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Title: ***Implementation of modern press brakes through lean practices***

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 Manufacturing Engineering**

Research Adviser: **Dr. Annamalai Pandian**

Submission Term/Year: **Spring, 2013**

Number of Pages: **64**

Style Manual Used: **American Psychological Association, 6th edition**

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Sawinski, Adam R. ***Implementation of modern press brakes through lean practices***

Abstract

The following field project study was performed at a sheet metal manufacturer of operator cabs, roll-over protective structures (ROPS), and electronic enclosures and consoles. This study describes literature, setting up a manufacturing line, implementing four modern day press brakes, and implementing the press operator and water strider standard work during the full production phase. The modern day press brakes possess the latest in bending technology and were a necessity in order to support Company XYZ's strategic initiatives related to growth and continuous improvement. The press brake project was justified and approved because Company XYZ's metal fabrication processes are more than 30 years old when compared to other leading businesses. The intention of this study was to verify a successful installation of four new modern day press brakes. The field problem resulted in several positive outcomes. These outcomes were a 36% improvement in the average forming efficiency, a 75% reduction in scrap, a onetime reduction in inventory, and a consolidation and reduction in maintenance costs by 15%. The verification methods included: a statistical process control chart, a reduction of inventory from five days to three days, scrap reduction, and an improvement of operator labor efficiency and delivery performance.

Acknowledgments

I would like to thank my family, friends, and immediate co-workers for their words of encouragement and understanding throughout my journey. I would also like to thank my field project advisor, Dr. Pandian, for his helpful suggestions and constructive criticism during the completion of this project.

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Chapter I: Introduction

Company XYZ is located in Rochester, Minnesota and is a leading manufacturer within the industries it serves. Company XYZ's product offering is comprised of two business segments, cabs and electronic enclosures and consoles. The electronic enclosures and consoles are manufactured under the Emcor brand. In North America, the cab products are recognized among industry professionals to be a leading manufacturer of operator cabs and roll-over protective structures (ROPS). ROPS are a cab product that surrounds the user operating the tractor, skid loader, bull dozer, etc. Additionally, Emcor enclosures and consoles are solutions designed to hold electronic components such as computers, monitors, and surveillance technology. The industries these products serve include: industrial, test/measurement, energy, military/defense/aerospace, and datacom/telecom.

Although the business segments look different, they require similar skill sets: metal fabrication, robotic welding, powder coat paint finishing, and assembly work. Presently, Company XYZ's fabrication machines are decades behind our toughest competitors. Company XYZ's legacy presses are 30 to 40 years old and range from 60 to 400 tons. The current machine setup process reveals costly and time consuming operations. The setups range from 17 minutes up to 60 minutes. Consequently, the overall forming efficiency is 64%. There are several contributing factors to the forming efficiency rate. For example, flat part blanks are designed from a standard bend allowance chart without tooling in mind, no consistency between machines, and a lack of precision ground tooling. Company XYZ has been using homemade tool sets and damaged tool sets since the company was founded 62 years ago. The machines that use these homemade or damaged tools consist of five different operating manuals, tool sets, and spare part lists. In an effort to support Company XYZ's strategic initiatives related to growth and continuous improvement, a process improvement project dealing with modern day equipment must be set in place.

Sheet metal is frequently used in the forming process. There are several types of press brakes such as mechanical, pneumatic, hydraulic, and servo-electric. A mechanical press brake is powered by spinning a flywheel that stores energy. In today's economy, these presses are outdated for the most part but do serve as superior machines depending on the application ("Applications of different types of press brakes," 2011, para. 4). A pneumatic press brake obtains its power from an air compressor that moves air cylinders, which then supplies force to the ram ("Press brake specifications 220," 2012, para. 60). The most common used press brake in today's world is the hydraulic press brake. This press brake is powered by hydraulic cylinders to cycle the ram. The hydraulic cylinders allow the ram to stop immediately at any point through the stroke height ("Hydraulic press brakes," n.d., para. 2). The latest press brake technology is called a servo-electric press brake. These brakes operate solely on electricity but have limitations with pressing forces and maximum working lengths ("New servo electric press brake," n.d., para. 1).

The type of metal used in a press brake is called sheet metal. Sheet metal is metal transformed into thin flat sheets. Sheet metal can be cut and bent into a variety of different shapes ("What is sheet metal?," n.d., para. 1). Company XYZ uses a variety of thicknesses, ranging from 20-gauge (0.32 inches) to ½ inch-thick material. Sheet metal is available in flat pieces or as a coiled strip. The coils are unwound and sheared into sheets using the precision blanking line. There are many different types of metals that can be made into sheet metal. The main types of sheet metal Company XYZ consumes are hot-rolled and cold-rolled mild steel, high-strength steel, aluminum, and galvanneal.

The machine that bends metal is called a press brake. The lower part of the press brake contains a V-shaped tool. This tool is called a die. The upper tool of a press brake is called a punch. The punch is used to press the sheet metal down into the V-opening of the die. This causes the metal to change shape or bend. There are several approaches in press brake forming, but the most common method used at Company XYZ is air forming.

The problem at hand deals with air forming on modern day press brakes. Air forming is a three-point method, which uses the top two edges of a die and the tip of a punch. Currently, Company XYZ's design team creates formed parts by applying bend allowances to them. These allowances come from a standard bend allowance chart. All flat blanks are generated in this manner. Design does not take into consideration the actual allowances used in manufacturing. The press brake operators are then in charge of re-engineering the part at the machine. They are forced into running flanges long and others short in order to make a good part. This is due to the flat blanks not being accurately calculated to the correct sizes. In a worst-case scenario, a flat part is taken back to design and is either made smaller or larger. Consequently, there are costly rework hours and wasted time spent at the production machines.

Statement of the Problem

To remain competitive in an increasingly aggressive world, Company XYZ must reduce operating costs while increasing quality and customer response time. In support of Company XYZ's expansion and continuous improvement, a project was set in place to improve labor efficiency rates, scrap reduction, inventory levels, and consolidate maintenance.

Purpose of the Study

The intention of this study is to:

1. Increase the average operator labor efficiency to 100% by reducing the setups from 60 minutes down to eight minutes or less.
2. Reduce operating costs of the equipment and support standardization of spare parts and improve maintenance by 15%.
3. Enable our design department to take on more complex formed part geometry to reduce designed costs in our products.
4. Capture annual savings by reducing material scrap.
5. Reduce inventory through lead-time reductions. Reduce the total time throughout the shop for a press brake formed part from five days to three days.

Advantages of the Study

The assumptions of this study are:

1. The reduction of inventory and equipment will free up at least 2000 square feet of floor space within the shop.
2. Approximately, 78% of Company XYZ's expenses will be virtually eliminated by the reduction in setup times, reduction of inventory, combination of tooling based blank unfolding, and upgraded presses and controls.
3. Better safety systems will lower safety risks.
4. A majority of the setup process for new parts will take place off-line so that tooling evaluation can happen at the design stage instead of during the pilot or production stage.
5. Off-line programming will substantially reduce the amount of time it takes to get new parts through the tryout process.

Definition of Terms

5S. "Is a housekeeping methodology for the shop floor. There are five rules of housekeeping for a lean environment and they help to expose waste. The five rules are: sort, set in order, shine, standardize, and sustain" ("Lean manufacturing glossary, definitions, and terms," 2009, para. 1).

Air Bending. "A forming method in which the press brake tooling touches the workpiece tooling at three different points: at the tip of the V-shaped section of the upper die and at the top of each corner of the lower die" ("Bending fundamentals 120," 2012, para. 4).

Air Forming. "Another term used to describe air bending" ("Bending fundamentals 120," 2012, para. 5).

Angle. "The measurement, in degrees, of the bend a workpiece is bent to form a part" ("Bending fundamentals 120," 2012, para. 6).

Back gauge. "Adjustable components of the press brake against which the workpiece is located when forming takes place" ("Press brake components 110," 2012, para. 2).

Bottom Bending. "A forming method in which the die tooling touches down on all surfaces of the workpiece" ("Bending fundamentals 120," 2012, para. 10).

Coining. "A forming method that uses extreme force to displace material, usually by a reduction in workpiece thickness" ("Bending fundamentals 120," 2012, para. 13).

Compressive Stress. "A force that attempts to squeeze or compress a material" ("Overview of properties for plastics 135," 2012, para. 9).

Die. "The tool typically attached to the lower portion of the die set containing a recess that provides space for the shaping or shearing of sheet metal" ("Punch and die operations 120," 2012, para. 14).

Flange. “An angular bend in which one edge of the workpiece is bent while the other portion of the workpiece lies flat” (“Die bending operations 130,” 2012, para. 11)

Flywheel. “The device on a mechanical press brake that spins continuously as the press is powered up. The flywheel stores the energy necessary to cycle the press when the clutch is engaged” (“Press brake components 110,” 2012, para. 16).

Gauge. “The unit of thickness in a sheet of metal” (“Press brake specifications 220,” 2012, para. 37).

K-factor. “Is the ratio of the neutral axis to the material thickness” (“Sheet metal fabrication resources,” 2011, para. 1).

Neutral Axis. “A line through the thickness of the bend” (Childress, 2012, para. 2).

Precision Blanking Line. “Converts coiled steel into specific sheet sizes by unwinding the tightly wrapped coil and flattening it out into metal blanks” (Kuvin, 2010, para. 3).

Press-Stroke. “The distance marked by the farthest ends of reciprocating vertical movement of the press ram” (“Die components 130,” 2012, para. 36).

Process Validation. “Establishing by objective evidence that a process consistently produces a result or product meeting its predetermined specifications.” (“Process validation,” n.d., para. 7).

Punch. “The upper portion of a die set that shapes or penetrates the sheet metal.” (“Press brake components 110,” 2012, para. 32).

Ram. “The portion of the press brake that moves up and down to form and bend metal” (“Press brake components 110,” 2012, para. 34).

Spring Back. “A material's tendency to return to its original state once its state of motion has been disturbed” (“Bending fundamentals 120,” 2012, para. 39).

Stage Bending. Is placing multiple tool sets into the press brake at the same time, while forming a complex part. The different stages are for specific tool types or lengths that are needed to form the part.

Standard Work. "Standard work lists the normal tasks done with the least amount of waste possible at the current time" ("Lean manufacturing glossary, definitions, and terms," 2009, para. 49).

Stroke Height. "The vertical distance the ram travels as it cycles" ("Press brake specifications 220," 2012, para. 74).

Tensile Stresses. "A force that attempts to pull apart or stretch a material" ("Intro to adhesive bonding 110," 2012, para. 42).

Water Strider (Mizusumashi). "A term used to describe the activities of the person responsible for maintaining correct inventories on the production line" ("Lean manufacturing glossary, definitions, and terms," 2009, para. 58).

Limitations of the Study

The results and effects during this study are limited to a specific time frame. The fabrication project is a continuous improvement project and will take years to achieve world class status.

Methodology

This report will present implementation of various continuous improvement ideas, background on air forming, and cost saving opportunities resulting from the implementation of four modern brakes. It will also discuss an overview of the press brake research prior to purchasing the new equipment and the machine ramp up phase conducted prior to purchasing the machines. A comparative analysis study between the operator standard work and the water strider standard work will be presented. Lastly, the process implementation, verification, and validation will present: labor efficiency rates, reduction in scrap, and inventory levels.

Chapter II: Literature Review

The focal point of this project was to successfully implement four 150 ton press brakes in order to resolve costly and time consuming setups. This study will also evaluate the setup support solution that involves a water strider to pick parts, standardize containers, and perform material handling to ensure the maximum uptime of the new machines. The conclusion of this project will ensure all four machines are ready for full production. The resulting outcome will have an overall forming efficiency of 100% or greater, a 75% reduction in inventory, and a 40% reduction in material scrap. The overall forming efficiency is a daily percentage of how effective the operator worked throughout the shift. Proper inventory management and material scrap is vital in keeping operating costs low as possible.

Continuous Improvement

Continuous improvement is a gradual infinite change in a process, service, or product. Continuous improvement leads to excellence by resulting in significant breakthroughs relating to products and services; however, these innovations do not happen overnight. They typically take place over time and are structured in two ways (Martin, 2010, para. 4). The two methods of continuous improvements are: incremental and breakthrough. Incremental improvements are small, continuous improvements, which benefit companies if they are completed on a recurrent basis. On the other hand, a breakthrough improvement also known as the step change, is completed in one giant leap. Breakthrough improvements also take several years to complete and often happen only by chance ("Continuous Improvement," n.d., para. 1). Nevertheless, the methods of achievement are the same.

In today's world, businesses are unable to remain idle in their improvement efforts. Continuous improvements must be made to keep up with competitors and stay in business. In every process, machine, program, and project lies an improvement cycle. The continuous improvement cycle used most often is Plan-Do-Check-Act (PDCA) ("Cycle Time," n.d., para. 1). It is a repetitive four step approach used in the business world to control and monitor continuous improvement activities.

Plan. The continuous improvement cycle begins by establishing the objectives and processes necessary to deliver results that match the ending outcome. It is very important to provide a firm foundation for the improvement cycle. At this step the name, purpose, beginning, end result, and the inputs and outputs are defined. Furthermore, the process of identifying these goals begins with determining the current state though research and analysis ("Continuous Improvement," n.d., para. 2). Research helps confirm current states, future states, and possible continuous improvement strategies. In addition, analysis establishes evidence by quick experimentation, data analysis, and to determine system responses. The research and analysis approach generally involves numerous tests of small changes which can increase the results of continuous improvement efforts (Morris & Hiebert, 2011, pg. 27). In addition, the need to improve is established. This can be accomplished by anyone in an organization. The change agent should identify the successes within their company and focus on one activity for a specific amount of time. The planning stage entails investigating the current situation, gathering data, and creating ways to make the improvements.

