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Scrap Reduction at EFD

Caitlin E. Macko
Worcester Polytechnic Institute

David J. Byler
Worcester Polytechnic Institute

Nathan Warren Griggs
Worcester Polytechnic Institute

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David J. Byler, Nathan W. Griggs, and Caitlin E. Macko

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Professor Amy Zeng, Primary Advisor

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Abstract

This project, sponsored by Electron Fusion Devices, seeks to provide the groundwork and recommendations for reducing costs resulted from wastes produced within the Injection Molding Department. Extensive background research on both Lean and Six Sigma ideals was first conducted. An analysis of their current scrap tracking tools and processes led to a focus on overall scrap reduction and made a pilot study necessary. We designed a new set of scrap tracking sheets and procedures for data collection and analysis, and recommended future steps for the company's endeavor in reducing scraps.

Executive Summary

Background

The goal of this project was to provide EFD with the groundwork and recommendations to reduce costs resulting from waste produced within their injection molding department, including molding scrap and machine downtime. We focused on overall scrap reduction in line with six sigma ideals. The company went through several drastic changes as the project progressed, mainly involving moving four buildings into one and shutting down production due to an economic recession and inventory build-up. For these reasons, the initial goal of our project was open for adjustment as we began our procedures.

Methods

Extensive background research on Lean and Six Sigma ideals was initially conducted to gain an understanding of all materials that we could utilize to complete our project goal. The scope of the project and all of the stakeholders involved were identified next through communication with EFD. A schedule of deliverables was then produced using a Gantt chart to allow for complete transparency of the process. Next we began to measure the current scrap loss that is taking place in the injection molding department. This data collection mainly involved analyzing their current documentation pertaining to scrap. After further examination and several brainstorming sessions with individuals at EFD, the goal of the project shifted to create a new means of scrap tracking in the injection molding department. We developed a data collection program for EFD to follow in order to generate the baseline of scrap production that we had previously expected to establish from their documentation.

Major Findings and their Implications

The two-week pilot study that we designed was slated for Monday, January 26th through Monday, February 9th and accounted for ten business days. The tracking sheets were modified by EFD employees to focus on material coming in (raw and regrind) and material going out (trash), rather than recording details regarding what happens to material once it was already "in the system." Due to several obstacles, including a complete company move and an economic recession discussed in Chapter 6, only three jobs were captured throughout the timeframe allotted. Also, for some jobs, not all of the required data was recorded.

Overall, finished pieces accounted for 66% of material usage, followed by regrind at 30%, floor scrap at three percent, QA at one percent, and setup at 0.33%. While the data is not as complete as we would have liked, it shows some important information not previously known by the company. Specifically, the fact that on three small jobs, floor scrap accounted for three percent of waste was previously unknown. Also, the fact that 31% of the raw material produces regrind, rather than finished product, could affect management decisions about how regrind is handled, stored, and used. The pilot study served the purpose that was intended: to provide EFD with the groundwork to generate proper scrap amounts and highlight areas that produce the most significant amount.

Conclusion

Our initial background research on-site with EFD exposed the various data sheets traveling between different departments at one time collecting similar sets of data. The inefficiencies of the paper trail made it very difficult for anyone to break down the data that has been captured and make use of its content. Switching between electronic databases and older paperwork also made it extremely difficult to combine similar scrap-related data that had been spread across different departments. We found that there had been little attempt to adjust old materials or introduce new ones that would consolidate paperwork across departments and streamline the scrap tracking.

We found that a significant amount of scrap could be captured by creating and utilizing new forms of paperwork designed specifically for scrap tracking. It also would have been difficult to introduce new forms of paperwork without providing the standard work instructions along with it. Despite the addition of the standard work instructions to the paperwork, we came to the conclusion that formal training will also be needed to ensure that the scrap tracking will be performed correctly.

Recommendations

By examining the past documentation that was originally used by EFD, we believe several projects can be created to reduce unsystematic activities. One recommendation includes a project breaking down the past documentation, including which type of data each captures, where it is located, and who documents on it; this project would allow EFD to combine certain aspects of the documentation and eliminate data duplication. It is recommended that EFD tracks the percentage of which types of materials are used, whether it is virgin material or regrind, for each individual job; this data will help to determine specific percentage of materials used for each job, how often a product is reused, and how often this reuse and mixed percentage creates poor products (rejects).

