Spring 5-1-2019

Analysis of the Effect of an Ergonomic Improvement Program on Incident Rates in a Forklift Manufacturing/assembly Plant

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ANALYSIS OF THE EFFECT OF AN ERGONOMIC IMPROVEMENT PROGRAM ON INCIDENT RATES IN A FORKLIFT MANUFACTURING/ASSEMBLY PLANT

A Thesis

Presented to

The College of Graduate and Professional Studies

Department of The Built Environment

Indiana State University

Terre Haute, Indiana

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

Occupational Safety Management

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by

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May 2019

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ABSTRACT

The company experienced a high volume of recordable injuries and decided it was time to implement an ergonomic program in order to drive down the number of ergonomic related injuries. The ergonomics program was implemented in mid-2016 and positively impacted the company's incident rate.

Due to the high ergonomic related incident rate the company had in 2016, the decision was made to implement an ergonomic improvement program in 2017. The goal is to determine the effectiveness of the ergonomics improvement program.

This project consists of the study of data before and after the implementation as well as a review of related literature. This study began with assessing risk of each job task in the facility after realizing the need for an improvement. After each task was assessed and assigned a risk priority number, the project was added to a common spreadsheet. The project leaders chose projects to complete from the common spreadsheet and produced a PDCA for each completed project. The PDCA entailed a section for planning, doing, and checking for sustainability of the project. Upon completion of the project, a walk to present the improvements was conducted for recognition. No statistically significant reduction of injuries was found, although there was a 17% reduction of injuries. However, a significant reduction in severity of each injury was noted throughout the study.

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CHAPTER 1

INTRODUCTION

Background

Broadly, manufacturing can be defined as the conversion of raw materials into finished products. A forklift manufacturing/assembly facility involves a variety of activities such as product design, process and material selection, production planning and control, material handling, packaging, and marketing and sales. During this conversion process, the key factors that dictate the productivity and competitiveness of one manufacturer over another are the ease, efficiency, and quality of product. In order to have a successful forklift manufacturing/assembly facility, ergonomics must be an important component of the process. Ergonomics is the "study of work". A systematic ergonomics improvement process removes risk factors that lead to musculoskeletal injuries.

In order to be systematic, the improvement must be able to be sustained. Sustainment can be achieved many ways, but the main method discussed in this study is by changing work instructions/standard work documents on the production floor. If there is a high turnover rate in the company, sustainability is crucial. Once an ergonomic improvement is made, it must be documented and training on the new method must be applied in order for it to be considered sustained. That way if the employee who was present at the time of the improvement ever decides to separate from that position, the improved way remains active in production.

The forklift manufacturing/assembly facility studied in this project is located in Central Indiana. The facility was experiencing workers compensation cases for sprains/strains, tendonitis, carpal tunnel syndrome, and other repetitive motion injuries. From 2015 to 2016, the recordable injuries increased from 21 to 46 with 75% of those recordable injuries being ergonomic injuries. The facility management and safety team decided to implement an ergonomic risk assessment program immediately following the 2016 calendar year.

Need For Study

The company observed an elevated number of ergonomic related injuries in 2016 and the decision was made to implement an ergonomic improvement program. This study will assess the effectiveness of the program.

Null Hypotheses

The Null Hypothesis:

There will be no statistically significant reduction in the rate of ergonomically related injuries after implementing a program of ergonomic improvements at a forklift manufacturing/assembly facility.

Alternative Hypotheses

The Alternative Hypothesis:

There will be a statistically significant reduction in the rate of ergonomically related injuries after implementing a program of ergonomic improvements at a forklift manufacturing/assembly facility.

Research Question:

Is there a statistically significant reduction in the rate of ergonomically-related injuries after implementing a program of ergonomic improvements at a forklift manufacturing/assembly facility?

Primary Goal

The primary goal of this research project is to evaluate the effectiveness of an ergonomics program that was implemented at a manufacturing/assembly facility.

Objectives

- Evaluate the scope of the problem
- Conduct a review of literature related to:
    - Ergonomics in manufacturing
    - Ergonomics and six sigma
    - Six sigma methodology in manufacturing
    - Ergonomics in safety
- Collection and Analysis of data from January 1, 2016-December 31, 2018 about ergonomically related injuries at Company X.
- Developing or adopting a risk assessment model to follow
- Statistically compare rates from before and after implementation of ergonomic program
- Summarize the data and make recommendations based on the findings

Limitations

- Amount of time used for the study
- Multiple safety professionals conducting risk assessments so there is no way of assuring consistency
- Limited financial funding for process
- Posture portion of RPN assignment is focused on one body part per risk assessment, not multiple body parts

Delimitations

- The study will be conducted at a Central Indiana forklift manufacturing/assembly facility.
- The data will be analyzed from January 1, 2016 through December 31, 2018.
- The researcher will select the risk assessment model to be used.

Assumptions

- Assume consistency exists between different evaluators of the risk assessments
- Assume that injury data has been collected accurately and completely

Definitions

Risk Assessment Model

A systematic process of evaluating the potential risks that may be involved in a projected activity or undertaking.

Ergonomically Related Injury

An injury that occurs when there is ongoing exposure to ergonomic risk factor. Ergonomic injuries may be referred to as Repetitive Stress Injuries (RSIs), Repetitive Motion Injuries (RMIs), Musculoskeletal Disorders (MSDs), Cumulative Trauma Disorders (CTDs), or Cumulative Trauma Injuries (CTIs)

Forklift Manufacturing/Assembly Facility

A factory where manufactured parts are assembled into a finished part. The company studied in this project manufactures in-house parts and assembles forklifts with the material.

Force Gauge

A handheld measuring instrument used to measure the force during a push or pull test.

CHAPTER 2

REVIEW OF LITERATURE

Introduction to Ergonomics

This literature review will provide information on various approaches to implementing an ergonomic program in a manufacturing setting in order to study the effect it has on the number of ergonomic related injuries. This review will focus on the components of ergonomics in safety, ergonomics in manufacturing, six sigma in manufacturing, and six sigma in safety. To begin, it is important to discuss what ergonomics is and how it is incorporated into the workplace. The scope of ergonomics is very broad, but mainly refers to assessing work-related factors that may pose a risk of musculoskeletal disorder (MSDs) and the recommendations to correct them (Walter, 2007). Musculoskeletal disorders affect the muscles, nerves, blood vessels, ligaments, and tendons. Essentially, ergonomics is "fitting a job to a person, not "fitting a person to the job", which helps lessen muscle fatigue, increases productivity, and reduces the number and severity of work-related MSDs (OSHA). Ergonomics has been developed to the point where today it provides data for the evaluations and designs of manufacturing work, as well as applications to future work. Practicing good ergonomics achieves increased productivity, improved health of workers, higher satisfaction of jobs, and typically a boost in company morale. Research shows results that encourage the idea of ergonomics programs driving down the number of injuries a facility has. There are multiple approaches to this issue and with the help of various quality tools, companies can optimize the effectiveness and productivity of their systems, all while assuring safety and health of the employees.