Do. The second stage of the continuous improvement cycle involves implementing the plan, executing the process, or making the product. Testing and examination alternatives are conducted in a laboratory setting, during the pilot stage of a new process, or with new or existing customers. During this stage, data collection and creating charts will be used as well as in the next two stages of the continuous improvement cycle ("Cycle Time," n.d., para. 7).

Check. The third stage in the continuous improvement cycle involves measuring and collecting data from the second stage. The change agent compares the information against the expected results or targets from the first stage to determine any differences. In addition, the change agent will dissect the differences and establish ways to complete the continuous improvement activities so the plan will not be drastically altered. In example, charting data in step two can help make this step much easier. The change agent will be able to see trends over several PDCA cycles; consequently, converting the data to information. Information is what is needed for the final step of the continuous improvement cycle ("Cycle Time," n.d., para. 8).

Act. The final stage of the continuous improvement cycle consists of analyzing the differences to determine their root causes. The change agent also determines where and how to apply the changes which will improve the process or product the most. For significant differences, a request for a corrective action is helpful to distinguish between actual and planned results. Corrective action or preventative actions are "improvements to an organizations processes taken to eliminate causes or non-conformities or other undesirable situations" ("Cycle Time," n.d., para. 9). If the actions passed through the four step cycle do not result in a need to improve, the scope of the PDCA is redefined to plan and improve with more detail.

Continuous Improvement Methods

Six Sigma, lean manufacturing, and total quality management are the three main continuous improvement methods used today ("Continuous Improvement," n.d., para. 7). In many organizations, Six Sigma is a measurement system of quality that strives for perfection. Six Sigma is a strictly controlled set of tools and strategies using data and methods for eliminating all defects (Brue, 2002, p. 2). In other words, Six Sigma improves the quality of a process by classifying and removing the causes of defects while minimizing manufacturing variability. It also uses quality management methods like statistical methods while creating a special arrangement of people within an organization.

Along with Six Sigma, lean manufacturing is another continuous improvement strategy used today. Lean manufacturing is creating more value for customers with fewer resources (Fast, 2012, p. 116). According to Womack and Jones (2003), the purpose of lean manufacturing is to maximize the customer value while minimizing waste (p. 29). The ultimate goal of lean manufacturing is to supply perfect value to the end user through ideal processes which contain zero defects. This goal is not achievable, but it is the idea of constantly striving for perfection. The third continuous improvement method is total quality management.

Total quality management is another continuous improvement method used in industry today. TQM persistently improves the quality of products, processes, or services (Womack & Jones, 2003, p. 299). The quality of products, processes, and services are held responsible by everyone involved in the creation or consumption throughout the business processes. In order for a business to be successful, it must focus on the following eight key elements: ethics, integrity, trust, training, teamwork, leadership, recognition, and communication (Womack & Jones, 2003, p. 299). The three continuous improvement methods are inter-related with one another, and thus most companies use all three methods or a combination of two.

Continuous improvement can be completed at any level within an organization. On the shop floor, continuous improvement activities can make a significant difference (Fast, 2012, p. 85). An example of a continuous improvement opportunity may deal with a press brake. Air forming on a press brake can be very difficult if management does not improve areas in which it can control. For example, one variable is the sheet thickness of a part. If the sheet thickness changes 0.3 mm thinner or thicker, the degree will be roughly one degree off, depending on the degree being formed. Then, the next part formed might be back to the actual material thickness. Consequently, there are never two lots of steel that are exactly the same, which is where the issue arises.

There are three main types of continuous improvement activities dealing with press brakes. A kaizen event is one improvement approach to this situation. A kaizen event is a small continuous improvement activity typically focusing on quality enhancement or waste reduction (Brue, 2002, p. 80). A successful kaizen does not take months of preparation. The team leader begins planning by establishing the scope of the event, while identifying potential internal and external team members and a support staff. Moreover, the team leader establishes pre-event meeting criteria, event criteria, and post-event criteria (Brue, 2002, p. 89). Additional improvement activities that can be conducted on press brakes are creating standard work for the operator and the water strider. Creating these standards provides the least amount of variation and increases the consistency within the process. In addition, 5S projects are also found to help support and sustain continuous improvement activities. 5S improvements may also be conducted on press brakes. Continuous improvement activities are important to all organizations because these activities seek either incremental improvement over time or breakthrough improvement all at once (Fast, 2012, p. 90).

Air Forming

Air forming, also known as air bending, has forever been used in the forming process; however, its popularity began in the late 1970's. When air forming on a press brake, tensile stress and compressive stress need to be overcome in order to form the metal part. After the forming is complete, the material springs back towards its original position. The metal part must subsequently be bent over the desired angle in order to achieve the correct angle ("Bending

Fundamentals 120," 2012, para. 1). Additionally, spring back depends on the thickness of the material and the method of forming used. In the bending process sheet metal stretches or elongates in length. It is also very important to have an accurate blank size prior to the forming process.

Bend allowance determines the amount of stretching done throughout the form. The bend allowance is dictated by the bend angle, bend radius, thickness of the material, and a variable called the K-factor. The bend allowance will fluctuate based on the angle of a bend, the thickness of the material, and method of forming used. It is a necessity to calculate the bend allowance when creating a production part (Childress, 2012, para. 1). The bend allowance formula is (K-factor * thickness + radius) * angle * (pi/180) (Childress, 2012, para. 4). In other words, the K-factor is multiplied by the material thickness, and that number is then added to the radius of the bend. That number is then multiplied by the degree of the angle times pi over 180. After the bend allowance is determined, it is added to the finished length to get the appropriate blank size when completely formed (Childress, 2012, para. 1). In the process of bending sheet metal, the overall length of the part changes due to compression of the inside of the bend and the tension on the outside of the bend. The length of the neutral axis remains unchanged when the part is formed. The neutral axis is where the material neither compresses nor expands. It shifts inward towards the inside of the bend radius. In addition, the angle of a bend and radius of a bend determine the location of the neutral axis (Childress, 2012, para. 2). The K-factor is also an important aspect of the neutral line.

According to Smith (2012), "The K-factor is a ratio of the distance of the neutral line from the inside edge of the material to the thickness of the material" (para, 3). Typically, the size of the K-factor ranges from 0.25 to 0.5 because it is unfeasible for the compression to be greater than tension on the outside of the bend (Childress, 2012, para. 5). In other words, a higher K-factor equals a higher compression. In the end, the K-factor is determined by the material used and the type of bend created. The correct K-factor is essential when air forming on a press brake.

"Air forming is a three-point method that uses the top two corners of the V die and the tip of the punch as its three points," explains Benson (2003, para. 3). The punch is what also dictates the inside radius of the bend. Air forming is nothing like bottom bending or coining. In bottom bending and coining the radius (tip of the punch) is reproduced because there is not any extra room between the tools at the bottom of the bend. Air forming creates an inside radius based on a percentage of the V-die opening. The percentage of the radius formed during air forming depends on the type of material. For instance, 304 stainless steel produces a larger inside radius than mild cold-rolled steel (Benson, 2003, para. 3). There are no limitations when it comes to air forming. In fact, air forming requires less bending force, which allows the press brake operators to use smaller tools when compared to the other methods of bending.

The tooling combinations are set up so the distance between the punch and the side of the V-die is larger than the material thickness. Currently, the latest dies are more flexible because they use different press-stroke depths. This allows the press brake to form a wider range of shapes. In addition, different materials and thicknesses can be formed with the same punch and die. There are fewer tool exchanges because the same punch and die can be used over a wide range of materials and thicknesses, which results in higher productivity ("Bending fundamentals 120," 2012, para. 5). These are major advantages when comparing the different methods of forming. Air forming consists of three major types of bends.

The three types of bends are called 90° bends, overforms, and underforms. A 90° bend is simply a bend at 90°. An overform is an acute angle and is any bend less than 90°. On the other hand, an underform is an obtuse angle and consists of any bend greater than 90°. Overform bends are the most difficult to make in air forming because the amount of compression and tension that takes place on such a sharp radius. Typically, a sharp radius occurs on an overform with any radius tool below 63% of the given material thickness ("Bending fundamentals 120," 2012, para. 6). In general, the larger the radius of a bend the less amount of material used when compared to an acute angle.

Chapter III: Methodology

The press brake forming methods are currently decades behind other leading competitors. These machines vary from 30 to 40 years old and have long time consuming setups ranging from 17 minutes to 60 minutes. In order for Company XYZ to remain competitive in today's market, the project must reduce operating costs while increasing the company's quality and customer response time. This chapter will provide an explanation of the selected approach to this project: an overview of press brake research conducted prior to purchasing the new machines; the machine ramp up phase conducted before full production; a summary of how the operator standard work and water strider standard work relate to one another; and a description of the process validation which includes labor efficiency rates, reduction in scrap, and inventory levels.

Press Brake Research Overview

This project began by measuring Company XYZ's current process and establishing the need to improve the company's current situation. The research stage started with a fabrication group, which included manufacturing engineers, to floor supervisors, to upper management. The team members began researching all available press brake suppliers within today's market. The fabrication group reviewed the potential suppliers in three stages, and at the end of each stage, one press brake supplier was eliminated. The first stage was completed at Company XYZ's manufacturing plants. The second stage involved an on-site demonstration with complex Company XYZ production parts. During this stage, the researchers performed time studies to test the group's theories on change over which were confirmed at all three vendors. The final stage focused on the remaining two suppliers. This stage included a request for quotation (RFQ) and site visitations to one of the supplier's customers. An RFQ is a standard business practice where suppliers are asked to bid on specific products or services. Typically, an RFQ involves a variety of information such as payment terms, quality levels, contract lengths, and price per item ("Request for Quotations," 2013, para. 1). The fabrication team made a decision at the end of the third stage.

Machine Ramp up Phase

Before any offline programs or setup sheets were produced, a machine layout needed to be created, proposed, and approved by upper management. The approved machine layout is included in Appendix A. Next, the creation of step (.stp) files was critical to the process. Step files are 3D models of part geometry, which were used in the offline programming portion of this project. The offline programming software can use other types of 3D files and even 2D files, but for consolidation purposes step files were the optimal choice. Once the step files were created, the offline programming, creation of setup sheets, and machine tryouts could begin. This part of the project was very time consuming. It took more than six months to complete because there were more than 2,000 parts to program, setup sheets to create, and tryouts conducted at the production machines.

The process began by offline programming the press brake parts. First, the parts were imported as step files, and then the bend lines were chosen and the appropriate tools were selected for the part at hand. The part is then unfolded into a flat blank geometry. An example of this is displayed in Appendix B. At this point, the software uses three basic criteria when establishing the appropriate bend allowance: the punch tip radius, the v-opening of the die, and the lip radius of the die. These variables dictate the appropriate bend allowances needed when air forming the part. Consequently, the original blank changes to its nominal size.

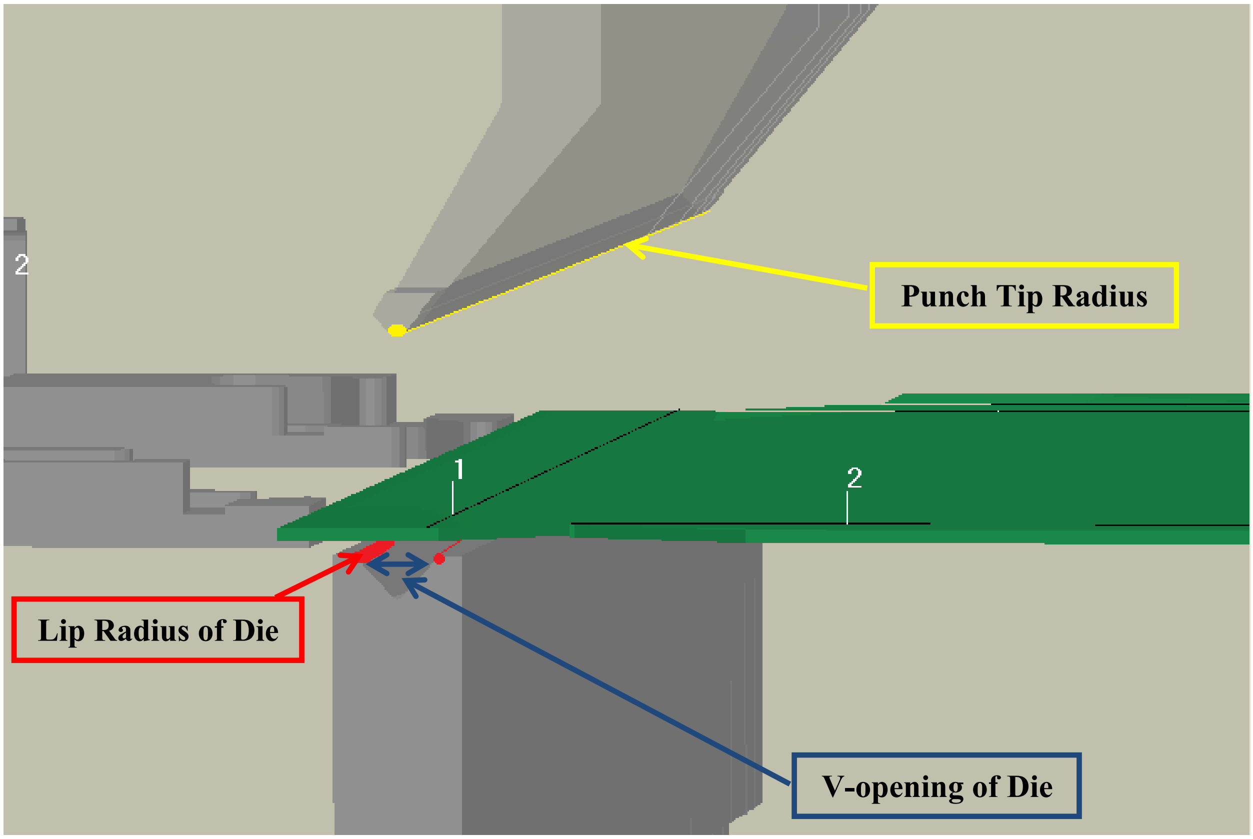

Figure 1: Bend Allowance Variables

Figure 1 exhibits the three main criterion that dictate the bend allowance in air forming. Yellow identifies the punch tip radius, red identifies the lip radius of the die, and blue identifies the v-opening of the die.

