+	60	64	70	80	+	32	36	44	60	79
	10	82	84	87	+	+	75	77	81	88	+	53	56	63	75	87
45	30	71	73	75	83	+	60	62	65	76	88	32	34	37	54	75
	20	76	78	82	88	+	67	70	75	83	+	40	44	52	66	82
	10	85	87	89	+	+	79	81	84	+	+	60	63	69	79	89
42	30	76	78	80	87	+	67	68	71	81	+	41	43	46	62	80
	20	80	82	86	+	+	72	75	79	86	+	49	53	59	72	86
	10	88	89	+	+	+	83	85	87	+	+	67	69	74	83	+
39	30	81	82	84	89	+	73	74	77	85	+	50	52	55	69	84
	20	84	86	88	+	+	78	80	83	89	+	57	61	67	78	88
	10	+	+	+	+	+	86	88	+	+	+	73	75	79	86	+
36	30	85	86	87	+	+	79	80	62	88	+	59	61	63	75	87
	20	88	89	+	+	+	82	84	87	+	+	65	68	73	82	+
	10	+	+	+	+	+	89	+	+	+	+	78	80	84	89	+
33	30	88	89	+	+	+	84	84	86	+	+	68	69	71	81	+
	20	+	+	+	+	+	86	88	+	+	+	73	75	79	86	+
	10	+	+	+	+	+	+	+	+	+	+	83	85	87	+	+
30	30	+	+	+	+	+	88	88	89	+	+	75	76	78	85	+
	20	+	+	+	+	+	+	+	+	+	+	80	81	84	+	+
	10	+	+	+	+	+	+	+	+	+	+	87	89	+	+	+
27	30	+	+	+	+	+	+	+	+	+	+	82	83	84	89	+
	20	+	+	+	+	+	+	+	+	+	+	85	86	89	+	+
	10	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
24	30	+	+	+	+	+	+	+	+	+	+	87	88	89	+	+
	20	+	+	+	+	+	+	+	+	+	+	89	+	+	+	+
	10	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

+ = GREATER THAN 90%   - = LESS THAN 10%+

Substation B

Liberty Mutual Manual Materials Handling Guidelines

TABLE 5F - FEMALE POPULATION PERCENTAGES FOR LOWERING TASKS

BEGINNING BETWEEN KNUCKLE AND SHOULDER HEIGHTS (≥28" AND ≤53")

HAND DISTANCE		7 INCHES					10 INCHES					15 INCHES				
FREQUENCY ONE LOWER EVERY		15s	30 s	1m	5m	8h	15s	30 s	1m	5m	8h	15s	30 s	1m	5m	8h
OBJECT WEIGHT (POUNDS)	LOWERING DISTANCE (INCHES)															
51	30	-	-	-	-	25	-	-	-	-	-	-	-	-	-	-
	20	-	-	-	-	43	-	-	-	-	23	-	-	-	-	-
	10	-	-	-	21	58	-	-	-	-	38	-	-	-	-	-
48	30	-	-	-	-	35		-	-	-	17	-	-	-	-	-
	20	-	-	-	17	53	-	-	-	-	33	-	-	-	-	-
	10	-	-	-	30	67	-	-	-	14	49	-	-	-	-	12
45	30	-	-	-	12	46	-	-	-	-	26	-	-	-	-	-
	20	-	-	-	26	63	-	-	-	-	44	-	-	-	-	-
	10	-	-	11	41	75	-	-	-	22	59	-	-	-	-	20
43	30	-	-	-	17	54	-	-	-	-	33	-	-	-	-	-
	20	-	-	-	33	69	-	-	-	15	51	-	-	-	-	14
	10	-	-	15	49	79	-	-	-	29	65	-	-	-	-	27
41	30	-	-	-	24	61	-	-	-	-	41	-	-	-	-	-
	20	-	-	-	41	75	-	-	-	22	59	-	-	-	-	20
	10	-	-	22	57	83	-	-	-	37	72	-	-	-	-	35
39	30	-	-	-	32	68	-	-	-	14	50	-	-	-	-	13
	20	-	11	16	49	80	-	-	-	29	66	-	-	-	-	27
	10	-	14	29	64	87	-	-	13	45	77	-	-	-	-	43
37	30	-	-	-	40	74	-	-	-	21	58	-	-	-	-	20
	20	14	16	23	58	84	-	-	-	38	72	-	-	-	-	36
	10	14	21	38	71	+	-	-	19	54	82	-	-	-	16	52
35	30	-	-	16	50	80	-	-	-	30	66	-	-	-	-	28
	20	21	24	31	66	88	-	-	14	47	78	-	-	-	11	45
	10	21	30	47	77	+	-	13	27	62	86	-	-	-	23	61
33	30	-	13	24	59	85	-	-	-	39	74	-	-	-	-	37
	20	29	33	41	73	+	13	16	22	57	83	-	-	-	18	55
	10	30	39	57	82	+	13	21	37	70	89	-	-	-	33	69
31	30	14	20	34	68	89	-	-	16	50	80	-	-	-	13	48
	20	40	44	52	80	+	21	24	31	66	88	-	-	-	27	64
	10	40	50	66	87	+	21	30	47	77	+	-	-	12	43	76
29	30	23	30	45	76	+	-	14	25	60	85	-	-	-	22	59
	20	51	55	62	85	+	31	35	43	74	+	-	-	-	38	73
	10	51	60	74	+	+	32	41	58	83	+	-	-	20	54	82
27	30	34	42	57	82	+	16	23	37	70	89	-	-	-	33	69
	20	62	65	71	89	+	43	47	54	81	+	-	12	16	50	80
	10	62	70	81	+	+	44	53	68	88	+	-	16	30	65	87
25	30	47	55	68	88	+	27	35	50	79	+	-	-	13	46	77
	20	72	75	80	+	+	56	59	66	87	+	18	21	27	62	86
	10	72	79	87	+	+	56	65	77	+	+	19	27	43	74	+
23	30	60	67	77	+	+	41	49	63	85	+	-	13	24	59	85
	20	81	83	86	+	+	68	71	76	+	+	31	34	41	73	+
	10	81	85	+	+	+	68	75	84	+	+	31	40	57	82	+
21	30	72	78	85	+	+	56	63	74	+	+	19	25	39	71	+
	20	87	89	+	+	+	78	80	84	+	+	46	50	56	82	+
	10	88	+	+	+	+	78	83	+	+	+	46	55	70	89	+
18	30	86	89	+	+	+	76	81	87	+	+	43	50	63	86	+
	20	+	+	+	+	+	89	+	+	+	+	69	72	76	+	+
	10	+	+	+	+	+	89	+	+	+	+	70	76	85	+	+
15	30	+	+	+	+	+	+	+	+	+	+	70	76	83	+	+
	20	+	+	+	+	+	+	+	+	+	+	86	88	+	+	+
	10	+	+	+	+	+	+	+	+	+	+	87	+	+	+	+
12	30	+	+	+	+	+	+	+	+	+	+	89	+	+	+	+
	20	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	10	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

+ = GREATER THAN 90%   - = LESS THAN 10%