Ergonomics in Safety

Gene Kay, an occupational health and safety engineer once said, “With the right assessment, training, management support, and processes in place, you can proactively identify and eliminate ergonomic issues before they result in debilitating injuries” (2016). These debilitating injuries are not only miserable for the employee enduring them, but also for the company’s pocketbook when they are expected to pay the worker’s compensation. A report ran by Liberty Mutual Insurance Group indicated lower back injuries alone cost companies approximately one billion per year, which divides out to an average cost of $8,321 per incident (Leamon, 1994).

Figure 1. Photo showing categorized injury rates.

The most common part of the body that gets injured related to ergonomics is the back. Research shows 33.5% of the workforce suffers from back injuries each year. The National Safety Council reported that in the USA 400,000 workers face disabling back injuries every year and 28% of the U.S. industrial population would experience disabling lower back pain at some time in their career (2017). Aside from just back injuries, OSHA statistics indicate that MSD-related workers' compensation expenses cost businesses between $15 and $20 billion each year (Kay, 2016). Of course, a work-related injury doesn't stop there. In addition to the steep financial cost, these injuries can, and typically do, come with absenteeism. Collectively, both the loss of work and compensation costs, the financial responsibility is estimated to be as high as $54 billion annually (Kay, 2016).

Before a plan of action can be put into place to eliminate the risk of musculoskeletal disorders or cumulative trauma disorders, it is important to first understand how they are contracted. There are many different types of musculoskeletal and cumulative trauma disorders (Karwowski & Salvendy, pg. 301).

- Carpal tunnel syndrome: numbness and tingling in the thumb, index, and middle fingers caused by compression of the median nerve at the wrist level
- Tendonitis: inflammation of the tendon occurring from repeated action of the muscle/tendon unit
- Cumulative Trauma Disorders (CTDs): physical injuries (characterized by discomfort, impairment, disability, or persistent pain in joints, muscles, or tendons) which develop over a period of time as a result of repeated biomechanical or physiological stresses on a specific body part

These MSDs are caused by repetitive motions which result in stress or strain on some part of the body and can be aggravated by the addition of strenuous lifting or static postures. Static loading occurs when muscles are required to generate tension without movement (Fernandez & Goodman). The risk for injury increases if the operator is required to hold a position for an extended period of time, or if the operation requires vibration tools. Both static postures and vibration can cause constriction of blood vessels, leading to loss of grip strength, ultimately exacerbating an already poor ergonomic situation.

Many factors are considered when studying ergonomic related injuries in safety. There are four main occupational risk factors associated with ergonomics; awkward postures, excessive manual force, high rates of repetition, and long task duration (Putz-Anderson, 1988). According to Humantech, there are many awkward postures to look for, including but not limited to; wash rag, tool/target, elbows out, shoulder too high/too low, hungry head, butts up, and twist and shout. In addition to the posture, it is crucial you look at the repetition, forcefulness, frequent heavy lifting, pushing, pulling, or carrying heavy objects in awkward postures. If a program was implemented that focused on improving ergonomics in each job task, the company would have less employees getting hurt and a significantly lower number of worker compensation claims. An initial investment in an effective ergonomic program removes barriers to quality, productivity, and human performance by customizing the task for the person instead of forcing a person to tailor to the task. Laura Walter mentioned in her article for EHS Today that “workplace MSDs are one of the most significant occupational safety and health problems in the United States, according to NIOSH” (2010). With advancements in technology and our knowledge of ergonomics, safety professionals should be able to combat that issue with a variety of tools/resources to build new ergonomic programs.

Ergonomics in Manufacturing

Everywhere in manufacturing, there is opportunity for ergonomic improvement. Obviously, ergonomic related injuries are an issue in certain industries. A study conducted by Gene Kay indicated that health care, construction, warehousing, and manufacturing are the industries with the highest occupational risk (2016). These industries often experience the highest rates of ergonomic related injuries. It is no surprise that industries are in business to make money. Also what is not surprising is that work related injuries cost companies lots of money. Studies show manufacturing companies recognizing the hazards that can potentially cause an ergonomic injury and implementing ways to abate them so they aren't spending large amounts of money on employee injuries. Companies need to start asking if they can afford the cost of not incorporating ergonomic improvements into their operations. We know that the application of good ergonomic design of the workplace can improve productivity and keep employees safe. This is shown by manufacturing companies moving towards transforming their workstations to better encompass ergonomic standards. The link between improved ergonomics and productivity gains becomes clear when you follow a risk management process. A simple process multiple companies have adopted is that of 6 steps.

1. Provide Management Support- a strong commitment by management is critical to success of the program
2. Involve Workers- the employees that conduct the work every day know the job far better than anyone else so allow them to be a part of the assessment
3. Provide Training- Ensure workers are aware of what ergonomics is and the changes being made to his/her work station so he/she uses the tools correctly
4. Identify Problems- Find the job tasks that are most risky and correct those first

5. Encourage Early Reporting- Helps to prevent or reduce the progression of an issue
6. Evaluate the Process- sustainability piece

Six Sigma in Manufacturing

Research shows many successes associated with incorporating the strongest quality tools to launch new programs. The 6 step process shown above is effective, but not nearly as effective as the six sigma process. The basics of six sigma were actually designed to improve the performance in the manufacturing industry, originally developed as a kind of quality control for large scale manufacturing companies (Simplilearn, 2018). Six Sigma was actually developed in 1986 by Motorola, but now it is used internationally by millions of companies. The purpose of six sigma is to identify and remove elements of a process that cause defects, ultimately improving the quality of the product. The six sigma process has a very defined set of steps to reach these goals and is easily transparent with majority of industries. The idea that companies foster when considering using this quality tool is that of continuous improvement. Manufacturing companies must continuously improve in order to succeed and continue to grow. Six sigma is a quality tool which drives process changes by data. Once a project or goal is defined by the company, they follow a strict process that is defined by 5 stages; define, measure, analyze, improve, and control.

Six Sigma’s main feature for improvement in the manufacturing industry is focusing on quantifying and measuring the financial return of any project it is applied to. Before implementing a six sigma project, the company has to form a team in which each individual has a dedicated goal. The team’s primary goal of any Six Sigma project is to ensure minimum defects throughout the entire process (Simplilearn, 2018). Why do six sigma within your organization? Simplilearn, the world's leading providers of online training for Digital Marketing and Project Management, shared seven benefits of six sigma in an article published in 2018.