After the flat part is created, the part is imported into the machine software. This part of the offline programming process is called BYBENDPART. The bending sequence, back gauge positions, and the tool setting plan are dictated during this process. The bending sequence is an establishment of the most efficient bending order. For example, a four bend part will have four different steps in the forming process. There are typically certain sequences, which will allow this part to be formed properly without causing harm to the part or the operator. Following the bending sequence, the back gauge finger positions need to be addressed. The back gauge fingers are metal stops, which locate the part in the proper position. The software allows the user to apply the back gauge positions automatically or manually. Based on the part at hand, one way is easier than the other. The third step in the offline programming process involves creating the tool-setting plan. In this process, the user can again establish the tool setting plan automatically or manually depending on the part being constructed. The last step in the offline programming procedure is the automatic calculation (AC) process. AC is a quick and easy step if everything calculates correctly. Basically, this step searches for any problems dealing with the offline program. If the program is free of issues, then it is exported to the machines and ready for the tryout process.

After the offline program is created, a setup sheet can be produced. A setup sheet is a document designed by Company XYZ. Its purpose is to provide the water strider and operator with information they need to complete their jobs in the most efficient manner possible. The setup sheet provides information such as the part number, revision number, tooling, inspection criteria, blank type, location, weight of the part, routing instructions, safety precautions, the container type, and the first form view. The part number identifies the part and the revision number identifies the current revision of the part being produced. Furthermore, the punch is listed with all of its sectional tooling and the die is listed with all of its sectional tooling. Sectional tooling is tooling cut into small lengths; these lengths can be used in any order. The inspection criterion is what the operator is expected to check after he or she makes the first form. Since the part has already gone through the tryout process, the first part is anticipated to be a good part. Therefore, the operator is only expected to check the first flange and every angle throughout the first part. The operator does not need to check the remaining flange dimensions because the part was unfolded using the tooling based blank unfolding software. Additionally, the blank type identifies the part as a purchased part or a manufactured part. A purchased part is a part Company XYZ has purchased from an outside vendor, while a manufactured part is a part that Company XYZ has manufactured. Below the blank type is the location of the blank. The location determines what machine manufactured the blank, such as, laser, turret, or straight sides. Typically, the weight information is used on heavier parts. Company XYZ has a safety rule where an operator needs to have help lifting anything heavier than 35 pounds. In addition, the setup sheet includes routing instructions and safety precautions. The routing instructions tell the operator and water strider anything he or she needs to know about the part, such as, how to manufacture it, how to measure it, and where it goes once it is completed. On the other hand, the safety precautions relay to the operator any safety measures associated with producing the part; for instance, "watch your fingers on step three." In addition to the safety precautions, Company XYZ utilizes the container type and first forming view. The container type establishes how the finished part is to be transferred to the next operation. There is a picture that displays how to stack the parts as well. The first form view provides the operator on how to orientate the part into the machine during the first form. There is also a picture showing this process. An example setup sheet is located in Appendix C.

The tryout process is the final stage before a released program can be confirmed. A released program is a program at the press brake that has been proven accurate by measuring all flanges and angles. In the beginning of the tryout process, the operator pulls up the part at the machine for the first time. The operator then forms the first flange; the operator measures the dimension of the flange and the angle of the bend. If necessary, the operator makes adjustments to the program. Typically, most of the adjustments deal with the angles due to the varying material thicknesses. There are no two lots of material with the same material thickness. In fact, the same gauge of material from two different lots is slightly different. The tryout process is continued on all remaining bends until the part is fully formed. At this point, if everything measures within the print tolerances the tryout process is complete and the part is saved into the released program directory.

Statistical Process Control

The press brakes are being measured using a statistical process control chart (SPC). SPC charts are a form of quality control and are used to monitor or control a specific process. Managing and observing a process makes certain it functions at its full potential ("Statistical Process Control," 2013, para. 1). The data for the SPC chart is constructed at the beginning of first shift. The operator obtains the same tooling and measuring caliper. Then, the operator steps through the program as if he or she were to bend a part but at each step measures the front of die (FOD) dimension. FOD is the distance between the front of the back gauge to the front of the die. The measurements are completed in three locations. The first location is at the far left of the machine the second location is in the middle of the machine, and the third location is at the far right of the machine. Figure 2 below shows the location of all three tooling stations and figure 3 shows how the measurements of the FOD were conducted. The data is then charted on the shop floor, so supervisors and operators are aware when a variation within the process occurs.

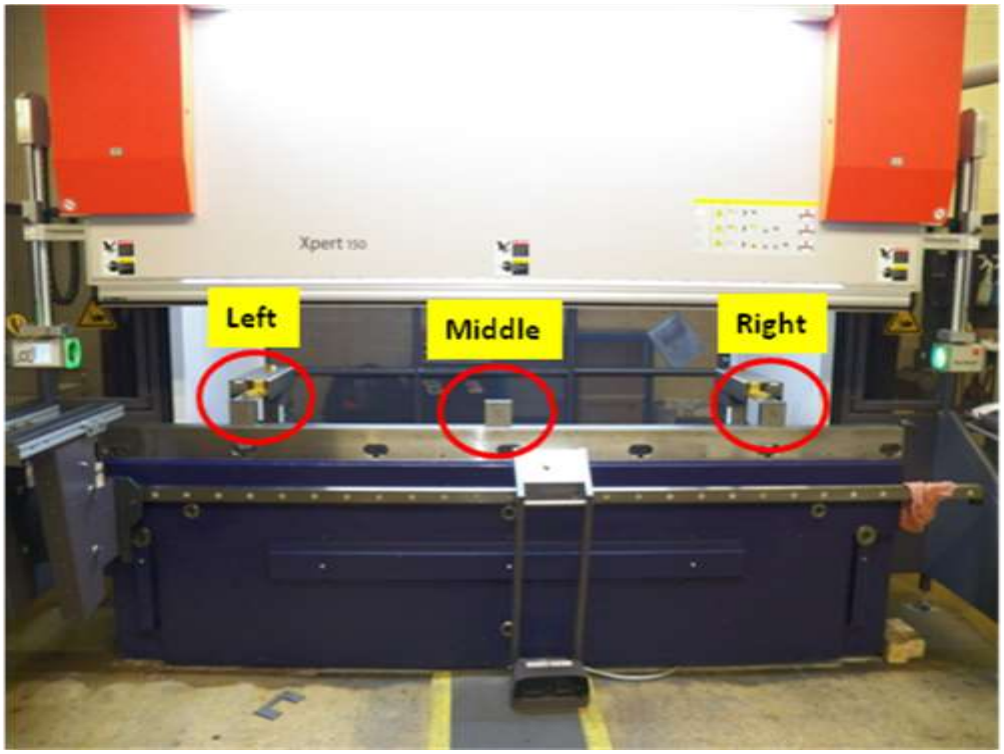

Figure 2: Tooling Stations

Figure 3: Measuring FOD

There are two types of variations, natural causes and assignable causes. A natural, also known as common, cause is a normal variation that has some sort of quantifiable history. On the other hand, an assignable, also known as special, cause is an unusual unquantifiable variation that has not been observed before. If an assignable cause arises within the process, the assignable cause must be identified immediately. Then, the assignable is removed and the SPC process returns to the tracking mode ("Statistical Process Control," 2013, para. 4). The natural and assignable causes are exposed when the data points are outside the upper control limits (UCL) and lower control limits (LCL). The UCL and LCL are control limits chosen so all of the data points will fall within these two limits as long as the process remains in control ("What are Control Charts?," n.d., para. 2). The benefits of an SPC are not attained right away; however, the SPC does provide long term maintenance. The SPC for one press brake recorded during the month of March is located in Appendix F.

Operator and Water Strider Standard Work

Operator and water strider standard work is a detailed definition of the most efficient method to produce parts on the new Bystronic press brakes. The work is balanced between the water strider and the press brake operator. Basically, the standard work is broken down into organized elements which are sequenced and repeatedly followed. Every step in the process must be followed the same way every time. This helps reduce variation within the process. If there are any variations within the process it will probably increase the cycle time or cause quality issues. "Cycle time is the total time from the beginning to the end of a process" ("Cycle Time," n.d., para. 1).

The setup cycle time for a press brake operator begins when the last good part is formed and ends when the next good part of the subsequent order is formed. After the operator forms the last part, he or she writes down the quantity formed and rearranges the empty carts and full carts in his or her area. The operator then exits the previous program and loads the new program based on the setup sheet. The water strider places the setup sheet on the inbound parts ahead of time. After that, the operator can remove the tooling from the press brake and place it on the tool cart. The tool cart is located at the right hand side of the machine. The operator wipes the bottom rail before loading the next set of tooling. The bottom rail is where the die is placed on the press brake. At this time, the operator positions the inbound cart closer to the machine and prepares him or herself in hitting the first part.

Once the first bend is made, the operator checks the angle. If the angle is good, then the operator checks the flange dimension. However, if the angle was bad, then the operator needs to correct it first before checking the flange length. Moreover, the operator is instructed to only inspect the first dimension. The operator forms the next bend and measures the angle. The process is repeated until the first part is completely formed. Once the first good part is formed the setup process is complete. The standard work for the press brake operator is provided in Appendix D. The cycle time of the setup process is essential in achieving the overall forming efficiency. The faster the setup time, the more working rate (in hours) the operator achieves. On the other hand, the cycle time for the water strider is less defined.

The sole purpose of the water strider position or helper position is to support the press brake operator with anything he or she may need to run the machine. Essentially, the water strider is completing all of the non-value added work. By definition, non-value added work is any activity that does not provide to the product or the process ("Quality Training," 2012, para. 12). In other words, Company XYZ gets paid to form parts not to do such things as bring parts to the machine, bring pallets to the machine, bring cardboard to the machine, bring parts to shipping, and put away tooling. The non-value added work that the water strider conducts is essential to the process. In addition, everything the water strider accomplishes needs to be completed in order for the press brake parts to be formed. The non-value added work is necessary until the process is further improved. The standard work for the water strider is located in Appendix E.

Process Validation

The fabrication project is measured using three aspects: labor efficiency rates, reduction in scrap, and inventory levels. In the beginning of the project, the current overall forming efficiency was 64%. There are several contributing factors to this low efficiency; for instance, the age of the existing equipment, blanks being designed off of a standard bend allowance chart without the tooling in mind, minimal consistency between machines, the lack of precision ground tooling, and too excessive non-value added work done by the operators. Purchasing these modern day press brakes resolves the following issues: age of legacy machines, blanks being designed off of a standard bend allowance chart, no consistency between machines, and the lack of precision ground tooling. In order to meet the goals set forth in this project, the non-value added work conducted by the water strider was addressed. The water strider is the setup support solution. This person performs of all the material handling, such as, finding parts, obtaining tooling, and supporting the press brake operator with anything he or she needs. The press brake operator is now able to stay at his or her machine and continually run production parts. Additionally, the average efficiency is determined by one water strider helping four press brake operators. The second process validation is the reduction of scrap.

Every year, Company XYZ scraps a great deal of bad parts or extra parts run to support setup on the legacy machines. The new press brakes will provide a combination of tooling based blank unfolding and upgraded presses, controls, and precision ground tooling to ensure this expenditure is virtually eliminated. In addition, the new machines produce a first good part every time so the production orders are made to exact quantities. Before the fabrication project, production orders were always ran with five extra parts. These parts were used as setup parts on the legacy machines. Production orders created with exact quantities aids in the last process validation, which is reduction of inventory.

"Inventory is the process of storing raw material, in-process parts, completed parts, and finished manufactured products" ("Quality Training," 2012, para. 10). Any excess inventory is considered waste. Waste is anything that does not add value to a product or service ("Quality Training," 2012, para. 19). The inventory reductions associated with the fabrication project result from reducing the lead time of formed parts. In other words, the lead time reductions minimize the amount of in-process inventory. The order quantities will also be reduced to smaller batches because the new press brakes can setup on a new part in eight minutes or less. Inventory is more often than not the largest current asset item and must be correctly accounted for since it helps dictate Company XYZ's profits or losses.

Benefits and Opportunities

The new Bystronic brake presses provide several important benefits. The investment of these premier machines has been a preferred resolution in solving the many variables in press brake forming ("Pressbrake xpert," n.d., para. 1). There are several benefits and opportunities involved with the fabrication project. For example, implementing the press brakes themselves will significantly reduce setup costs by driving the most complicated setups down to eight minutes or less. The setup reduction is compared to the current setups, which are 60 minutes or more on the legacy equipment. Furthermore, the press brakes will reduce the training period of a new brake operator from 18 months down to one week or less. However, this is something that will be completed outside the scope of the project. Additionally, this project will have a reduction in operating costs of the equipment, a standardization of maintenance spare parts, and the capability of designing and forming more complex part geometries. A reduction in inventory through lead-time reductions will reduce the total time through the shop for a press brake formed part from five days down to three days. Another opportunity for reduction is minimizing the amount of scrap metal. An added benefit to the fabrication project is a safer work environment because the operators will not need to run the brake with the safety system disabled. Moreover, the new brake presses will allow much of the setup process for new parts to occur offline, so tooling can be evaluated through the design stage instead of during the production stage. Offline programming will reduce the amount of time it takes to get a new part through the tryout process. The four press brakes will result in an annual cost savings of nearly 72% of the total amount invested on this project.