Other valuable tracking systems could evaluate employee ergonomics, as well as the need for formal training and/or auditing materials. Upon the successful implementation of the data tracking system in the injection molding department, we recommend that EFD carry over the system to various other departments in order to further reduce scrap costs company-wide. Furthermore, this scrap data collection system can become even more useful by creating cause and effect diagrams to determine what parts of machines are causing the most scrap and tracking machine downtime to record overall waste in the operations.

Acknowledgements

We would like to thank the following people for their valuable contributions to our project. Without their support, this report would not have been possible.

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- Wil Van Den Boogaard –Director of Operations at EFD
- Steve Costa – Molding & Tip Assembly Manager at EFD
- Dan Crane – QA Manager at EFD
- Professor Amy Zeng – Project Advisor from WPI

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Authorship Page

All writing, editing and revisions were done equally by all members of the group.

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Chapter 1—Introduction

Electron Fusion Devices, or EFD, is one of "the world's leading designer and manufacturer of precision dispensing systems that apply accurate, consistent amounts of adhesives, sealants, lubricants, and other assembly fluids used in virtually every manufacturing processes" (EFD). Since being founded in 1963, EFD has expanded its influence from simpler silver brazing markets, to more complex; including dispensing systems and materials. All of the plastic materials that are utilized by the dispensing systems produced by EFD, including dispensers and valves, are formed within the injection molding, or IM, department at EFD. Molding machines and operators work on a 3-shift day, ideally running for 120 hours a week. This, combined with 24-hour production and a constant stream of demand, makes the department the biggest moneymaker for EFD. Perhaps as a result of this magnificent success, one aspect that has been almost completely overlooked up to this point is the waste resulting from day to day operations in the IM department, including scrap, machine downtime, and communication disconnects. We, along with EFD, believe that there is great potential for improvement in this aspect of the department.

1.1 Problem Statement

Our project, sponsored by Electron Fusion Devices, was aimed at evaluating waste in the injection molding department and its financial impacts. Major contributors to waste are scrap, machine downtime, and communication disconnects. Machine downtime comes from operator errors, set-up time, maintenance work, or machine failure. All of these areas had ample potential to be examined to improve the operations in the IM department. We primarily concentrated on quantifying the amount and sources of scrap produced during production, changeover, and maintenance, and identify future studies to be done to reduce the costs associated with each.

Currently there is no direct means for EFD to track the amount of scrap that is produced; however, one source estimates a loss $250,000 per year in scrap. EFD has become known throughout the industry for the highest quality products; relying on the use of virgin material for highest initial quality, as well as scrapping any product that shows the slightest deviation from strict specifications. In recent years, the company has expanded its operations within the injection molding processes for its main products (plastic barrels, tips, end-caps, hubs, and pistons) thereby increasing the amount of scrap produced. Up to this point, scrap loss has not been a major concern for the company due to the high profit-to-cost ratio, even while scrapping uncounted hundreds of thousands of units determined not fit for sale. While some data is available regarding the type and quantities of this scrap, the total scrap and resulting financial loss has not been quantified.

1.2 Goals and Objectives

The end goal of the project was to provide EFD with the groundwork and recommendations to reduce costs resulting from waste produced within their injection molding department, including molding scrap and machine downtime. We will focus on overall scrap reduction in line with six sigma ideals. We will:

- **Define** the process and the stakeholders involved
    - Determine scope and stakeholders through communication with EFD
    - Create a schedule for deliverables
- **Measure** the scrap loss in the injection molding process
    - Analyze current documentation for available scrap data
        - Several databases exist; must be combined
        - Identify missing data
        - Collect missing data
    - Examine both set-up and in process scrap

Once the amount of scrap is determined, our next goal is to identify major sources of scrap loss and to identify potential methods of scrap reduction. We hope to increase the department's profitability and reduce the environmental impact of wastes. We will evaluate the current processes and take measurements of key aspects of the processes that relate to scrap.

- **Identify** major sources of the scrap loss
    - Analyze "Workmanship Standards for Plastic Injection Molding Components".
    - Analyze databases
        - Create Pareto diagram
    - Process mapping
        - SIPOC process mapping
            - Includes suppliers, inputs, process, outputs, and customers
        - Create specific process flow diagrams (machine process) including all inputs, process steps, and outputs
- **Analyze** potential methods of scrap reduction
    - Create cause-and-effects diagrams
        - Fishbone diagram to determine specific action items
    - Form brainstorming team
        - Discuss open items and stimulate ideas
    - Structure a list of possible solutions to each specific problem identified

Finally, after analyzing the data through cause-and-effect relationships, our final goal is to create feasible recommendations to EFD on how to improve the process in order to reduce and control scrap loss.