1. Six Sigma helps your organization eliminate errors
2. Six Sigma improves business processes and sustains quality improvements
3. Six Sigma has applicability across a wide variety of industries
4. Six Sigma helps companies ensure compliance
5. Six Sigma helps nurture managerial and leadership ability
6. Six Sigma certified individuals receive an excellent salary
7. Six Sigma allows hands-on experience in quality management

Six Sigma in Safety/Ergonomics

Many companies, including DENSO and Company X (name of company omitted for business sensitive reasons), recognized the risks associated with ergonomically risky job tasks and decided to implement an ergonomics program through the aid of a couple different six sigma quality tools. Saravanan and Senthil conducted research on Company X's ergonomics program and published their findings for review and reference. According to Company X's internal company data, many of their injuries occurred through operators not handling objects in a proficient manner, named officially "manual handling injuries" (2011). An article published by Worksafe indicated that manual handling injuries is one of the main challenges in Occupational and Safety practices (2006). Company X decided to apply the DMAIC method to highlight the root causes leading to the manual handling injuries occurring in their facility.

The first phase is Define. Company X defined a lost time injury as a work-related injury which resulted in an employee being absent from work. The second phase is Measure. Company X conducted interviews with supervisors and technicians. Surveys were then derived from the interview data and distributed to the employees. The third stage is Analyze. Company X analyzed the data from the surveys and learned that the employees have lack of training and feel that they are missing safety's support for issues they experience. The fourth stage is improvement. After company X completed a fishbone diagram to identify the 5 critical factors, solutions to the risks were brainstormed.

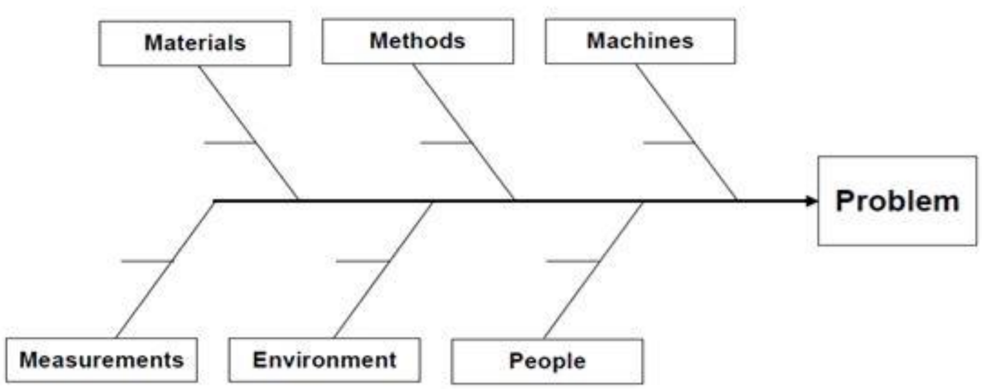

Figure 2. Photo Showing the Fishbone Diagram

Company X implemented new processes to improve the quality of work. The fifth stage is control. Company X composed a control plan which required management and employees to collaborate from that day forward to improve the safety culture.

DENSO on the other hand, used a different six sigma approach to implementing their ergonomics program. DENSO, a company in Long Beach, California, manufactures air conditioning components. They saw a 27% drop in recordable injuries between 1998 and 2000 after implementing a proactive ergonomic program. DENSO used a series of Kaizen events. Kaizen events are small projects that quickly implement low-cost improvements that result in a measurable impact (Smith, 2002). In 1995, DENSO hired Humantech Inc. to train 60 company employees in skill based ergonomics. This strategy required regular input from the entire company staff ranging from upper management to the operators. These trained employees identified high risk work areas and assigned a risk priority number (RPN) to each task. These numbers helped generate a prioritized list for what workstation/job task they needed to improve first. The reliability of the risk factor survey served this program well. Because Six Sigma is driven by data, consistency in assigning risk priority numbers is crucial. Also, this quantification provides “proof” that the ergonomic changes are true improvements. DENSO saw a significant improvement in their number of injuries after implementing this ergonomic program with the help of Six Sigma.

In conclusion, DMAIC and Kaizen are just a couple of the six sigma tools that can aid in implementing new programs in the manufacturing industries. There are other six sigma tools; the 5S system, Poka-Yoke, PDCA, and 5 Why just to name a few. Manufacturing excellence initiatives (Six Sigma) must save the company money. Yet, the goal for ergonomics is to reduce injuries, an area that does not get categorized on the metrics sheet. However, ergonomics and six sigma go hand in hand because once an ergonomics program is implemented using quality tools the injury rates go down and the cost savings goes up.

Definitions:

Ergonomics: science of designing the workplace to accommodate the worker

WMSD: work-related musculoskeletal disorders

CHAPTER 3

METHODOLOGY

Evaluate the Scope of the Problem

When evaluating the scope of the problem, it was necessary to look through the data collected by the safety department by reviewing past ergonomic related injuries from 2016-2018. Each reported incident was searched for the relationship of ergonomics and injuries within the manufacturing/assembly facility.

Literature Review

A review of related literature was conducted focusing on the following topics:

- Introduction to Ergonomics
- Ergonomics in Safety
- Ergonomics in Manufacturing
- Six Sigma in Manufacturing
- Six Sigma in Safety/Ergonomics

Literature sources were found through searches conducted at the Indiana State University library and scholarly articles, journals, and textbooks.

Collection and Analysis of Data

Collection and analysis of data from January 1st 2016- December 31st 2018 at the manufacturing/assembly facility about ergonomically related injuries was evaluated. All injuries, near misses, property damages, lacerations, etc. that are recorded form the dates listed above were reviewed for correlation of ergonomics and the injury. This provided information on how many incidents occurred within a manufacturing/assembly facility that were caused by repetitive motion or poor ergonomic posture. This data was pulled from the incident database which includes extensive detail about the injury in its entirety. The analysis took place and from that information one categorized what type of risk was associated with each ergonomically incorrect task.

RPN Model

Adopting a risk assessment model from a consultant hired by the company to follow was next. A consistent risk assessment model must be followed for uniformity of the process. The model addressed the force, frequency, and posture associated with each job task. The force was related to how heavy a part was or the amount of push/pull force it took for an operator to move an object. The frequency was related to how many times a body part was repetitively moved or how often the task was required of an operator in an eight hour shift. The posture was related to whatever body part was being evaluated. If the body part was in a poor posture it was rated a two. After the force, frequency, and posture were determined, they were scored based off a risk priority number (RPN). The risk priority number was determined by multiplying the number assigned to the force, the number assigned to the frequency, and the number assigned to the posture all together.

Posture	Force	Frequency	RPN	Risk Level
1	1	1	1	Low
1	1	2	2	Low
1	2	1	2	Low
2	1	1	2	Low
1	1	3	3	Medium
1	3	1	3	Medium
1	2	2	4	Medium
2	1	2	4	Medium
2	2	1	4	Medium
1	2	3	6	High
1	3	2	6	High
2	1	3	6	High
2	3	1	6	High
2	2	2	8	High
1	3	3	9	High
2	2	3	12	High
2	3	2	12	High
2	3	3	18	High

Posture	Force	Frequency
1 = Neutral	1 = Low	1 = Low
2 = Awkward	2 = Medium	2 = Medium
	3 = High	3 = High

Figure 3. Photo Showing the RPN Matrix Used to Assess the Level of Risk.