The total cost savings are derived from an evaluation of labor, maintenance, and scrap material. Presently, Company XYZ utilizes 150 hours per day to produce 100 formed hours of work. The outcome of this project is expected to increase productivity with the new machines through a combination of setup reduction and water strider support. The total hours estimated to be used (operators and water strider) to produce 100 hours per day is 90. In other words, assume the future load is going to increase as new programs are added and current volumes grow; this translates into more than a quarter of a million dollars per year of labor reduction. The synergy of standardized equipment has a positive impact on training, maintenance, and spare parts management. At the moment, Company XYZ's press brakes span six different machine and control types. The fabrication project will improve the up time and reduce the maintenance expenses because spare parts and preventive maintenance (PM) will be consolidated to one type. With the combination of tooling based blank unfolding and upgraded presses and controls, scrap material is predicted to reduce by approximately 75%. However, some of the scrap will not be impacted by this project. The scrap material is based on bad parts or extra parts used to setup the legacy machines.

As indicated in the aforementioned statements, Company XYZ has the opportunity to establish a competitive advantage when quoting new business. The capabilities of these new machines will allow the design team to create significantly more complex formed parts without the use of expensive dedicated tooling. Welding is the key cost driver, thus combining parts will reduce weld without drastically increasing setups. An example of this is shown below in Figure 4. Additionally, the machine control displays to the operator how to stage bend the part using one setup. Offline programming allows a design engineer to make adjustments to the part geometry to improve manufacturability before any metal is committed. This significantly reduces the development time and scrap. The outcome of this project is imperative to the growth of Company XYZ because it is a major transition from prehistoric equipment and processes to present technology.

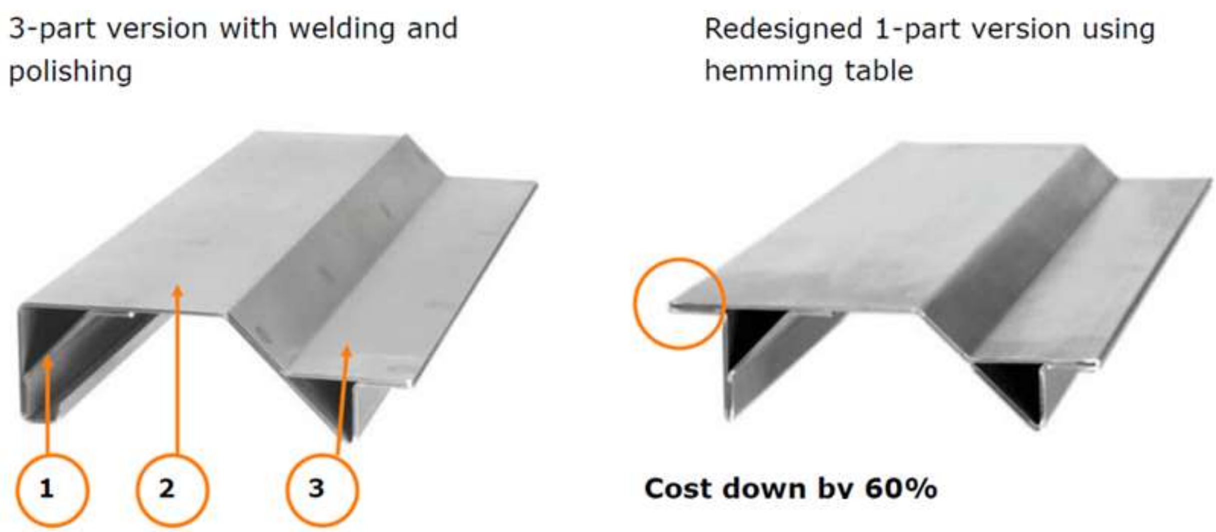

Figure 4: Multiple Parts vs. One Part

Displays a welded part versus a redesigned formed part. The welded part is manufactured using a press brake, a welder, and a metal finisher. The formed part consists of one part. From Pressbrake Xpert. (n.d.). *Bystronic*. Retrieved from, http://www.bystronicusa.com/us-en/products/Pressbrakes/Xpert.php

Limitations

Limitations associated with this project are small. In fact, there are only two risks involved. The first restriction of the fabrication project is not implementing it at all. Failure to add at least one modern press brake leaves Company XYZ exposed to extended down time on legacy machines. The average age of the current press brakes is 30 years or older, making the current system more susceptible to wear related failures and unscheduled maintenance. Additionally, the average setup time is longer than eight minutes, and with more complicated setups, up to two hours. This results in the need to keep larger run sizes to maintain capacity. This could also cause the inventory reduction benefit from occurring. Furthermore, if the new equipment does not produce a first good part this would have a negative impact on the overall scrap savings. The first part, good part assumption was proven valid by completing trial runs when visiting each supplier. The second limitation is associated with an unsuccessful implementation. Failing to institute the water strider position would cause fewer press brake strokes per hour as the operator would be required to perform other duties. In essence, the only limitations involved with this project are not implementing the new machines at all or implementing the water strider unsuccessfully.

Summary

The press brake forming process is decades behind other leading businesses in the industry. The initial research phase lasted roughly 12 months and comprised of three key stages. During these stages, the fabrication group reviewed potential suppliers, visited potential suppliers, and visited the potential supplier's customers. Once the fabrication group came to a conclusion, the machine ramp up phase began. This phase consisted of creating a machine layout, producing offline programs and setup sheets, and testing the parts out at the production machines. The machine ramp up phase was a long, drawn out process that took more than six months to complete. Next, a Statistical Process Control was established to help control and monitor the forming process. The SPC makes certain that the process functions at full potential which is imperative to the success of the project. The press brake operator and water strider standard work was also implemented. The standard work is a sequence of events that is to be followed repeatedly without alteration. Another validation of the process is the reduction of scrap. The new press brakes provide a "first part, good part" relationship allowing the scrap material and inventory levels to be significantly reduced. In reality, the only limitation associated with the fabrication project is not doing it at all.

Chapter IV: Results

Company XYZ, a leading manufacture in Rochester Minnesota, is decades behind other leading competitors within its industry. In order for Company XYZ to remain competitive in today's world, it must reduce operating costs while increasing the company's quality and customer response time. The overall objective of the fabrication project was to successfully implement four 150 ton press brakes. In order for this project to be considered successful, several targets needed to be met. The first objective was to improve the overall forming efficiency to 100%, the second target was to reduce inventory by 40%, and the third objective was to reduce the amount of material scrapped from the press brakes by 75%. Additionally, the project aimed to reduce maintenance costs by consolidating all press brakes to one type.

Forming Improvements

In order to meet the first target set forth, the fabrication team began the project by measuring the current process. The present process yielded wasteful setup times and an overall forming efficiency of 64%. Contributing factors to the efficiency rate include the age of the equipment, blanks being designed from a standard bend allowance chart, inconsistency between machines, and a lack of precision ground tooling. These factors led the fabrication team looking at new technology to help resolve the forming issues and significantly increase efficiency. In an effort to support the forming efficiency goal, the team completed two tasks. The team first implemented modern press brakes and software which are capable of much faster setups. The advanced technology will allow the setup process for new parts to occur off-line, thus tooling evaluation can happen at the design stage instead of during the production stage. Furthermore, the off-line programming software will substantially reduce the amount of time it takes to get parts through the tryout process. In addition to the implementation of this more advanced technology, the team also established the setup support solution to pick parts, pick standardized containers, and perform all material handling. The operator in this position is called the water strider and will be completing all non-value added work involved in the forming process.

The overall forming efficiency is an average of the non-value added work plus the value-added work. In other words, the water strider (non-value added) and the press brake operator (value-added) are combined together to create the average forming efficiency. The water strider records 0% efficiency everyday because his or her tasks are all associated with non-value added work. On the other hand, the press brake operators range from 120% to 130% on a weekly basis. This translates into 10 hours of work in an eight-hour day. The four operators at 32 hours plus one water strider at 8 hours equals a total of 40 hours per week. The earned hours by the five operators comes to a total of 40 hours per week. This equates to an average efficiency of 100%, found by dividing the total earned 40 hours by the total 40 working hours. Table 1 below summarizes the overall forming efficiencies for the month of March.

Table 1

Overall Forming Efficiencies

Overall Forming Efficiency - March						
Date	**Operator 1**	**Operator 2**	**Operator 3**	**Operator 4**	**Water Strider**	**Averages**
3/1/2013	125%	98%	103%	102%	0%	86%
3/4/2013	105%	109%	110%	101%	0%	85%
3/5/2013	97%	110%	103%	85%	0%	79%
3/6/2013	135%	99%	110%	113%	0%	91%
3/7/2013	89%	94%	98%	97%	0%	76%
3/8/2013	106%	102%	115%	100%	0%	85%
3/11/2013	93%	104%	121%	112%	0%	86%
3/12/2013	107%	124%	138%	123%	0%	98%
3/13/2013	98%	114%	127%	135%	0%	95%
3/14/2013	101%	149%	170%	153%	0%	115%
3/15/2013	125%	140%	118%	147%	0%	106%
3/18/2013	117%	97%	146%	132%	0%	98%
3/19/2013	109%	164%	135%	138%	0%	109%
3/20/2013	100%	125%	136%	141%	0%	100%
3/21/2013	118%	123%	144%	116%	0%	100%
3/22/2013	128%	134%	127%	139%	0%	106%
3/25/2013	136%	145%	129%	133%	0%	109%
3/26/2013	148%	157%	119%	123%	0%	109%
3/27/2013	131%	136%	124%	127%	0%	104%
3/28/2013	132%	146%	111%	126%	0%	103%
3/29/2013	129%	125%	144%	135%	0%	107%

The data was recorded for one month which came from four operators on four different machines. In addition, the operators all worked on the day shift. The efficiency rates were calculated each day of the month and recorded in the table below. For example, on the first of March Operator 1 earned 125% forming efficiency. The efficiency was calculated by dividing the total earned 10 hours by the total 8 working hours in a given day. This was calculated to equal 125%. The earned hours are dictated and recorded by labor cards. For instance, a certain part has a specific setup time and run time involved. Generally, each part has different setup times and run times. At the end of each shift, the operators earned hours are recorded and divided by the total working hours. The data is then received by running a report. The report provides the operator's forming efficiency rates as percentages.

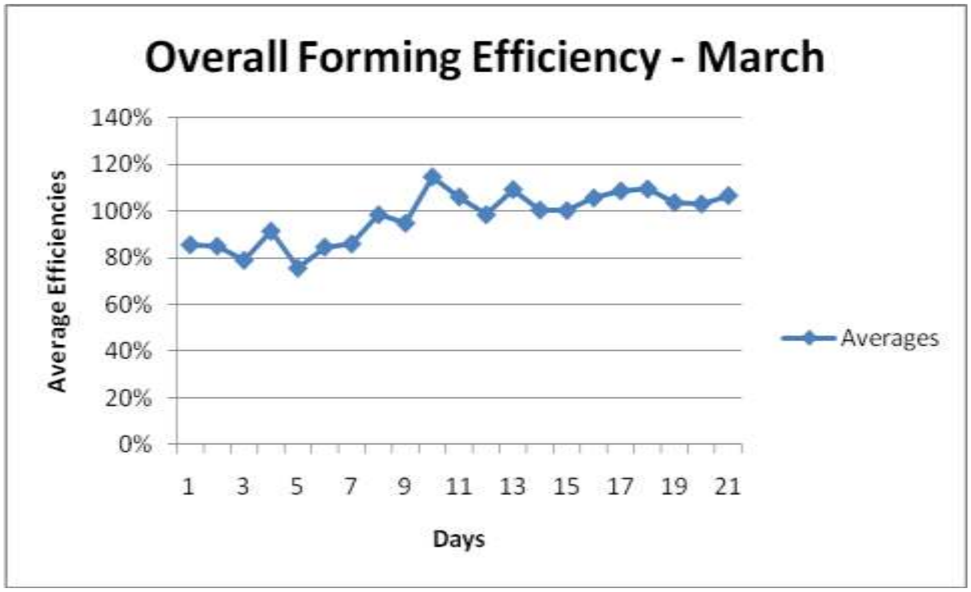

Figure 5: Overall Forming Efficiencies - March

Figure 5 reveals the average efficiencies for four press brake operators and one water strider. Notice how the rates are up and down in the beginning. This is a result of the fabrication team implementing the new standard work for both the press operators and the water strider. As the month progresses, the rates become gradually closer if not better than the goal of 100%.

Inventory Reduction

The new press brakes have proven to manufacture a good part the first time. The fabrication team conducted trial runs at each of the three suppliers. The team also completed onsite visits to other customers of the three press brake suppliers to confirm that the "first part, good part" assumption is valid. The "first part, good part" situation leads to a reduction in inventory. Smaller run sizes can be used instead of large run sizes because there is zero scrap generated on released programs. Subsequently, the inventory turns are increased through smaller run sizes. A high inventory turnover rate signifies that Company XYZ performs correct inventory management and sells product faster, resulting in more profit. In addition to this, higher inventory turnover rates allow fewer inventory stocks, less storage space, and less capital costs. An increase in inventory turns also allows for an increase of money in and out of the company. This is also known as cash flow. Ultimately, the inventory reductions were confirmed by reducing the lead time of press parts from five days to down to three days, which equates to a 40% reduction.