- **Implement:** Make recommendations on how to improve the process.
    - Perform regression analysis (if applicable)
        - Predict potential cost savings vs. scrap reduction
    - Determine potential new process capabilities
    - Complete cost benefit analysis
        - Which recommendation provides best outcomes
- **Control:** Recommendations on how to control proposed processes
    - Mistake proofing, also known as Poka-Yoke.
    - New accountability and auditing materials

This will be a first pass at scrap loss analysis at EFD, and as such, the group will focus only on identifying and improving the largest sources of scrap loss in the process—the areas in which the least costly changes will create the greatest savings. Full implementation of any recommendations is beyond the scope of this project, however, trial runs or studies could be completed before a final presentation. Regardless, our analysis will establish a baseline for scrap loss at EFD and pave the way for future improvements and savings through scrap control at EFD.

1.3 Company Profile: Electron Fusion Devices (EFD)

Electron Fusion Devices, or EFD, was founded in the early 1960s to tap into the silver brazing market with the development of new technologies. EFD officially hit the market in 1963 with the introduction of new fusion welding techniques, improving the efficiency and strength of previously used methods. After several years of successful business operations within this market, EFD expanded into the jewelry industry in 1966. EFD's operations continued to grow as its reputation for quality products attracted more customers, stretching across the U.S., Canada, and Europe.

In 1972 EFD introduced a new line of products to better meet the needs of the customers within the brazing market. They developed automatic fluid dispensers for productive applications of precision metal brazing pastes. These dispensers were also being employed within many manufacturing processes that included the use of adhesives, lubricants, paints, and other liquids.

Fluid dispense valve technology was invented in 1976 and EFD gained a competitive advantage by being first company to develop dispensable industrial solder paste. With the introduction of this new technology and a steady stream of business, EFD acquired assets of Atlas Electronics, a precision machining company. The company's headquarters were also established with the purchase of two buildings located in East Providence, RI in 1980. Sales offices were also built in France, Canada, and the UK.

The solder paste sector of the organization continued to grow with the chemical development of ESP solder cream and other customizable formulas. EFD's manufacturing began to include the injection molding of plastic barrels and tips that were being used to dispense these fluids. In 1989, EFD finished the construction of its manufacturing facility in Lincoln, RI. It is primarily used for injection molding, precision machining, valve assembly, and ESP solder paste manufacturing, packaging, and sales.

In 2000, EFD was acquired as a subsidiary of the Nordson Corporation. Nordson designs, manufactures, and markets systems that apply adhesives, sealants and coatings to a broad range of consumer and industrial products (EFD). By combining technologies and expertise, EFD has "become the world's leading designer and manufacturer of precision dispensing systems that apply accurate, consistent amounts of adhesives, sealants, lubricants, and other assembly fluids used in virtually every manufacturing processes" (EFD).

1.3.1 Organizational Charts

EFD is a subsidiary of the Nordson Company that is based out of Ohio, but is operated as its own entity. The executive management is head by Peter Lambert, vice president at Nordson and president of EFD. The hierarchy then breaks into five main sections that are relevant to the project; Director of Operations, Lean Implementation Manager, Director of Finance & Administration, director of HR, and Engineering Manager. In order to further breakdown these sections for the relevance of the project, we looked more in-depth at the operations hierarchy as well as the injection molding department. Under the head of operations lies Scott O'Connell (Industrial Engineer), Danny Crane (Quality Assurance Manager), Jeff White (Manufacturing MGR III: Molder Products), and James Moore (Manufacturing MGR III: Electromechanical Products). We have designated key individuals from these organizational charts to take part in the project as key stakeholders, project champions, and valuable resources.