A matrix like the one displayed was an aid in determining the number assigned to each force, frequency, and posture of a task (see figure above). In order to get the force reading a hand-held force gauge was used or the weight of the part was measured. In order to determine the frequency, the number of wrist turns, or other repetitive motion, was calculated. In order to determine the posture rating, one referred to the adopted guidelines while considering the duration of time the employee was in the awkward posture (see figures below). The RPN assignment conducted by safety personnel was indicated on the top portion of the PDCA form (refer to Appendix A,B,C).

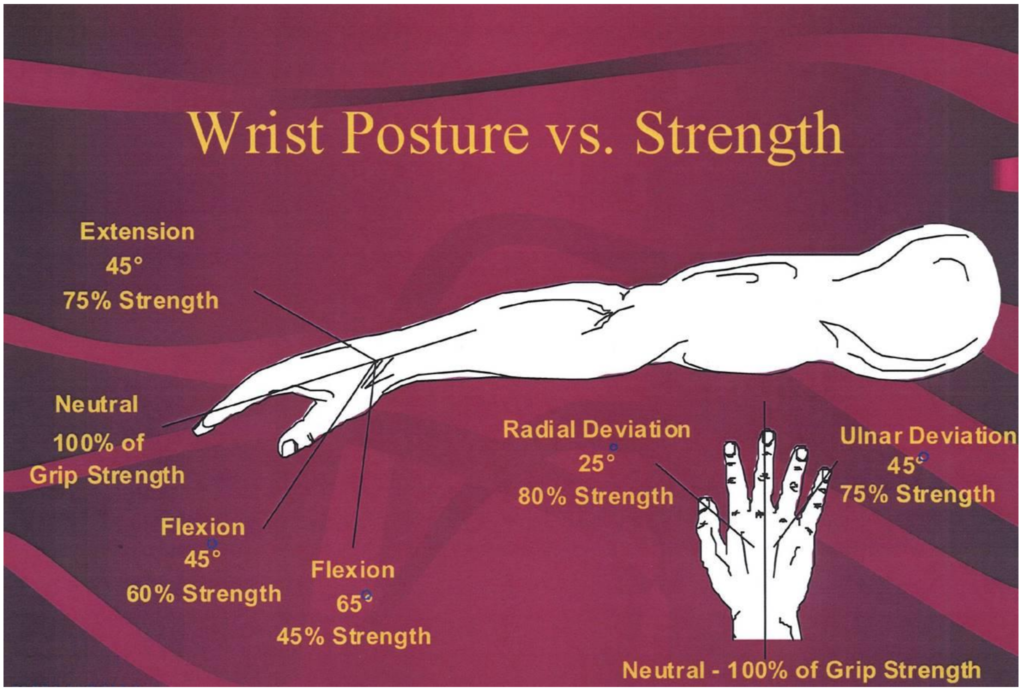

Figure 4. Photo Showing Ergonomic Positions of Hand and Arm.

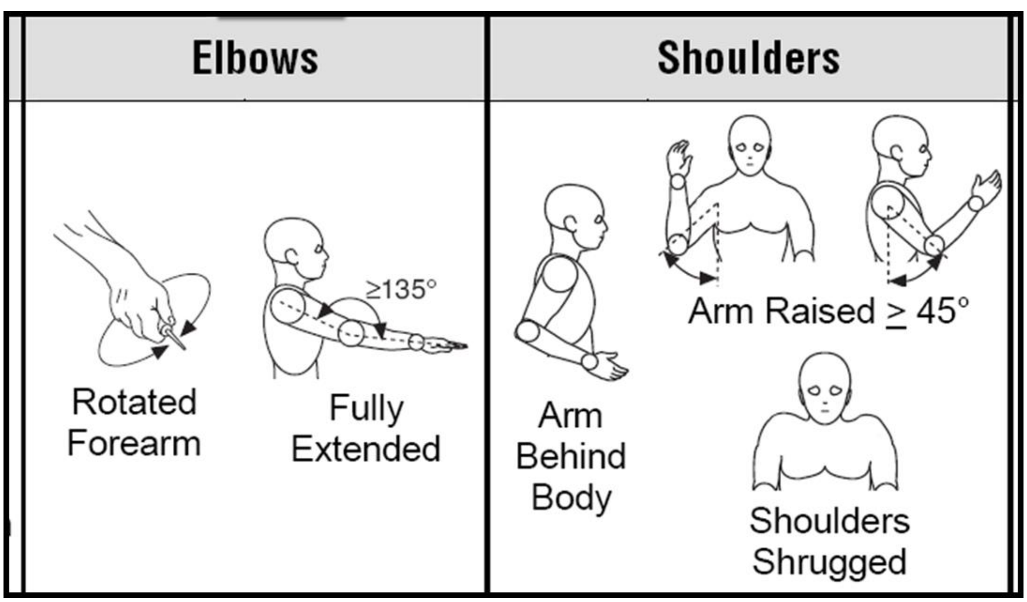

Figure 5. Photo Showing Examples of Poor Ergonomic Postures in Elbow and Shoulders.

Project Spreadsheet

Once all the risk assessments were conducted for each job task in the facility, the results were compiled into an excel spreadsheet. The spreadsheet included the following required fields:

- Project Number
- Project Status (Unassigned, Active, Complete)
- Department
- Work Cell
- Project Leader (filled in as the project was chosen)
- Problem Statement
- Date the Risk Assessment was conducted
- Before RPN
- After RPN (filled in after project was completed)
- Completion Date
- Communication Level

The process was to first create the excel spreadsheet with the above credentials. Then, the project leaders were instructed to choose a high RPN project (indicated in red on the spreadsheet for any RPN over twelve). Once the project leader chose a project, he/she began to fill out the Plan Do Check Act (PDCA) form.

PDCA

The PDCA form was a standardized quality document that remained consistent for completion and tracking of every project in the facility. (See Appendix D for examples). The project leader filled out the top portion of the PDCA with all the identifying information about the project.

Plan:

- What do you need to understand the problem better?
    - Talk to the operator
    - Review work instructions and control plans
    - Walk through the process
    - Review tooling, gauges, prints

Do:

- Implement the solution on a small scale.
    - Collect data- was the solution successful?
    - Does the solution need modified?
    - Is the solution sustainable?

Check

- Review what you learned in the “Do” phase.
    - Analyze the data collected
    - Did the solution eliminate the issue?