Scrap Reduction

In result of implementing four modern press brakes with advanced technology, Company XYZ experienced a reduction in scrap costs associated with setup parts. Presently, scrap parts are generated through forming bad parts and producing extra parts run to support setup on the legacy machines. The combination of tooling based blank unfolding and upgraded presses and controls virtually eliminated the scrap experienced per year. This translates into a 75% reduction in scrap, as some of the scrap will not be impacted by this project. Manufactured parts, manufactured rollover protective structures (ROPS), and stock assembly are the three types of material affected by the press brake project.

The manufactured level consists of any part that is sitting within a process at any given time. The manufactured level is scrapped 68% of the time. The manufactured ROPS is high strength steel that is used for structural applications such as cab frames for John Deere. The total amount scrapped for this type of material is 26%. Stock assembly is any material that is purchased from an outside vendor, and its annual percentage of scrap is approximately 6%. The percentage Company XYZ reclaims from each type of material was significantly increased. The scrap factor for a manufactured part will be reduced by 90%, and the scrap factor for manufactured ROPS and stock assembly will be reduced by 75%. The percentages of reclaimed scrap equate to an overall scrap reduction of 75%.

Maintenance Consolidation

In the past, maintenance was performed on the legacy machines on a routine basis. The average age of the legacy presses was 30 years or more, making the old system more susceptible to wear related failures and unscheduled maintenance. The legacy press brakes spanned six different machine types, control types, and spare parts lists. Replacing the old machines with the new machines consolidated everything to one machine type, one control type, and one spare parts list. This will improve the up time and minimize maintenance expenses because spare parts and preventive maintenance (PM) can be consolidated. Preventive maintenance and extending the life of the machines is critical and is monitored with total preventive maintenance (TPM).

TPM is a management approach that places routine maintenance responsibilities on the machine operators instead of hiring separate maintenance employees. TPM's provide the press operators with a sense of responsibility and awareness of their machines. Moreover, they force the operators to take care of their machines and not misuse or abuse the equipment. The operators at Company XYZ are required to perform one task daily. There is a cleaning schedule and pictorial work instructions located on the machine. The work instructions aid the operators in performing many tasks, including checking oil levels, greasing, blowing out filters, replacing oil filters, checking gauges, and checking mechanical leakage. The maintenance staff still plays a role in the preventive maintenance because there are some duties that require a mechanic's expertise. The maintenance savings associated with the fabrication project is approximately 15% of the annual expenditures from 2011.

Chapter V: Discussion

In an effort to support Company XYZ's initiatives of growth and continuous improvement, the fabrication team developed a plan to improve its press brake fleet with modern equipment. The intention of the fabrication project was to implement modern press brakes and Bysoft software capable of much faster setups. At the same time, the fabrication team implemented a setup support solution involving a helper to pick parts, standardized containers, and perform material handling to ensure the maximum uptime on these new presses. To accomplish the aforementioned objectives, the project was executed during three phases: the research phase, the machine ramp up phase, and the full production phase.

During the first phase, the fabrication team was established and research on possible vendors began. The fabrication team analyzed potential suppliers in three stages while eliminating one supplier at the end of each stage. This first stage consisted of an initial visit and review of the companies and their equipment. The second stage involved an on-site visit and demonstration of Company XYZ's most complicated production parts, and the final stage involved an RFQ. At this point, the fabrication team assembled together and agreed upon the supplier that would work best for Company XYZ's needs.

In the second phase, the machine ramp up process was launched. This phase was the longest of the three and consisted of completing tasks imperative to the successful implementation of the new machines. A machine layout was first created, submitted, and approved by upper management. The step files were then created. Once a large number of step files were produced, offline programming, the creation of setup sheets, and machine tryouts began. There were approximately 2,000 parts to be run through these three steps prior to the production phase. The machine ramp up phase took six months to complete.

In the final phase of the project, operator and water strider standard work were implemented in order to achieve the main objective of the fabrication project: reducing machine setup time. The operator and water strider standard work was broken down into organized elements, which were sequenced in a specific order. Each step within the two processes must be followed the same way every time. Additionally, the order of the elements for the press operator and water strider were tied together, so the objective of 100% efficiency can be met.

The overall fabrication project was evaluated using three key measures: labor efficiency rates, a reduction in scrap metal, and a reduction in inventory levels. At the beginning of the project, the current overall forming efficiency was 64% and the scrap factor was approximately 25% of the total cost of the fabrication project. The project yields a 1.1 year payback while virtually eliminating the press brake scrap. The reduction in scrap aids in the last key measureable: inventory reductions. Company XYZ had a lot of waste and unneeded inventory throughout all of its manufacturing processes. The inventory reductions related with the fabrication project resurrected from reducing the lead time of formed parts from five days down to three days. The order quantities were also reduced to smaller batch sizes because the new press brakes are capable of setting up more efficiently and the first part produced is a good part. The implementation of four new press brakes also significantly improved the following:

1. Allowed 80% of the setup process for new parts to occur offline so that tooling evaluations can happen at the design stage and not during the production stage.
2. Reduced the overall operating costs of the equipment and support standardization of spare parts and maintenance.
3. Lowered safety risks through better press safety systems.

4. Enabled the design department to take advantage of more complex formed part geometry to reduce costs in our products.

Limitations

The limitations associated with the press brake project are minimal, but can be separated into two categories. This first category involves no implementation at all. Failure to add at least one modern press brake will leave Company XYZ exposed to an extended machine down time situation. Furthermore, the average setup time will not be reduced from 60 minutes to an average of 8 minutes or less, which results in the need to run larger run sizes. Consequently, the reduction in inventory and scrap would not occur but only get worse over time. The second category is associated with an unsuccessful implementation. Failing to establish the water strider would lead to a reduced number of strokes per hour of the machine as the operator would be required to perform other duties. The limitations to this project are minute but possible if the project is not implemented properly or at all.

Conclusions

Overall, the fabrication project deemed successful by implementing four 150-ton press brakes and a setup support solution. This project study accomplished four main objectives toward Company XYZ's pursuit to total quality management: increasing the average forming efficiency from 64% to 100%, reducing the scrap rate by 75%, reducing inventory, and consolidating maintenance related issues and reducing cost by 15%. Over the course of the past year, all of the goals were completed through the fabrication team's efforts of continuous improvement to the air forming process.

In order to ensure the fabrication project is maintaining over time, an SPC was put in place during the initial stages of the production phase. The data for the SPC is created at the beginning of 1st shift. The operators obtain the information and chart it on a graph that is located on the shop floor. Examination of the graphs provides valuable information when the machines experience issues. This can be observed by investigating the SPC charts for any data points outside of the UCL and LCL. Furthermore, the smallest amount of variation increases the consistency within the process. The conclusion of this project made certain all four machines were ready for full production as well as the helper support solution.

Recommendations

Based on the project conclusion, several recommendations can be made. First, the overall forming efficiency is currently on the edge of underperforming. This is due to the newly implemented standard work processes for the water strider and press operator. Over time, this process will gradually improve and the forming efficiency will rise. In order to achieve the state of world-class status, the pressroom manufacturing engineer and shop floor supervisors need to continually coach and improve the process daily.

In addition to continuous coaching and daily improvement processes, the continued use of the SPC is recommended to ensure that the new press brakes are performing within their control limits and not influenced by any abnormal variables. The abnormal variables may cause production parts to be formed incorrectly resulting in scrap and rework. In addition, the SPC history can be used to validate any improvements or recommendations in the future. The use of the SPC should only be removed if the SPC tracking process is deemed unnecessary.

In support of Company XYZ's expansion and continuous improvement efforts, the company should consider applying the methodology used in the fabrication project on future continuous improvement projects. The company is looking at improving the laser cells, turret operations, and the pressroom at their secondary manufacturing plant.

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Appendix A: Press Room Layout

Below is the proposed and approved floor plan for this project. The four new machines are green in color and the pink squares represent parts flowing in and out of the machines.

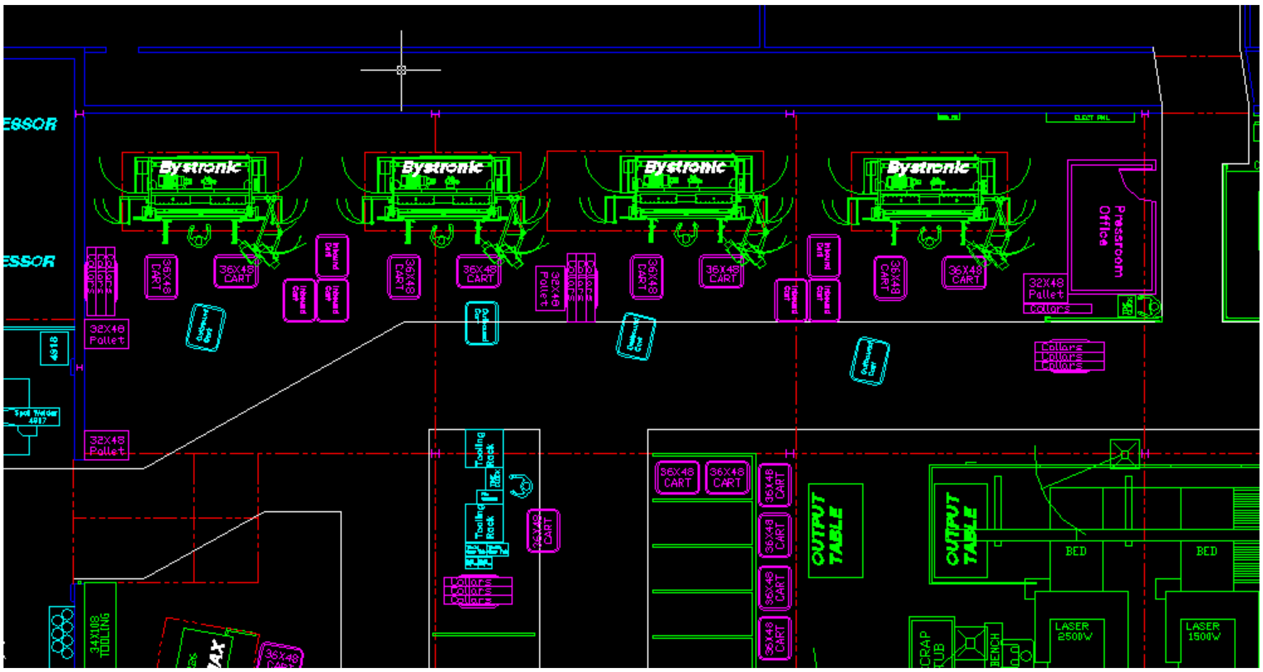


Figure A1: Press Room Layout

Appendix B: Selecting Bend Lines

The picture below is showing what the offline programmer does when selecting the bend lines (in gray), the tools, and bending method.