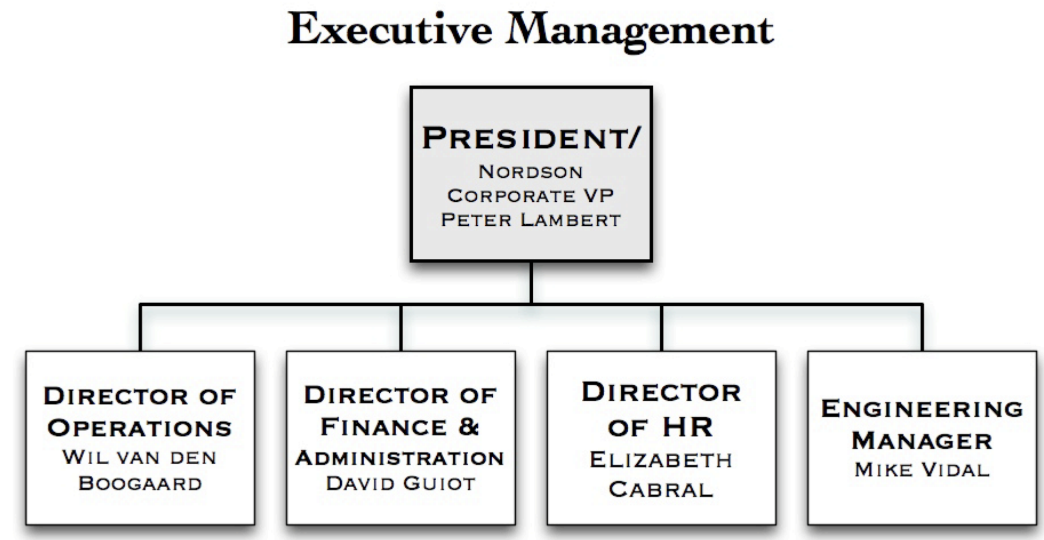


Figure 1: ***Executive Management Organizational Chart***

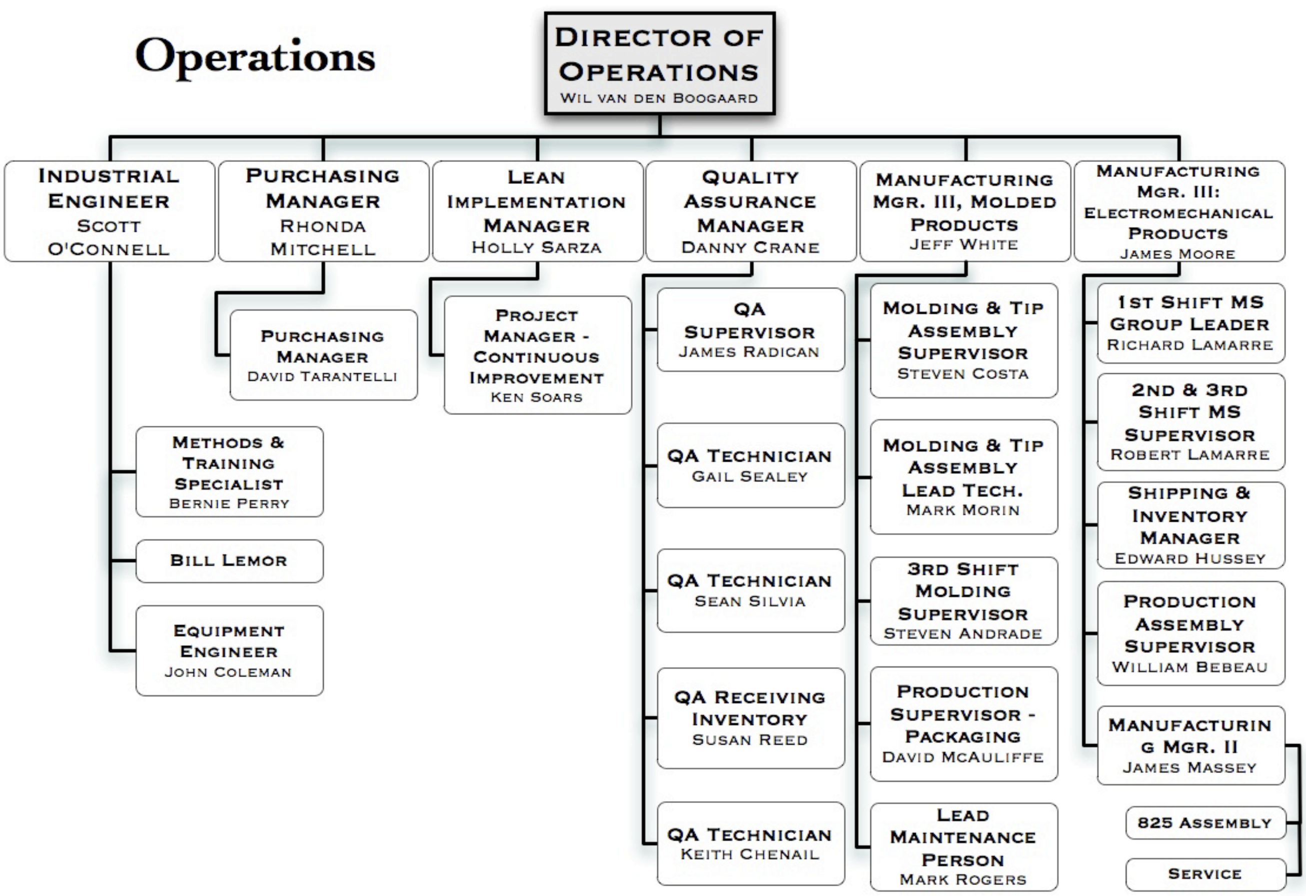


Figure 2: ***Operations Organizational Chart***

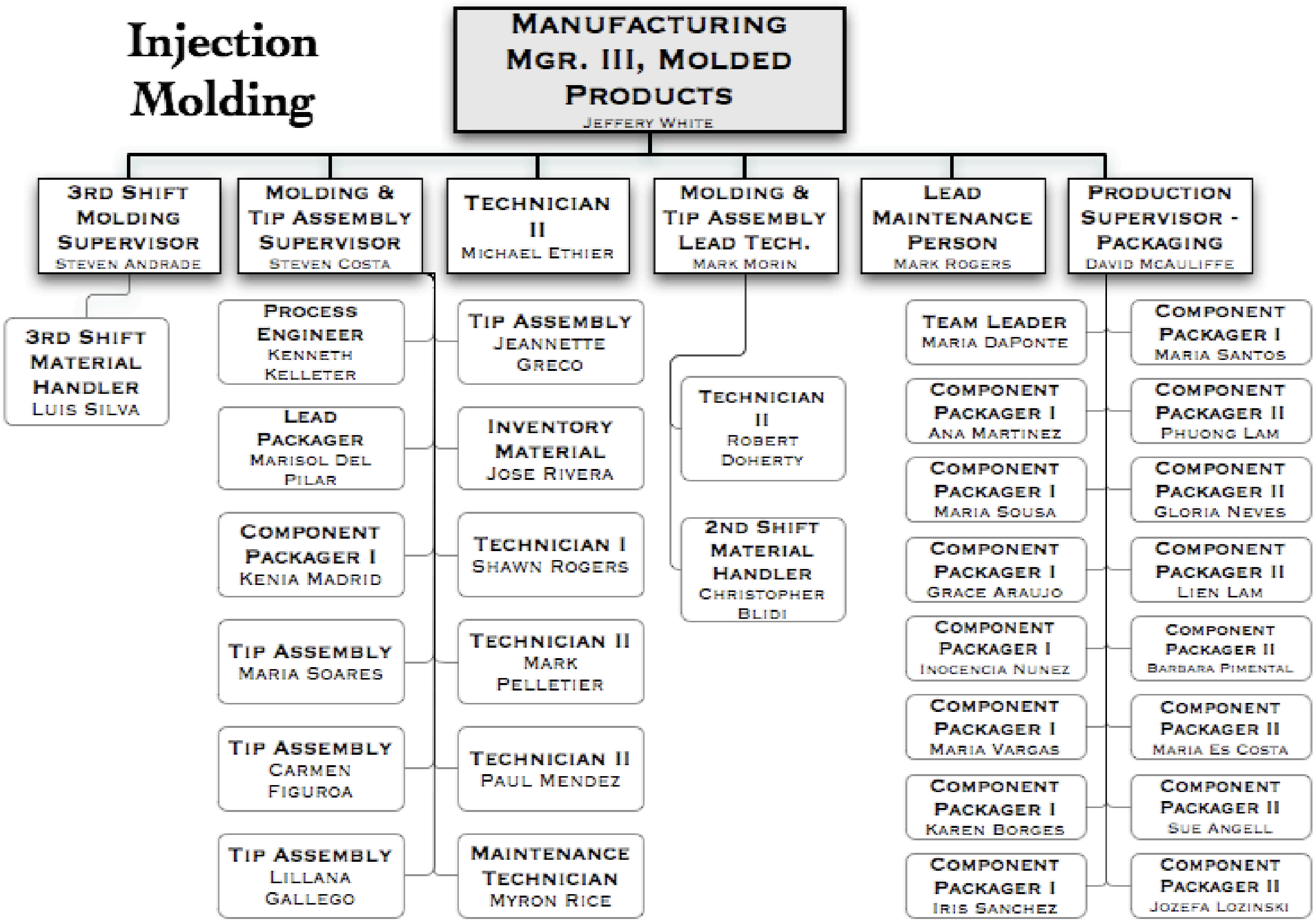


Figure 3: Injection Molding Department

1.3.2 Key Raw Plastic Suppliers

EFD deals mainly with two suppliers for their raw plastic materials, ECM and Ashland. ECM Is stationed out of Worcester, MA and specializes in advanced color development technology. They manufacture performance-enhancing color and additive concentrates, custom engineered thermoplastic resins, and specialty filled compounds on a custom or toll basis. The materials that are purchased from ECM are generally used when producing custom colors for hubs, barrels, pistons, or end-caps. It can also be used for general-purpose production not including color, but simply virgin plastic material. Ashland is a much larger corporation that has international reach, formed by four main businesses; Ashland Distribution, Ashland Performance Materials, Ashland Water Technologies, and Valvoline. EFD deals directly with Ashland Distribution's North America division, utilizing the virgin plastic material for primarily barrels and pistons.