Act

- Determine what changes need made to sustain the corrective action.
    - Update work instructions, control plans, or fixtures
    - Train operators to the new standard- sustainment
    - Monitor effectiveness by getting operator feedback

Once the project leader filled out the PDCA, he/she would submit it to the safety department for review. Once approved, the project was added to a weekly "project review walk" with the upper management personnel of the company. This project walk was organized to give the project leader an opportunity to display his/her improvement and receive recognition and feedback. The review of these projects helped sustain them by introducing the change to everyone as opposed to just the affected operator. Highlighting these completed projects helped improve safety in the workplace, but also the efficiency of production because everyone was on the same page about the changes and it helped others think about where they can implement that same change elsewhere in the facility. The level of communication (management) was added to the project spreadsheet and the project was marked complete. A sampling of completed projects, divided by the hierarchy of control that was used, is included in the appendix. (See Appendix X).

Statistical Analysis

During this study descriptive statistics of annual injuries were collected and recorded for the years of 2014-2018. For the purpose of this study, the year 2016 was split in half due to the timing of implementation of the ergonomics program. The variables considered in this test were the ergonomic injury rate (per 100 employees), non-ergonomic injury rate (per 100 employees), and average days lost (per 100 employees). The variables were calculated from the OSHA 300 log and converted to a rate per 100 employees. The null hypothesis was there will be no statistically significant reduction in the rate of ergonomically related injuries after implementing a program of ergonomic improvements at a forklift manufacturing/assembly facility. The alternate hypothesis was there will be a statistically significant reduction in the rate of ergonomically related injuries after implementing a program of ergonomic improvements at a forklift manufacturing/assembly facility. T tests were conducted to compare mean injury rates of both ergonomic related injuries and all other injuries before and after implementation of the program. Data was displayed in graphs and tables.

CHAPTER 4

FINDINGS

Total numbers of ergonomic and non-ergonomic related recordable injuries were identified from company OSHA 300 logs. Rates were calculated based on the number of employees each year. The program was implemented beginning in July of 2016, so the first six months are included in the pre-implementation period and the latter six months are included in the post-implementation period.

Table 1 Table Showing Number of Recordable Injuries from 2014-2018.

Year	Total Recordables	Rate of Recordables Per 100 Employees	Total Ergonomic	Rate of Ergonomic Per 100 Employees
2014	10	2.14	4	0.86
2015	21	4.05	5	0.96
1-6/2016	26	8.66	12	4.00
7-12/2016	20	6.66	9	3.00
2017	25	3.97	7	1.11
2018	22	3.14	4	0.57

A t test was conducted to compare the mean rates per 100 employees for ergonomic injuries and non-ergonomic injuries. Results of the t test for the ergonomic injuries was t=.2839 with a P=.3952 (mean before implementation=1.528, standard deviation before implementation=1.383; mean after implementation=1.272, standard deviation after implementation=1.003). Results of the t test for the non-ergonomic injuries was t= -.8752 with a P=.2154 (mean before implementation=2.214, standard deviation before implementation=0.907;

mean after implementation=2.534, standard deviation after implementation=0.421). Neither of these tests are significant at the α=.05. Due to the variation of injury numbers, there was virtually no way to have a significant t test. Even though there was a 17% reduction in the average of ergonomic injury rates following implementation, the variation in rates is too great to show a significant difference.

Table 2 Table Showing Body Parts Injured From 2014-2018

Year	Wrist/Arm	Shoulder/Elbow	Hand/Fingers	Back
2014	1	3		
2015		2	1	2
1-6/2016		6		6
7-12/2016		6		3
2017	3	2	1	1
2018		1		3

A table was created by listing a breakdown of the body part affected from ergonomic injuries. A t test was conducted to compare OSHA lost work days for incidents occurring before and after implementation of the ergonomics program. There were 16 cases before implementation that averaged 58.5 days, and 13 cases after implementation that averaged 27.6 days. The t test results were t =1.72 with P =.048 (mean before implementation=58.5, standard deviation before implementation=61.30; mean after implementation=27.6, standard deviation after implementation=22.65) indicating a statistically significant reduction of OSHA lost work days per injury. This test result indicates a significant reduction in the severity of each injury.

A comparison was conducted to determine the amount of variance when assigning risk priority numbers (RPN). Considering there were multiple people assessing risk and assigning the RPN numbers, a comparison was necessary to determine consistency. Twelve projects assessed by the same two employees were compared. All of which were rated similarly, with none varying more than a rate of 2. This comparison indicated good consistency throughout the RPN assignment phase of the program.

As for the nature of the injuries seen after the implementation, there is no significant difference in their severity. The company had sprains and strains before the ergonomic program implementation. However, the company had significantly less sprains and strains after the program was implemented. There was not enough data to conduct a statistical analysis, but the number of ergonomic related injuries decreased drastically after the program implementation.

CHAPTER 5

SUMMARY, CONCLUSIONS, RECOMMENDATIONS

Summary

This study looked at a forklift manufacturing facility's ergonomic related injuries from 2014 to 2018. The company experienced 12 ergonomic related injuries in 2016 and 4 ergonomic related injuries in 2018 after implementation of an ergonomics program in late 2016. Following implementation, the average days lost per injury was reduced significantly. This ergonomics program included employees identifying risks in their areas pertaining to force frequency and posture. Project leaders resolved those risks through the PDCA process with problem definition, corrective action, and sustainment of improvements. Company management sustained the program through accountability meetings and positive reinforcement walks.

Conclusions

In this author's opinion, there were many benefits to implementing an ergonomics program. An observation was that the engineers began to incorporate ergonomics in the design phase instead of re-designing something they didn't consider ergonomics for initially. The mentality of the employees changed drastically by bringing the idea of ergonomics to the forefront. Originally, the implementation of this project was perceived by the employees as another task to complete. However, after they saw the impact it made, they accepted it and began to brainstorm other improvements they could implement throughout the facility.

Recommendations

A recommendation to make this program more effective is to expand the problem styles to any safety risk related to the job task instead of just ergonomic risk. This would allow for additional opportunities for necessary improvements which would also potentially factor into the decrease of recordable injuries. Another recommendation for additional study is to compare the severity assignment of each project before and after a project was completed to improve the task. A comparison of the pre and post risk assessment would be necessary. Lastly, considering implementation of an audit program to follow up with the sustainment of the improvements is a future research suggestion in regards to this study. Sustainment is a critical piece to this ergonomic process. Confirming the validity of the project would not only benefit future employees, but also enhance the integrity of the program.

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APPENDIX A: LETTER OF SUPPORT

Date: 3/4/2019
Subject: Letter of Support – Data for Thesis – Miriah Cherry

To whom it may concern:

Miriah Cherry has requested permission to utilize data developed during her course of employment to develop a thesis in pursuit of her master's degree. Crown Equipment strongly supports its employees pursuing higher education and achievement. As such, the Greencastle plant authorizes her to utilize this data with the caveat that data will be sanitized from any reference to Crown Equipment locations or employees. The reuse or reproduction of this information is to be conducted within the same guidelines, protecting Crown Equipment and its employees.