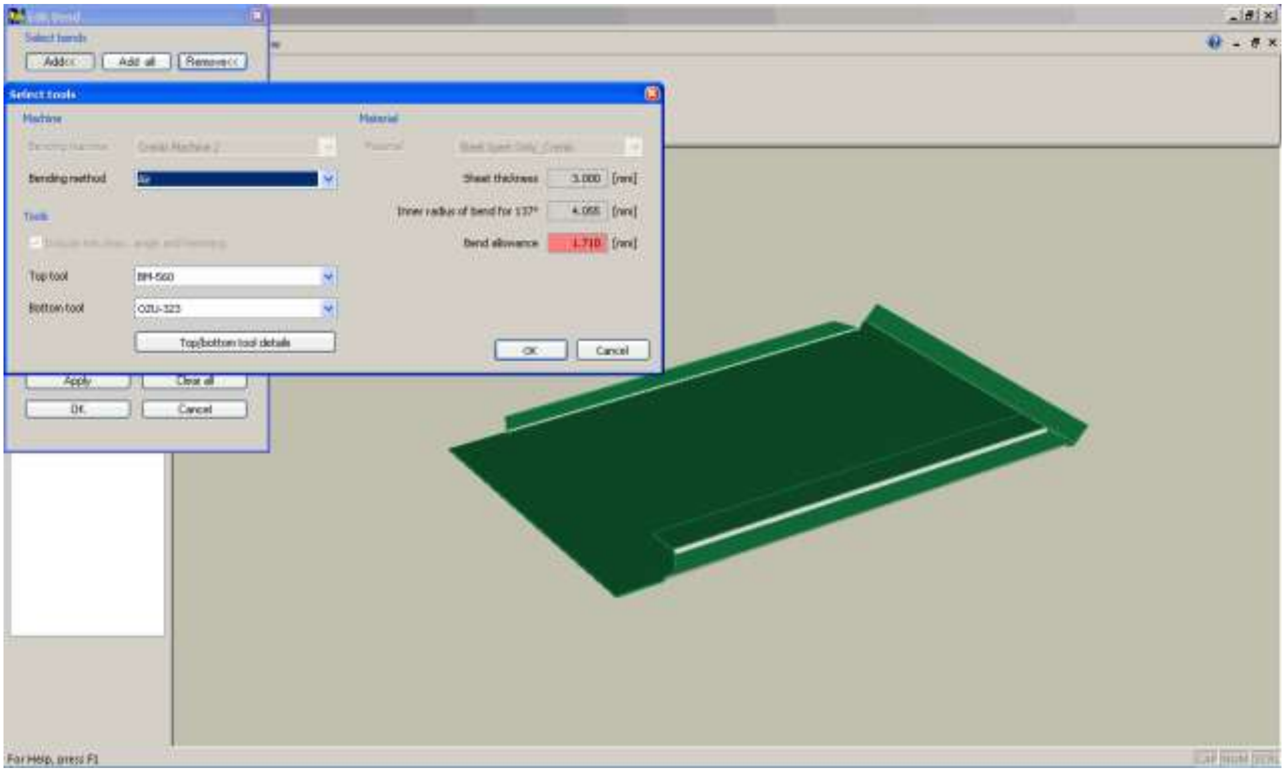
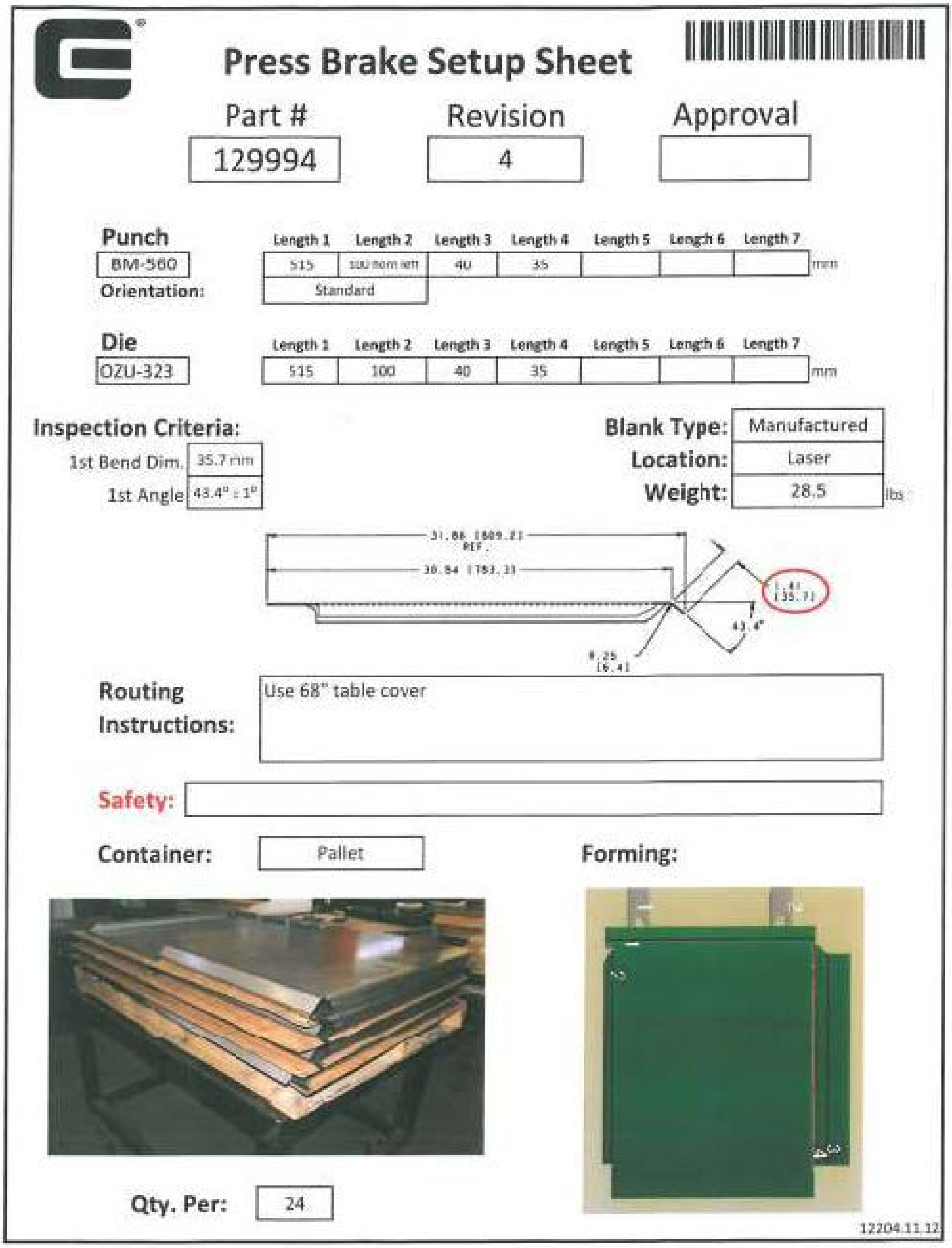


Figure B1: Selecting Bend Lines

Appendix C: Setup Sheet

The picture below is an example setup sheet used at the new brake presses.



Press Brake Setup Sheet

Part #	Revision	Approval
129994	4	

Punch: BM-560

Length 1	Length 2	Length 3	Length 4	Length 5	Length 6	Length 7	
515	100 nom left	40	35				mm

Orientation: Standard

Die: OZU-323

Length 1	Length 2	Length 3	Length 4	Length 5	Length 6	Length 7	
515	100	40	35				mm

Inspection Criteria:
1st Bend Dim. 35.7 mm
1st Angle 43.4° ± 1°

Blank Type: Manufactured
Location: Laser
Weight: 28.5 lbs

Routing Instructions: Use 68" table cover

Safety:

Container: Pallet

Forming:

Qty. Per: 24

12204.11.12

Figure C1: Setup Sheet

Appendix D: Operator Standard Work-Simple Part

The operator standard work and Auto CAD prints are split into three scenarios: easy, medium, and hard parts. An easy part consists of one or two 90° bends. A medium part consists of four to five bends with at least two different angles. Lastly, a hard part is considered to have eight to twelve bends with roughly six different angles. The three standard work documents and their prints are located below. They are in chronology order from simple to complex.

Elm. #	Element Description	1	2	3	4	5	Avg. Time	Avg Time		Rating	Rest Allow	Std Min	Comments / Waste Observations / Improvement Suggestions
								VA	NVA				
1	Write quantity formed on route sheet. Place route sheet and setup sheet on outbound cart	0.15	0.08	0.11			0.11	0.11		100%	115%	0.13	
2	Move outbound cart to outbound queue	0.12	0.14	0.16			0.14	0.14		100%	115%	0.16	
3	Move inbound cart to outbound	0.24	0.12	0.22			0.19	0.19		100%	115%	0.22	
4	Get pallet/cardboard if needed from left hand side of press	0.22	0.15				0.19	0.19		100%	115%	0.21	
5	Exit and load new program from setup sheet	0.41	0.34	0.58			0.44	0.44		100%	115%	0.51	
6	Remove tooling and place on tool cart	0.54	0.55	0.65			0.58	0.58		100%	115%	0.67	
7	Wipe rail and load tooling form inbound cart	0.66	0.83	0.77			0.75	0.75		100%	115%	0.87	
8	Place setup sheet and route packet on inpsection table		0.11	0.10			0.11	0.11		100%	115%	0.12	
9	Position tool cart closer to the machine and bring monitor closer	0.26	0.20	0.20			0.22	0.22		100%	115%	0.25	
10	Hit pedal for the first time to make sure the safety lights are engaged. If not, stop and reset them.	0.14	0.12	0.15			0.14	0.14		100%	115%	0.16	
11	Make 1st hit	0.19	0.18	0.20			0.19	0.19		100%	115%	0.22	
12	Check 1st angle and flange	0.52	0.44	0.32			0.43	0.43		100%	115%	0.49	
13	Make correction to angle and all remaining angles if needed.			0.20			0.20	0.20		100%	115%	0.23	
14	Rehit part			0.19			0.19	0.19		100%	115%	0.22	
15	Check angle and if angle was more than 5° off check flange			0.32			0.32	0.32		100%	115%	0.37	
								Total Standard Minutes Per Unit				4.83	

Figure D1: Operator Standard Work-Simple Part

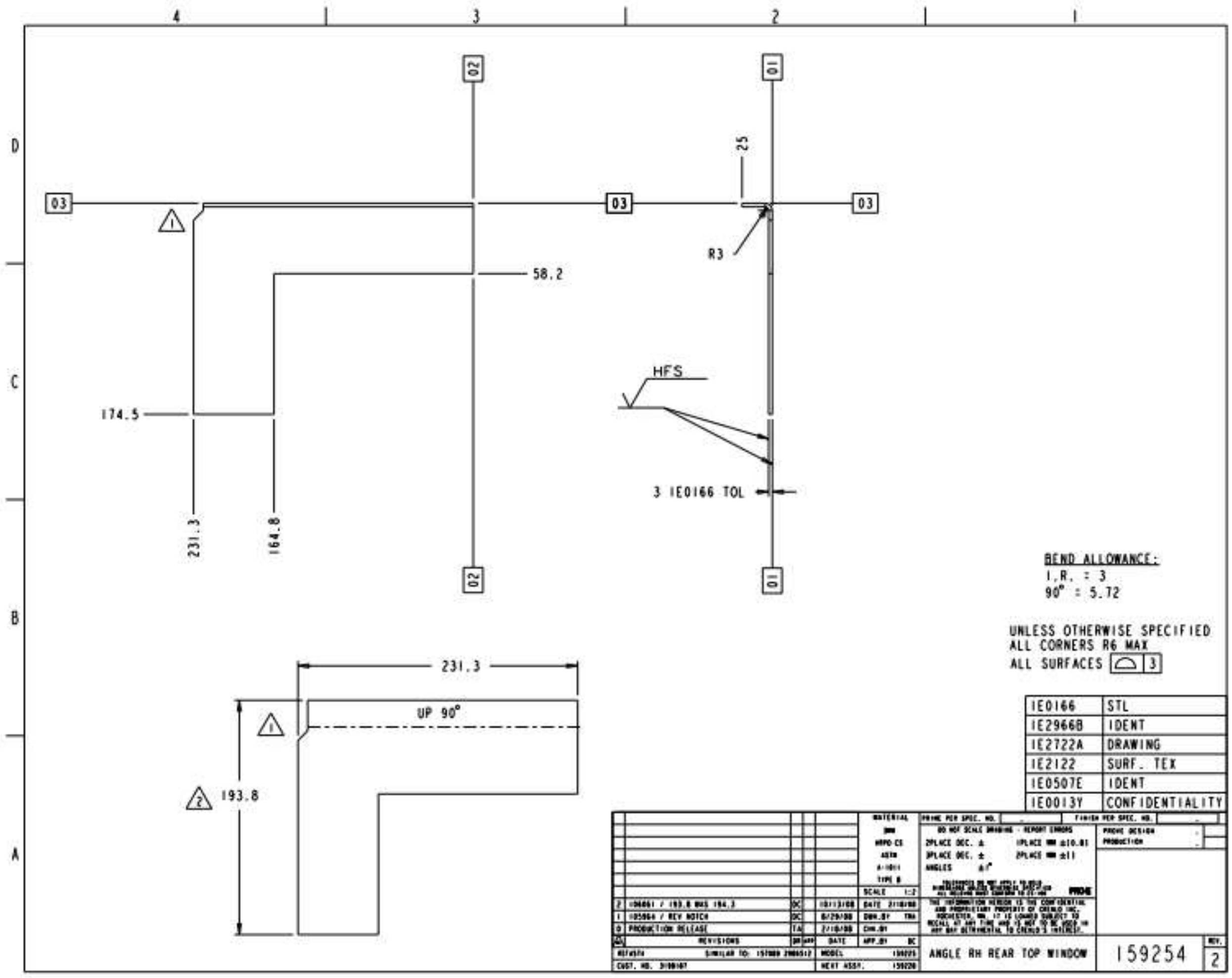


Figure D2: Product Detail-Simple Part

Elm. #	Element Description	1	2	3	4	5	Avg. Time	Avg Time		Rating	Rest Allow	Std Min	Comments / Waste Observations / Improvement Suggestions
								VA	NVA				
1	Write quantity formed on route sheet. Place route sheet and setup sheet on outbound cart	0.10	0.11	0.10			0.10	0.10		100%	115%	0.12	
2	Move outbound cart to outbound queue	0.27	0.24	0.12			0.21	0.21		100%	115%	0.24	
3	Move inbound cart to outbound		0.14	0.15			0.15	0.15		100%	115%	0.17	
4	Get pallet/cardboard if needed from left hand side of press	0.65	0.30	0.35			0.43	0.43		100%	115%	0.50	
5	Exit and load new program from setup sheet	0.20	0.46	0.47			0.38	0.38		100%	115%	0.43	
6	Remove tooling and place on tool cart	0.43	0.24	0.26			0.31	0.31		100%	115%	0.36	
7	Wipe rail and load tooling form inbound cart	1.66	1.28	1.06			1.33	1.33		100%	115%	1.53	
8	Place setup sheet and route packet on inpsection table	0.10	0.08	0.09			0.09	0.09		100%	115%	0.10	
9	Position tool cart closer to the machine and bring monitor closer	0.07	0.08	0.12			0.09	0.09		100%	115%	0.10	
10	Hit pedal for the first time to make sure the safety lights are engaged. If not, stop and reset them.	0.15	0.27	0.31			0.24	0.24		100%	115%	0.28	
11	Make 1st hit	0.42	0.44	0.30			0.39	0.39		100%	115%	0.44	
12	Check 1st angle and flange	0.58	0.49	0.77			0.61	0.61		100%	115%	0.71	Dropped blades on last time
13	Make correction to angle and all remaining angles if needed.												
14	Make 2nd hit	0.34	0.30	0.36			0.33	0.33		100%	115%	0.38	
15	Check 2nd angle	0.24	0.24	0.25			0.24	0.24		100%	115%	0.28	
16	Make correction to angle and all remaining angles if needed.	0.14					0.14	0.14		100%	115%	0.16	
17	Form 3rd hit	0.26	0.19	0.14			0.20	0.20		100%	115%	0.23	
18	Form 4th hit	0.20	0.14	0.10			0.15	0.15		100%	115%	0.17	
								Total Standard Minutes Per Unit				6.20	