1.3.3 Manufacturing Processes

The raw plastic material consists of small plastic pellets, stored in a large plastic bag inside a large cardboard container called a gaylord. The gaylords are stored on wooden pallets and transported by forklift and pallet jack. EFD keeps about three weeks of inventory of virgin plastic materials. When needed for a job, a Gaylord of virgin material is brought to an injection molding machine, where is it consumed by the IM process, described in detail in Chapter 2.

EFD's assembly areas are managed by 5S standards and are monitored by management and audited once a month. Assembly workers are equipped with modern equipment make the process more efficient and ergonomically safe. The areas produce all products using one piece flow, testing each before packaging. If the product, valve or dispenser, does not work 100% through the testing phase they are reworked and re-tested until they reach the requirement. Many of the parts used in the assembly process are purchased from outside vendors while some are produced by EFD's machine shop.

The machine shop works on demand for the valve and dispenser assembly areas. When parts are needed for the assembly process a kanban card will signal the machine shop to produce. The shop employs about a dozen machinists who operate primarily CNC lathes.

Another manufacturing process within EFD is the tip assembly area that contains four main machines, several assembly workers, and a maintenance engineer. The area is used to combine the hubs produced in the injection molding department with an array of needles. The needles vary in thickness and length, allowing for a precise amount of material to be dispensed. The tips produced are then transported to the packaging department.

There are two divisions in packaging: white packaging and brown packaging. White packaging is a clean room where barrels, tips, and kits are packaged for shipping. Workers are required to adhere to strict guidelines for attire and packaging methods in order to ensure zero contamination of product with foreign substances. White packaging places product in sealed plastic bags, which are then moved to brown packaging, where they are placed into cardboard boxes for bulk shipping. Since the product is already inside sealed plastic bags, the dirt and dust shed by the cardboard boxes can be ignored. By separating these areas, EFD provides a ready to use product to its customers, guaranteeing they are not contaminated in packaging and will not affect the customers dispensing of materials.

EFD also manufactures solder paste, whose production and packaging areas are directly connected. The different types of solder pastes are produced by several specialized workers on demand from the area supervisor. After completing the mixing stage, the solder paste enters QA and is tested for roughly 30 minutes. The solder paste will only move onto the packaging phase after approval from QA. There are usually four workers in the solder packaging area that transfer the paste into barrels. End-caps and tips are added to the barrels and then packaged into boxes of either 6 or 10.

1.3.4 Products and Customers

EFD manufactures numerous components satisfying needs in many different manufacturing and service industries. The following is a comprehensive list of products that are produced by EFD:

- Dispensers: portable, air powered, high pressure, Mikros dispensing pen, positive displacement, handheld dispensers, dispensing robots and tools, and tube coating dispensing systems.
- Dispensing Valves: valve controllers, pressure tanks, rhino bulk unloader, and jet dispensing systems.
- Dispensing tips: general purpose, tapered, flexible, angled, brush, and specialty.
- Syringe Barrels and Cartridges: general purpose, light sensitive, pistons, end-caps, adapters, ESD-safe, and filling systems
- Solder Paste: dispensing, printing, flux, solder equipment, and accessories.
- Specialty Products: Baitgun systems and accessories, specialty syringes and tips.
- Microcoat: lubrication systems and tanks.

Some of the industries that benefit from the manufacturing of these materials include automotive, fiber optics, food packaging and processing, lubrication, LED, life sciences, and solar systems. Because of this broad base of clientele, it allows EFD to enjoy the benefits of serving a niche market without being reliant on one specific customer or industry for its success.

1.3.5 SIPOC Chart

The SIPOC chart enables us to take the above information and apply it to the problem statement of the project. It clearly displays the suppliers, the inputs from these suppliers, the process in which this input is entering, the outputs that are produced from this process, and the customers that the outputs are being produced for. By investigating the SIPOC chart we understand better where to measure scrap and what process to examine more in-depth (injection molding). The chart provides a simple, 'at-a-glance' view of the process flow of raw plastic, from receiving to shipping. Information from this simple chart can be used throughout the stages of the project, identifying the customer's needs and requirements in relation to the specific process being improved.