Please feel free to contact me with any questions. Thank you.

Sincerely,

Kris Ladd

APPENDIX B: ENGINEERING CHANGE PROJECT EXAMPLE

Ergonomic Problem Solving Worksheet

Date:	8/30/18	Dept.:	Machining	Work Cell:	Haas 2	Affected Emp:	All	Project Leader:	
Project #:	2585	Force (describe)	Pull while bent over.						
Expected Comp. Month February		Frequency	30-50 times a shift						
		Posture (describe)	Poor						

	Step 1: Problem Definition Statement: Operators and truck drivers are having to set pallets on the floor and wrap them. This can cause long term injuries to an employees lower back.
Step 2: Plan	Order 4 wrapping polls for Fab and Machining so operator do not have to bend over to wrap pallets on the floor.
Step 3: Do	This was very successful in paint at the finish line.
Step 4: Check	This has helped posture out so now operators do not have to bend over while wrapping pallets.
Step 5: Act/Sustain the Improvement	Add WINKS to the trucks and every work station in Fab and Machining.
Step 6: Standardize	Any where parts are being moved on pallets.

Safety Use Only:	Before RPN	F	Fr	P	T	After RPN	F	Fr	P	T
		1	2	2	4		1	2	1	2

Before Change

Wrapping pallet with no poll

After Change

The Ergo friendly why to wrap a pallet.

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APPENDIX C: ENGINEERING CHANGE PROJECT EXAMPLE (2)

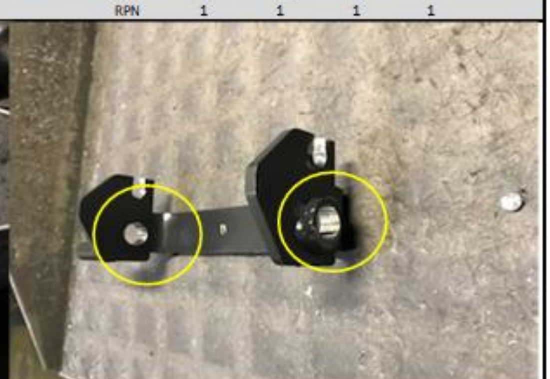
Ergonomic Problem Solving Worksheet

Date:	7/18/17	Dept: Machining	Work Cell: [redacted]	Affected Emp:	all machinist	Project Leader:	[redacted]
ERGO #:	1184	Force (describe)	4lb. Force				
Expected Comp Month July		Freq. (describe)	16 wrist turns per part. 20 parts per shift=320 wrist turns per shift				
		Posture (describe)	Good posture				

Step 1: Problem Definition Statement:
Part 124137 needs two holes deburred inside and out using a manual de-burr knife. This causes fatigue and possible injury to the wrist and fore arm. You use a tight grip while doing this process. Adding a de-burr tool will eliminate this action by de-burring in the machine. RPN = 3

Step 2: Plan	This tool was suggested by employees that run this part. Order the proper de-burr tool. Program the de-burr tool.
Step 3: Do	Tool has been received on 7/19/17, The tool has been programed on 7/3/17. Ran and tested on 7/21/17
Step 4: Check	Tool has been running for several parts and if functioning well. The part no longer requires de-burring on the holes . 320 wrist turns eliminated.
Step 5: Act/Sustain the Improvement	Work instructions have been revised showing this tool.
Step 6: Standardize	Looking for other parts we can utilize this type of tool.

Safety Use Only:		F	Fr	P	T		F	Fr	P	T
	Before RPN	1	3	1	3	After RPN	1	1	1	1



Before Change	After Change
Holes had large burr that took several rotations of the hand de-burr knife to remove. This caused a wringing type motion in the wrist.	No hand knife needed.

APPENDIX D: ENGINEERING CHANGE PROJECT EXAMPLE (3)

Ergonomic Problem Solving Worksheet

Date: 12/17/18	Dept: CB Assy	Work Cell: CB075A	Affected Emp: Mike	Project Leader:

Project #: 2921	Force (describe)	The force is the weight of the parts being handled.
Expected Comp. Month	Frequency	Operator performs this task every day, approximately 200 tires are pressed.
December	Posture (describe)	The posture is bad due to reaching over the conveyor to retrieve parts.

	Step 1: Problem Definition Statement: The operator at CB075A presses tires then reaches over to grabs items to finish the assembly of the tires. This task is performed approximately 200 time a day.
Step 2: Plan	Provide a rack system that would be at an ergonomic height and reduce the amount of reach for the operator.
Step 3: Do	Worked with the operator and Larry Krieg on the design. Based on the feedback from the operator and the rendering that I provided Larry, he was able to put together the rack that we have today. The rack has a roll out tray providing the operator reduced effort to reach across the conveyor.
Step 4: Check	The new rack is in place providing additional space on the back side around the tire press, as well as providing an ergonomic reach for the parts on the rack as the operator needs them.
Step 5: Act/Sustain the Improvement	No action required
Step 6: Standardize	Review other areas that could benefit from this set up.

Safety Use Only:		F	Fr	P	T
Before RPN		1	3	2	6
After RPN		1	3	1	3

Before Change

Comments: Photo above shows how the rack/work bench is bulky and does not suit the operators needs ergonomically.

After Change

Comments: Photo above shows how the new rack provides space on the back side as well as providing the operator an ergonomic reach for the parts. Thanks to Larry Krieg's great work on building this rack.

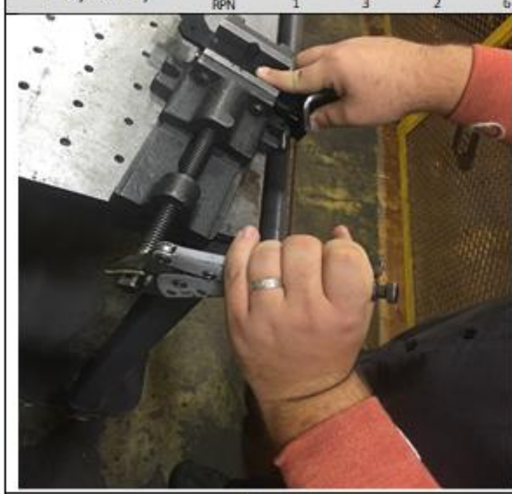
APPENDIX E: ENGINEERING CHANGE PROJECT EXAMPLE (4)

Ergonomic Problem Solving Worksheet

Date: 8/24/18	Dept: Machining	Work Cell: M-Flex Arm	Affected Emp: flex arm operators	Project Leader:
Project #: 2571	Force (describe)	<3 lbs.		
Expected Comp. Month September	Frequency	300 times per shift		
	Posture (describe)	operator bends wrist 75 degrees to tighten and loosen clamp		

	Step 1: Problem Definition Statement: Operator bends wrist to a 75 degree angle up to 300 times per shift to tighten vise down on parts when using flex arm
Step 2: Plan	talked to some of the operators and group leaders to determine the use of the vise and frequency
Step 3: Do	order a new vice to keep operator from bending and twisting wrist to clamp down parts
Step 4: Check	Correct wrist twisting and bending
Step 5: Act/Sustain the Improvement	update other flex arm vises
Step 6: Standardize	get new vices for the other flex arm

Safety Use Only:	Before RPN	F	Fr	P	T	After RPN	F	Fr	P	T
		1	3	2	6		1	3	1	3



Before Change

Operator twists and bends wrist up to 300 times per shift to clamp down parts at the flex arm station.