Figure D3: Operator Standard Work-Medium Part

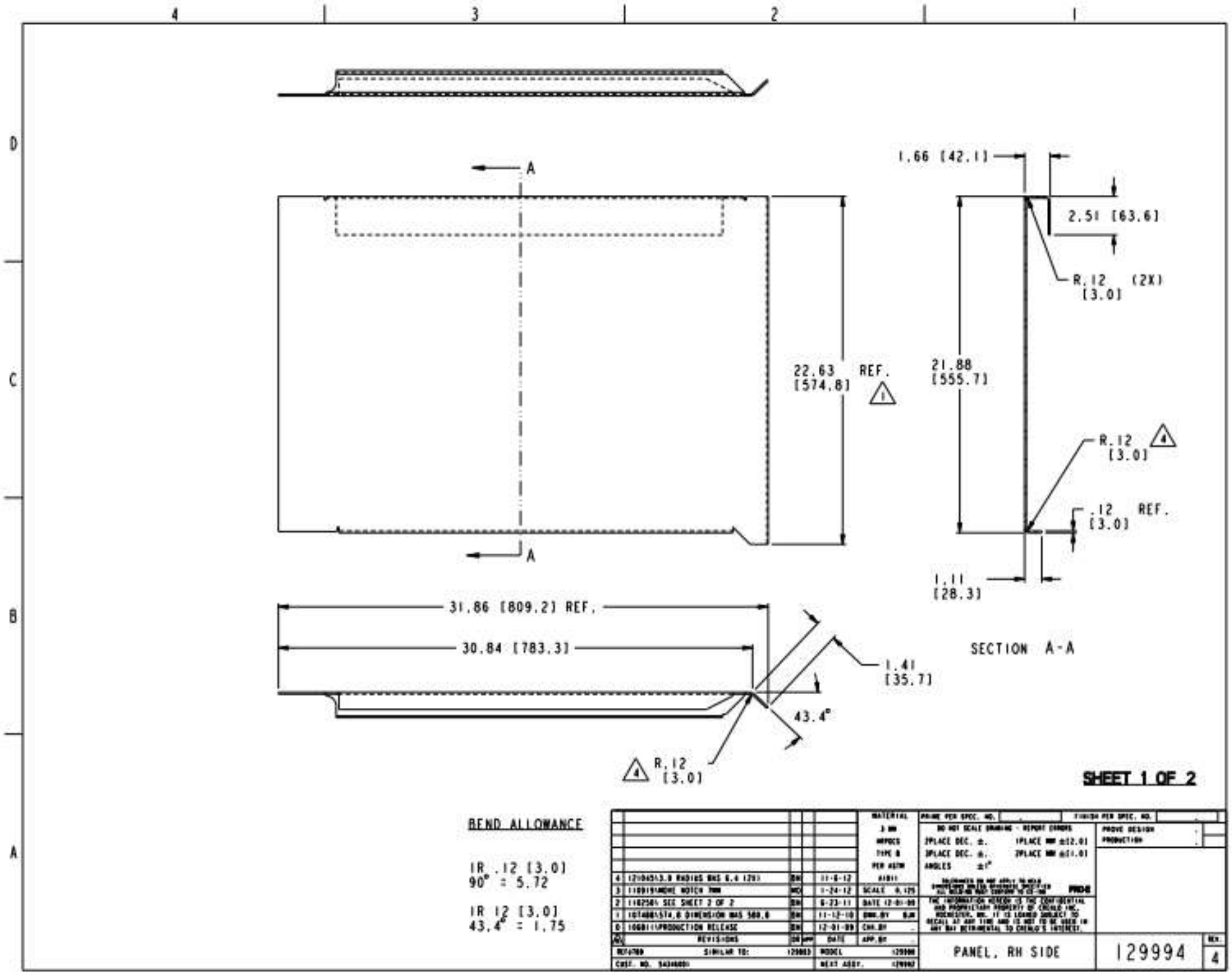


Figure D4: Product Detail-Medium Part

Elm. #	Element Description	1	2	3	4	5	Avg. Time	Avg Time VA	Avg Time NVA	Rating	Rest Allow	Std Min	Comments / Waste Observations / Improvement Suggestions
1	Write quantity formed on route sheet. Place route sheet and setup sheet on outbound cart	0.15	0.13	0.18			0.15	0.15		100%	115%	0.18	
2	Move outbound cart to outbound queue	0.14	0.12	0.16			0.14	0.14		100%	115%	0.16	
3	Move inbound cart to outbound	0.21	0.17	0.16			0.18	0.18		100%	115%	0.21	
4	Get pallet/cardboard if needed from left hand side of press	0.22	0.15				0.19	0.19		100%	115%	0.21	
5	Exit and load new program from setup sheet	0.45	0.62	0.53			0.53	0.53		100%	115%	0.61	
6	Remove tooling and place on tool cart	0.44	0.47	0.35			0.42	0.42		100%	115%	0.48	
7	Wipe rail and load tooling form inbound cart	2.83	2.69	2.67			2.73	2.73		100%	115%	3.14	
8	Place setup sheet and route packet on inpsection table	0.10	0.11	0.09			0.10	0.10		100%	115%	0.12	
9	Position tool cart closer to the machine and bring monitor closer	0.22	0.18	0.18			0.19	0.19		100%	115%	0.22	
10	Hit pedal for the first time to make sure the safety lights are engaged. If not, stop and reset them.	0.48	0.60	0.39			0.49	0.49		100%	115%	0.57	
11	Make 1st hit	0.31	0.24	0.32			0.29	0.29		100%	115%	0.33	
12	Check 1st angle and flange	0.88	0.82	0.71			0.80	0.80		100%	115%	0.92	
13	Make correction to angle and all remaining angles if needed.	0.81	0.32	0.27			0.47	0.47		100%	115%	0.54	
14	Make 2nd hit			0.31			0.31	0.31		100%	115%	0.36	
15	Check 2nd angle			0.34			0.34	0.34		100%	115%	0.39	
16	Make correction to angle and all remaining angles if needed.			0.19			0.19	0.19		100%	115%	0.22	
17	Make 3rd hit			0.50			0.50	0.50					
18	Check 3rd angle			0.26			0.26	0.26		100%	115%	0.30	
19	Make correction to angle and all remaining angles if needed.			0.21			0.21	0.21		100%	115%	0.24	
20	Make 4th hit			0.32			0.32	0.32		100%	115%	0.37	
21	Check 4th angle			0.21			0.21	0.21		100%	115%	0.24	
22	Make correction to angle and all remaining angles if needed.			0.17			0.17	0.17		100%	115%	0.20	
23	Make 5th hit			0.27			0.27	0.27		100%	115%	0.31	
24	Check 5th angle			0.19			0.19	0.19		100%	115%	0.22	
25	Make correction to angle and all remaining angles if needed.			0.18			0.18	0.18		100%	115%	0.21	
26	Make 6th hit			0.25			0.25	0.25		100%	115%	0.29	
27	Check 6th angle			0.27			0.27	0.27		100%	115%	0.31	
28	Make correction to angle and all remaining angles if needed.			0.21			0.21	0.21		100%	115%	0.24	
29	Make 7th hit			0.25			0.25	0.25		100%	115%	0.29	
30	Check 7th angle			0.22			0.22	0.22		100%	115%	0.25	
31	Make correction to angle and all remaining angles if needed.			0.25			0.25	0.25		100%	115%	0.29	
								Total Standard Minutes Per Unit				12.41	

Figure D5: Operator Standard Work-Complex Part

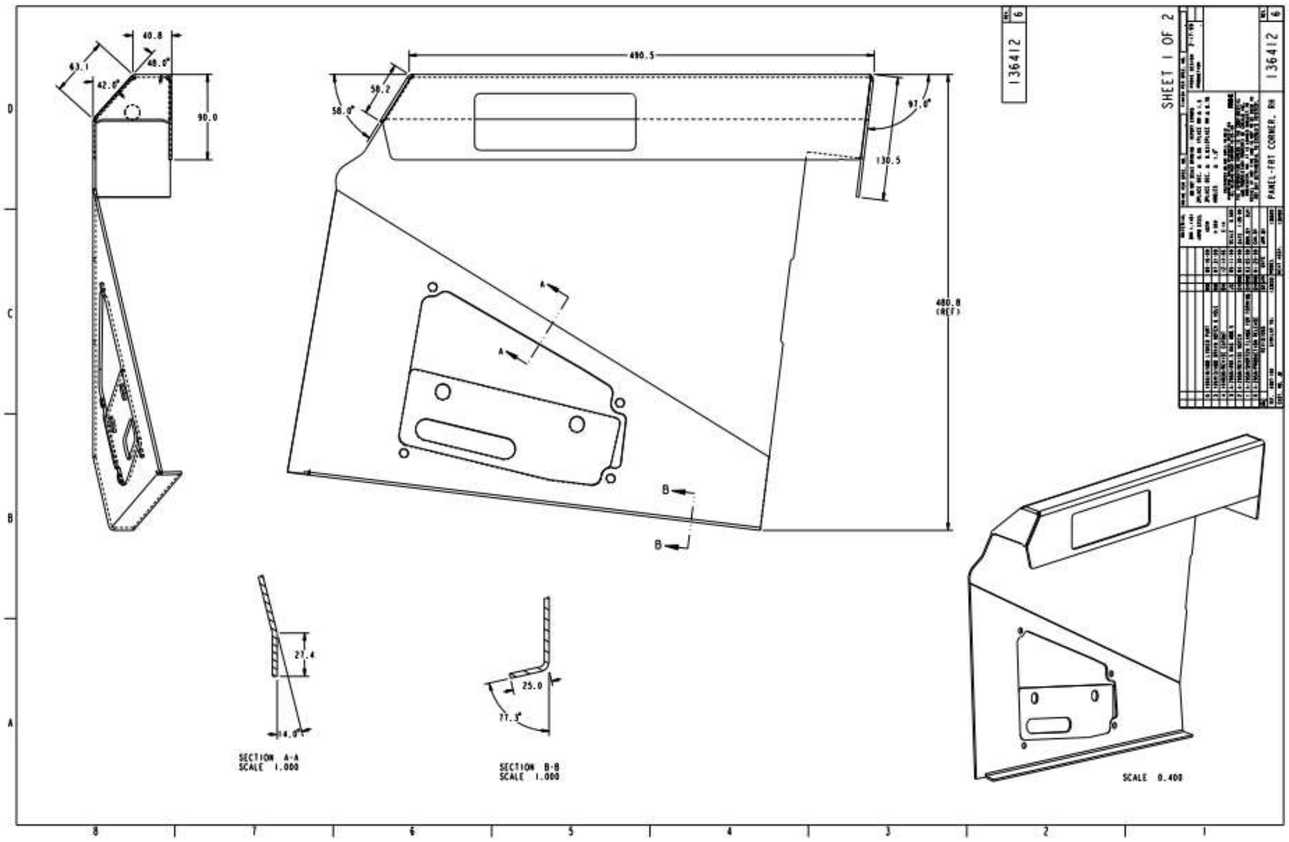


Figure D6: Product Detail-Complex Part

The following picture is the standard work layout for the press brake operator. The small white circles match up with element numbers above. The element numbers above are located on the left hand side of each standard work document.