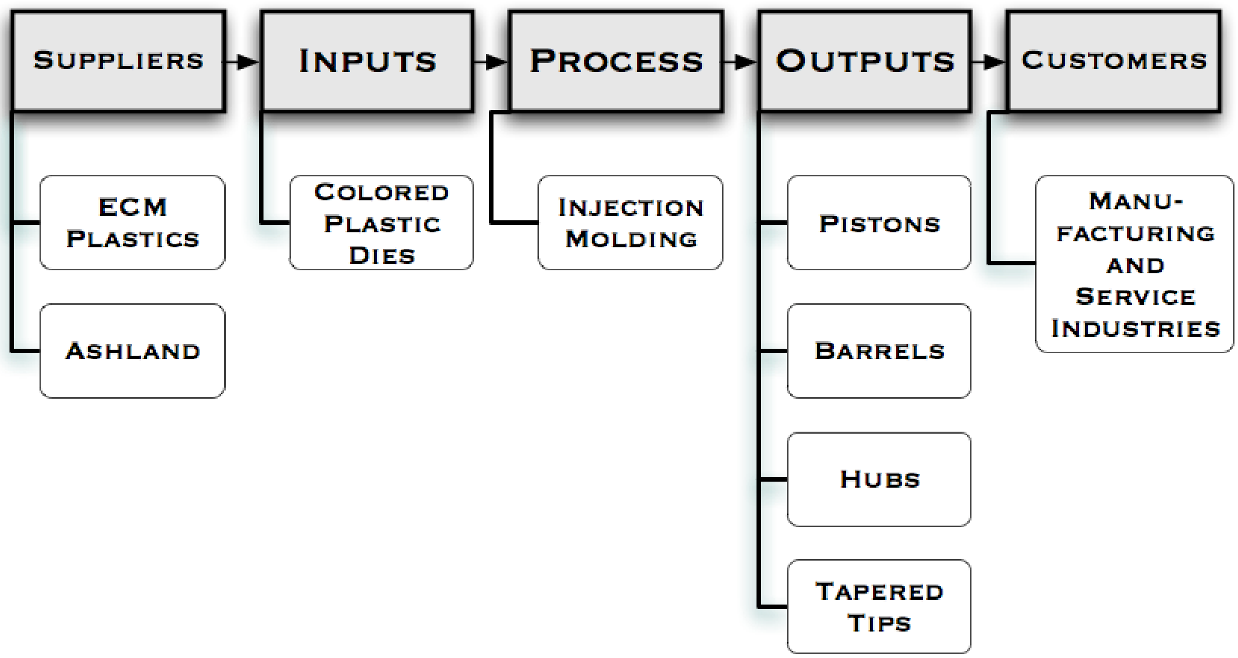


***Figure** 4: SIPOC Chart for Injection Molding Department*

1.4 Timeline from October 2008 to March 2009

This project required many crucial steps in order to gain valuable information about the current process and, in turn, generate recommendations to EFD on how to improve the process.

Table 1 displays major milestones of the project and when each section of the paper was completed. After a relatively late start to the project—making the first trip as a group to Electron Fusion Devices on October 1st—the first two chapters of the report were completed by the end of A-Term.

After studying the injection-molding department and analyzing current data to identify possible directions for the project, the team identified key missing data and developed and recommended a pilot study for gathering this data. During the first day of implementation, the company decided to revise the program significantly. The company's modified pilot program was implemented in the first weeks of February, and the team analyzed the data during the second half of the month. We made final recommendations and presented our findings to the company in the first week of March.

Table 1: Progression of Project between October 2008 and March 2009

Activity	A-Term	B-Term				C-Term			
	Week 1-2 10/1 - 10/16	Week 3-4 10/27 - 11/9	Week 5-6 11/10 - 11/23	Week 7-8 11/24 - 12/7	Week 9-10 12/8 - 12/21	Week 11-12 1/12 - 1/25	Week 13-14 1/26 - 2/8	Week 15-16 2/9 - 2/22	Week 17-18 2/23 - 3/6
Meet with Scott, Wil, etc./stakeholders at EFD									
Paper: Introduction									
Paper: Literature Review/Background									
Paper: Methodology section (DMAIC)									
Scrap data collection									
Pilot study									
Paper: Results/Analysis									
Paper: Conclusions									
Paper: Recommendations									
Paper: References									
Paper: TOC, Executive Summary, Authorship page, etc.									
List of Figures/Tables									
Final Presentation at EFD									