After Change

new vise allows the operator to clamp down part with out twisting or bending wrist

APPENDIX F: ENGINEERING PROJECT CHANGE EXAMPLE (5)

Ergonomic Problem Solving Worksheet

Date: 7/7/16	Dept: Mast Assy	Work Cell:	ML Utility 1	Affected Emp:	All	Project Leader:	

Project #: 41	Force (describe)	Up to 123 lbs of force to move carts
Expected Comp. Month	Frequency	Up to 76 times/shift
July	Posture (describe)	Poor due to leaning to push

	Step 1: Problem Definition Statement: Mast Staging Racks at Utility Stations 2 & 3 are very difficult to maneuver. Serious injury may occur. Force- with wheels at 90-degrees force is 43-45 lbs, with wheels in line and pushed perpindicular force was 114-123lbs, Frequency 38 trucks / day X 2 stages = 76 /day, Posture - hands at waist / elbow height. Force = 3, Frequency = 2, Posture = 2, RPN = 12.
Step 2: Plan	Studied the Process and found that the Castors on the racks are 3" wide, Resulting in a lot of surface contact with the floor. Specked out and ordered new "Apex" Castors that have very minimal surface contact.
Step 3: Do	cart in back building, currently fitting casters to cart, push/pull test to be completed this week. 7/7 Wheels have been replaced with a contoured wheel that makes less surface contact with the ground.
Step 4: Check	After changing Caster, Forces measured are as follows: Force- with wheels in-line is 20lbs avg vs 43-45 lbs, with wheels perpendicular force was 27lbs vs 114-123lbs. Force = 1, Frequency = 2, Posture = 1, RPN = 2.
Step 5: Act/Sustain the Improvement	Will begin replacing the Casters on all the Mast line staging racks.
Step 6: Standardize	Look into changing the Casters on the Carriage and Cylinder Carts as well.

Safety Use Only:	Before RPN	F	Fr	P	T	After RPN	F	Fr	P	T
		3	2	2	12		1	2	1	2

Before Change	After Change
3" wheels had a lot of surface contact making carts very difficult to move.	New Apex wheels have less surface contact making the carts easier to move.

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APPENDIX G: ENGINEERING CHANGE PROJECT EXAMPLE (6)

Ergonomic Problem Solving Worksheet

Date:	10/30/18	Dept:	Mast Assy	Work Cell:	ML140	Affected Emp:	Multiple	Project Leader:	
Project #:	2762	Force (describe)	1/16 of a pound to wrench the dampening bolt.						
Expected Comp. Month		Frequency	30-40 times per day.						
November		Posture (describe)	Wrist is bent and leaning over the mast.						

	Step 1: Problem Definition Statement: The operators at ML 140 when tightening the dampening bolts with a wrench, has their wrist bent while leaning over the mast. This can cause pain in the wrist and back.
Step 2: Plan	Get an attachment to go on a power rachet, instead of a wrench to tighten the dampening bolts.
Step 3: Do	Brian Sanders ordered the attachment for the rachet. Going to start using the the power rachet on the bolts. Had Dale Grove make work instructions on how to use the new attachment.
Step 4: Check	The attachment works well. Tightens a little more then needed, but they can back it off one or two turns with the wrench. Not as many wrench turns as before.
Step 5: Act/Sustain the Improvement	Made the work instructions, and trained all the operators on how to use the new tool.
Step 6: Standardize	We did the same thing with the wrench that we did with the power hammer. Instead of using a hammer to beat in the roll pins for the SC cylinders we use a battery powered hammer. That helps the operators from letting the hammer go from slipping, and their wrists from multiple swings.

Safety Use Only:	Before RPN	F	Fr	P	T	After RPN	F	Fr	P	T
		1	2	2	4		1	2	1	2

Before Change

The operator while using the wrench, has to lean over the mast and his wrist is bent.

After Change

The operator can keep their wrist straight and doesn't have to lean over the truck as much.

APPENDIX H: ADMINISTRATIVE CHANGE PROGRAM EXAMPLE

Ergonomic Problem Solving Worksheet

Date: 2/17/17	Dept: Weld	Work Cell: Tube Bender	Affected Emp: OHG tube processer	Project Leader: [redacted]

Project #: 19	Force (describe)	Lifting a 42 pound part from waist to shoulder height
Expected Comp. Month	Frequency	27 x a day/135 x per week/7,200 x per year
February	Posture (describe)	Lifting a 42 pound part from waist to shoulder height

Step 1: Problem Definition Statement:
Operator experiences back pain from picking up rear tubes. Part=42 pounds (force=3) frequency is daily x approx. 27 trucks (freq=2). Lifting part to shoulder height (posture=2).

Step 2: Plan	Walk the process and observe operators movements while performing this task.
Step 3: Do	Walked the process and discussed possible soutions with operator. Decided to make process a 2 man lift. Created a work instruction to outline the new process to safely lift part with two people to lower the risk of back injury.
Step 4: Check	The current process lowers the risk of back strain.
Step 5: Act/Sustain the Improvement	Work instructions created
Step 6: Standardize	This process will be eliminated with the use of the 5 axis laser and a lifting device to load and unload the part.

Safety Use Only:	Before RPN	F	Fr	P	T	After RPN	F	Fr	P	T
		3	2	2	12		2	2	1	4

Before Change	After Change
Operators lift parts into saw himself.	Two operators safely lift part into saw.

APPENDIX I: ADMINISTRATIVE CHANGE PROJECT EXAMPLE (2)

Ergonomic Problem Solving Worksheet

Date: 3/1/17	Dept: Plate Proc	Work Cell: Haas VF2 & VF3	Affected Emp: [redacted]	Project Leader: [redacted]	
Project #: 400	Force (describe)	Push force is 26 pounds, pull force is 32 pounds			
Expected Comp. Month	Frequency	1104 times per week			
March	Posture (describe)	leaning forward and backwards while pushing and pulling			

Step 1: Problem Definition Statement:
Operators are experiencing discomfort and fatigue from using the slat cleaner which weighs 39.8 pounds. Slat cleaner must be lifted from the ground and carried through a narrow doorway and placed upon the slat bed. The slat cleaner must be pushed and pulled across the slat bed to remove the slag buildup, the process takes 40 minutes per bed of 46 slats per bed times 8 beds 3 times a week for a total of 1104 push/pull motions per week.