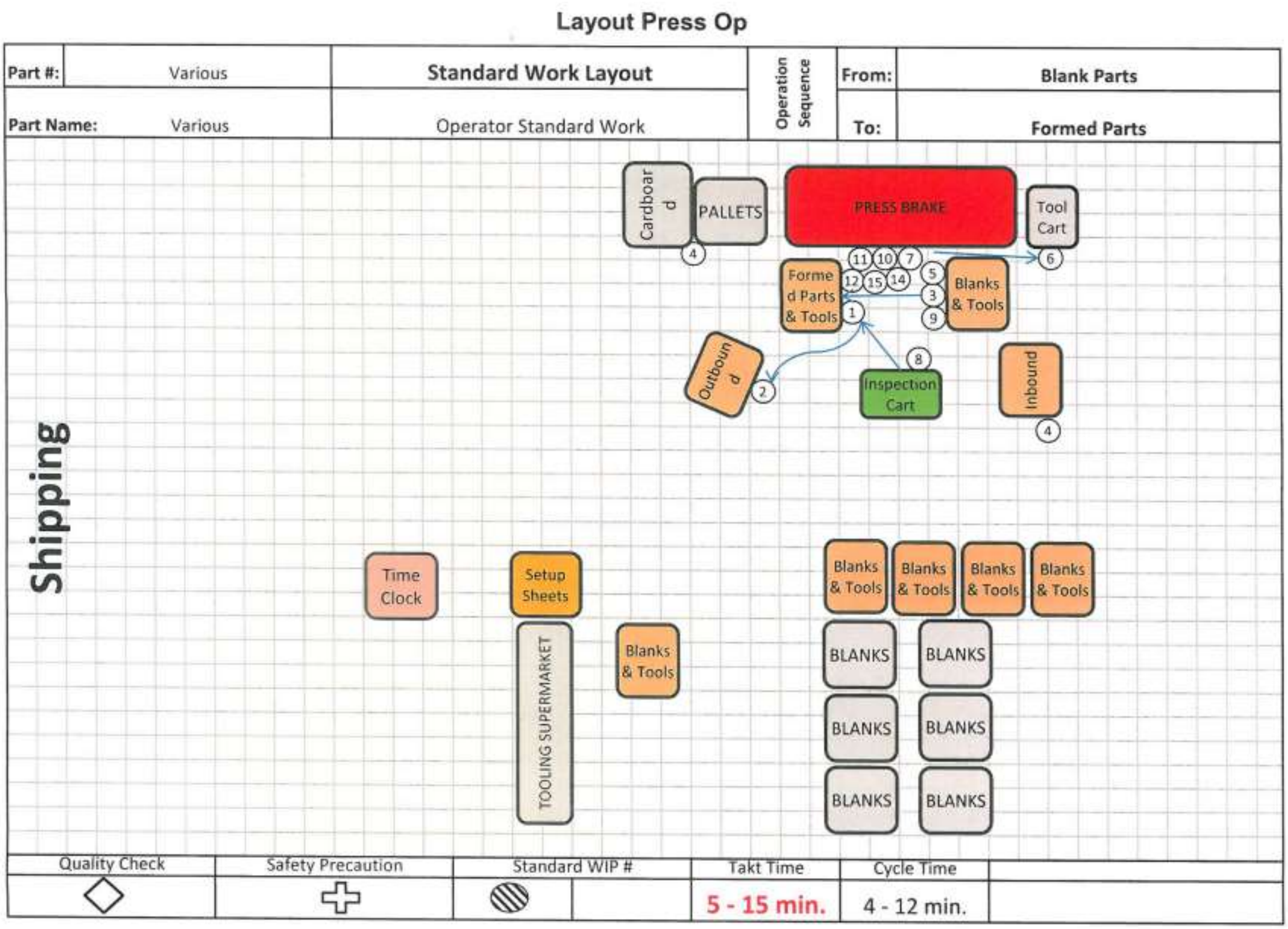


Figure D7: Operator Standard Work Layout

Appendix E: Water Strider Standard Work

The water strider standard work consists of two scenarios. The only difference between the two scenarios is where the finished part is located after it is formed. The first scenario is called "Bystronic to Shipping." In this situation, the water strider brings the parts to the shipping dock where they are sent across town to the other manufacturing plant. The second scenario is called "Bystronic to Next Operation." In this circumstance, the water strider brings the completed parts to the next operation. The next operations may consist of spot welding, PEM-Sert, tapping, or another press brake. The two standard work procedures are displayed below.

Elm. #	Element Description	1	2	3	4	5	Avg. Time	Avg Time		Rating	Rest Allow	Std Min	Comments / Waste Observations / Improvement Suggestions
								VA	NVA				
1	Find Bystronic orders and wheel cart over	0.38	0.24				0.31	0.31		100%	115%	0.36	
2	Use route sheet to obtain setup sheet	0.18	0.47	0.26			0.30	0.30		100%	115%	0.35	
3	Place listed tooling from setup sheet on parts and place setup sheet in routing packet	0.73	1.49	0.66			0.96	0.96		100%	115%	1.10	
4	Push cart into Bystronic holding area or "In Queue"	0.16	0.54	0.19			0.30	0.30		100%	115%	0.34	
	Repeat steps 1-4 as needed.												
5	Remove cart from "Out Queue" area to clocking station	0.67					0.67	0.67		100%	115%	0.77	
6	Pull paper work out of routing packet and Tag parts	1.34	0.87	0.92			1.04	1.04		100%	115%	1.20	
7	Clock off on all operations completed	0.50					0.50	0.50		100%	115%	0.58	
8	Put paper work on pallet	0.43	0.23				0.33	0.33		100%	115%	0.38	
9	Put setup sheet away	0.49	0.42				0.46	0.46		100%	115%	0.52	
10	Bring parts to shipping	1.16					1.16	1.16		100%	115%	1.33	
	Repeat steps 5-10 as needed.												
11	Bring tooling back to tooling center	0.45					0.45	0.45		100%	115%	0.52	
12	Whip tools tools and put away	1.94	2.17				2.06	2.06		100%	115%	2.36	
13	Return tool cart to right hand side of press	0.21					0.21	0.21		100%	115%	0.24	
14	Replenish pallets as needed	1.43					1.43	1.43		100%	115%	1.64	
15	Replenish cardboard as needed	0.39					0.39	0.39		100%	115%	0.45	
								Total Standard Minutes Per Unit				**11.70**	

Figure E1: Bystronic to Shipping Standard Work

Elm. #	Element Description	1	2	3	4	5	Avg. Time	Avg Time		Rating	Rest Allow	Std Min	Comments / Waste Observations / Improvement Suggestions
								VA	NVA				
1	Find Bystronic orders and wheel cart over	0.38	0.24				0.31	0.31		100%	115%	0.36	
2	Use route sheet to obtain setup sheet	0.18	0.47	0.26			0.30	0.30		100%	115%	0.35	
3	Place listed tooling from setup sheet on parts and place setup sheet in routing packet	0.73	1.49	0.66			0.96	0.96		100%	115%	1.10	
4	Push cart into Bystronic holding area or "In Queue"	0.16	0.54	0.19			0.30	0.30		100%	115%	0.34	
	Repeat steps 1-4 as needed.												
5	Remove cart from "Out Queue" area to clocking station	0.67					0.67	0.67		100%	115%	0.77	
6	Pull paper work out of routing packet and Tag parts	1.34	0.87	0.92			1.04	1.04		100%	115%	1.20	
7	Clock off on all operations completed	0.50					0.50	0.50		100%	115%	0.58	
8	Put paper work on pallet	0.43	0.23				0.33	0.33		100%	115%	0.38	
9	Put setup sheet away	0.49	0.42				0.46	0.46		100%	115%	0.52	
10	Bring parts to next operation	3.17					3.17	3.17		100%	115%	3.65	
	Repeat steps 5-11 as needed.												
11	Bring tooling back to tooling center	0.45					0.45	0.45		100%	115%	0.52	
12	Whip tools tools and put away	1.94	2.17				2.06	2.06		100%	115%	2.36	
13	Return tool cart to right hand side of press	0.21					0.21	0.21		100%	115%	0.24	
14	Replenish pallets as needed	1.43					1.43	1.43		100%	115%	1.64	
15	Replenish cardboard as needed	0.39					0.39	0.39		100%	115%	0.45	
								Total Standard Minutes Per Unit				**14.01**	

Figure E2: Bystronic to Next Operation Standard Work

The drawing below is the standard work layout for the water strider. The small white circles match up with element numbers above. The element numbers above are located on the left hand side of each standard work document.

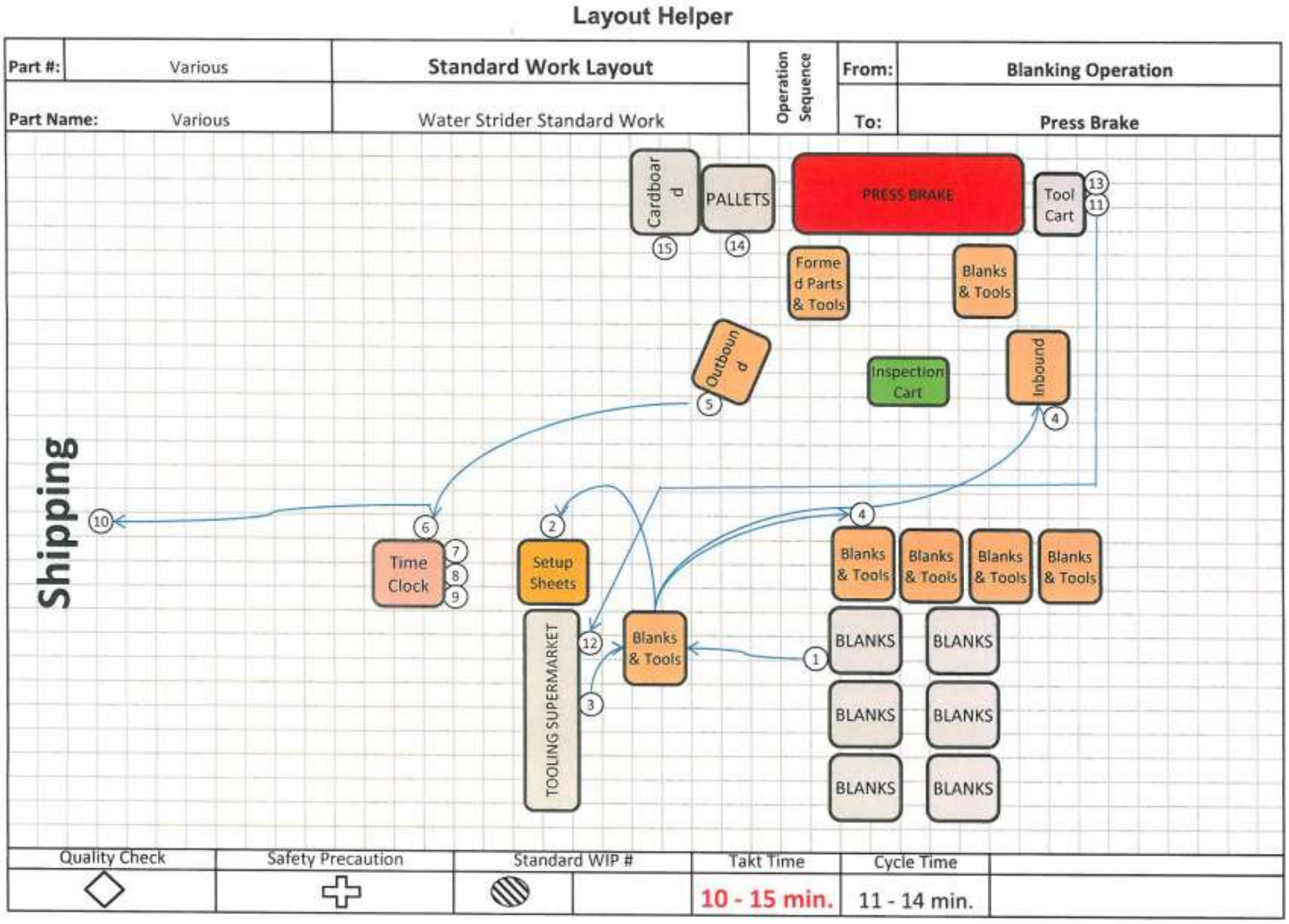


Figure E3: Helper Standard Work Layout

Appendix F: Statistical Process Control Chart

The SPC chart displayed below shows the front of die (FOD) dimensions for one press brake. The data was recorded in the month of March. There is no sample part involved with the SPC. The same die is used every time because all the dies have different overall widths. Each day three measurements were taken on the left, middle, and right hand side of the press. The FOD consists of measuring from the front of the die to the front of the back gauge using a digital caliper. The number is then recorded on a control chart located on the shop floor.

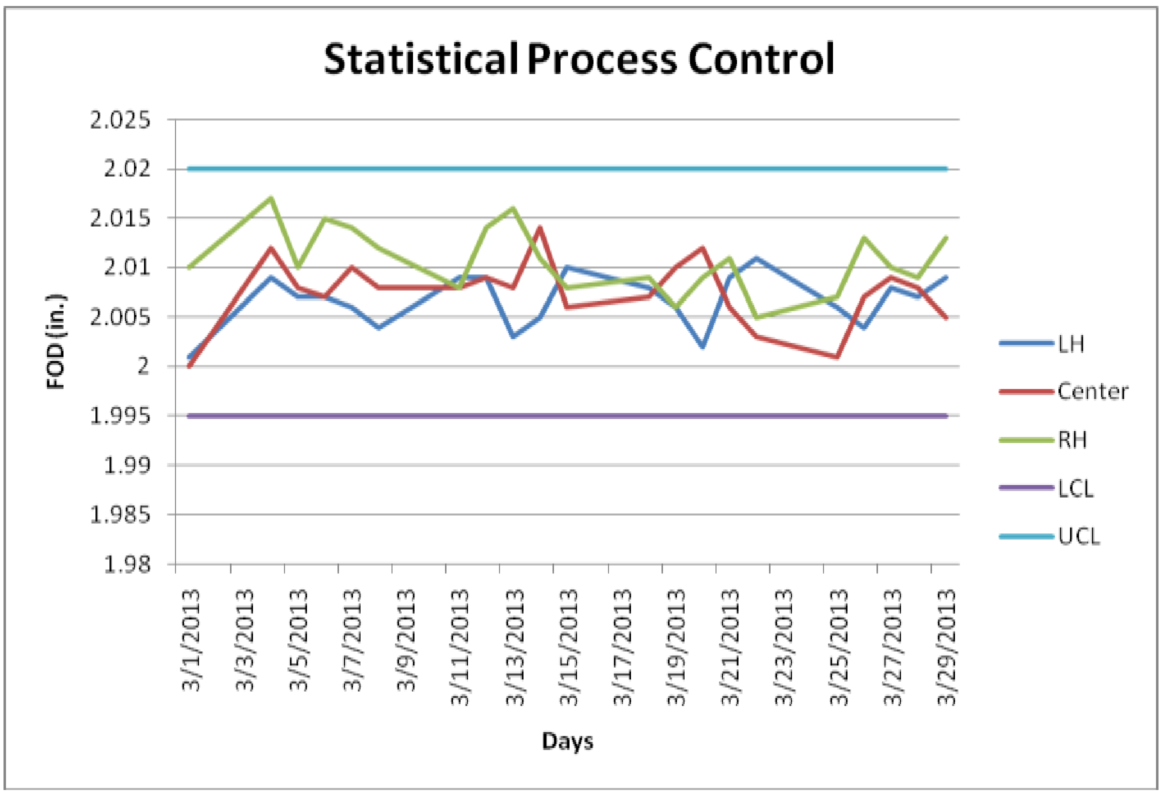


Figure F1: Statistical Process Control Chart