Step 2: Plan	Observed the process noting that the push force measured at 26 pounds pull force measured at 32 pounds. The tool was designed for an end load machine and ours are side load which restricts the space causing the operators to use more upper body strength to move the slat cleaner.
Step 3: Do	Compiled data on the cost associated with cleaning and changing frequency compared to changing all slats and eliminating the cleaning process all in all. Present data to upper management proposing to eliminate the slat cleaning.
Step 4: Check	According to the data collected, a $20,538 savings would result from eliminating the cleaning process.
Step 5: Act/Sustain the Improvement	Edit standard work and work instructions to reflect the eliminiation of slat cleaning on a regular basis and move cleaning to an as needed basis.
Step 6: Standardize	Present in tier meetings to inform of the new process.

Safety Use Only:		F	Fr	P	T		F	Fr	P	T
	Before RPN	3	3	2	18	After RPN	1	1	1	1

Before Change

Push force of 26 pounds and pull force of 32 pounds susatined for 1 minute to clean one slat. Restricted space and heavy vibration. Process performed 3 times per week

After Change

Move to a weekly slat change and eliminate the slat cleaning to improve the process.

APPENDIX J: ENGINEERING CHANGE PROJECT EXAMPLE (7)

Ergonomic Problem Solving Worksheet

Date: 9/1/16	Dept: Final Assy	Work Cell: FA 8 - Oil Filtration	Affected Emp: All	Project Leader: [redacted]

Project #: 196	Force (describe)	50 pounds of weight placed on the seat
Expected Comp. Month	Frequency	once every truck, 12 trucks a day
September	Posture (describe)	Lifting weight from the ground

Step 1: Problem Definition Statement:
In order to complete the oil cleanliness on the FC the operator presence switch has to be activated. Without the operator presence switch activated the pump on the truck will not circulate the oil. In order to activate the presence switch 50 pounds of weight is placed on the seat (12 trucks a day) which is lifted from the ground and makes the operators susceptible to injury.

Step 2: Plan	Find a way to eliminate the need to put weights on the seat
Step 3: Do	Make a jumper that bypasses the operator presence switch. We made the wires on the jumper excessively long so it will be very obvious if the jumper is accidentally left plugged in. The jumper was made so long the rear door could not be installed without moving the jumper out of the way.
Step 4: Check	The jumper has worked on every FC since we implemented it and it has completely eliminated the need to place 50 pound weights on the seat. The operators find it effective and are glad they no longer have to lift weights onto the seat.
Step 5: Act/Sustain the Improvement	We plugged the jumper in and it allows the pump on the truck to run without any weight on the seat.
Step 6: Standardize	Right now there are no other locations where we need to bypass the operator presence switch so there are no other applications for this at this time.

Safety Use Only:		F	Fr	P	T		F	Fr	P	T
	Before RPN	2	2	2	8	After RPN	1	1	1	1

Before Change

Weights were kept on the floor and the operator had to lift it up, over the arm rest, and place it on the seat in order to activate the operator presence switch

After Change

Putting a jumper in place completely eliminates the need for weights

APPENDIX K: ADMINISTRATIVE CHANGE PROJECT EXAMPLE (3)

Ergonomic Problem Solving Worksheet

Date:	1/18/19	Dept:	Laser	Work Cell:	F-Lasers	Affected Emp:		Project Leader:	
Project #:	3122	Force (describe)	4 ounces to 2lbs				
Expected Comp. Month		Frequency	100's of times				
March		Posture (describe)	bad				

	Step 1: Problem Definition Statement: Operators running laser 5 are required to run the flexarm while running the laser. Running the flexarm for more than a week at a time is causing pain and discomfort in the operators arm.
Step 2: Plan	Develop a rotation so one operator does not have to run the flexarm more then one week in a row.
Step 3: Do	Talked to Supervisor to implement a weekly rotation on the flex arm. Added the rotation to the Laser Operator Standard Work posted at each laser.
Step 4: Check	This solution appears to have resloved the issue of arm fatigue and discomfort
Step 5: Act/Sustain the Improvement	Since it is noted on the standard work document it is an administrative level control
Step 6: Standardize	Review with machining process techs to cover on the 2nd flex-arm

Safety Use Only:	Before RPN	F	Fr	P	T	After RPN	F	Fr	P	T
		1	3	2	6		1	2	2	4

Added to printed work instructions

Before Change	After Change
Operators working more than one week at a time on the Flex arm causing fatigue and pain in the arm.	Added weekly rotation to the standard work to avoid discomfort from perfoming repetitive actions.

APPENDIX L: ENGINEERING CHANGE PROJECT EXAMPLE (8)

Ergonomic Problem Solving Worksheet

Date: 12/8/16	Dept: Wave Assy	Work Cell: W-150	Affected Emp:	Project Leader:

ERGO #: 6	Force (describe)	Operator must stand 80 lbs battery up on end
Expected Comp Month December	Frequency	Operator must stand 4 batteries/truck, 11 trucks/day=44 times/day
	Posture (describe)	Batteries are approximately chest high. Standing on end brings arms and elbos shoulder high

Step 1: Problem Definition Statement:
At WV150, the operator is required to stand the 157890 Maintenance Free Battery up on end weighing 80 lbs (Force=3) prior to installing it in the chassis with the manipulator 44 times per day (Frequency=3) reaching out and bringing their arms and elbows shoulder high (Posture=2). Barbie Inman reported feeling pain in her elbow from flipping batteries. RPN=12

Step 2: Plan	Spoke with operators at WV150. Implemented a 2-person lift as an intermediate solution. Investigated options to get a battery manipulator that would stand the batteries on end for the operator.
Step 3: Do	Worked with S&K Air Power to create a manipulator that would be able to stand the battery on end and place the battery into the chassis.
Step 4: Check	S&K sent videos of the manipulator to show how it worked. By using the manipulator to stand the batteries on end, the operator will not exert any force.
Step 5: Act/Sustain the Improvement	The work instructions have been changed to show how to use the manipulator to stand the batteries up. Spent an entire day with the operator to make sure she was comfortable using the manipulator and that it did its job effectively. A few minor modifications are in the works to improve the manipulator.
Step 6: Standardize	This is the only location in the plant that is required to stand batteries on end to place them in the truck.

Safety Use Only:	Before RPN	F	Fr	P	T	After RPN	F	Fr	P	T
		3	3	2	18		1	3	1	3

Before Change	After Change
Two operators were required to stand 80 lbs batteries on end. In addition to the weight of standing them on end, operators had to be careful to avoid getting their fingers pinched under the batteries.	The operator never has touch the batteries to stand them on end, the new manipulator does it for them.

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