Chapter 2—Literature Review

In order to gain a better understanding of the direction and focus of our project, the team has compiled information on injection molding to provide an overview of the process we are observing. This section will also introduce and discuss, in detail, key tools and mindsets employed in manufacturing environments. These tools are designed to increase efficiency and decrease the bottom line costs by examining every detail of a given process. Six Sigma ideals will be examined, including the culture that is created by an initiative/journey and it's DMAIC (Define, Measure, Analyze, Improve, Control) process. While the terms "Six Sigma" and "Lean" are often mentioned together and achieve similar goals in the corporate world, the two efficiency improvement approaches each have their own history and methods of getting the job done. While Six Sigma tends to be strongly based on quality and defect statistics, Lean techniques are driven by waste reduction and demand initiatives (Jones). It is important for individuals to gain a base knowledge of both efficiency mindsets, as they tend to pull from one another's research methods. We also examined potential research methods, derived from Six Sigma and Lean, in order to further analyze data collected for the project.

2.1 Injection Molding

One of the most common methods of shaping plastic resins is injection molding. There are 13-20 controls per molding machine categorized under *pressure, time, temperature,* and *other controls for set-up and special functions*. Figure 5 displays the process of the injection molding machine at EFD.

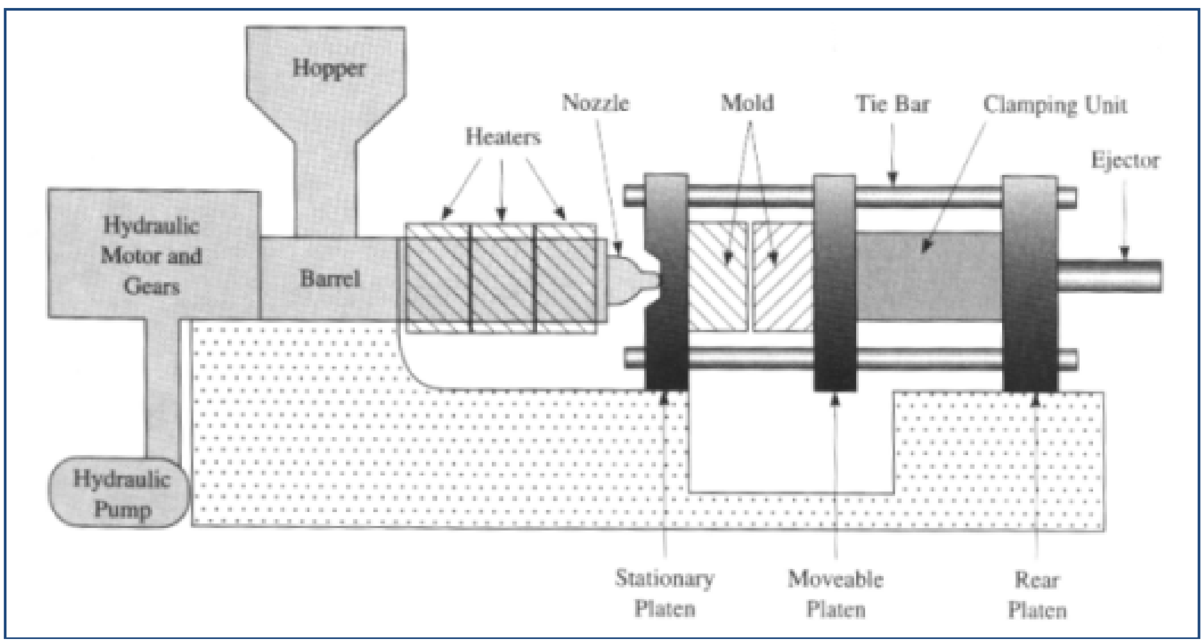


***Figure** 5: Injection Molding Machine Process*

(The Chemical Engineers' Resource Page)

2.1.1 Optimum™ Component Systems

EFD's dispensing components stand out from competitors with their state-of-the-art Engineered Fluid Dispensing ™. The system of components "improves yields and reduces costs by producing the most accurate, repeatable fluid deposits possible (EFD, p. 11)."

EFD produces four different products: hubs, tips, barrels, and pistons. EFD produces threaded tip *hubs* to ensure safe and secure attachment to barrels (EFD, p. 14). *Tips* are produced in a way that keeps a tight seal in order to prevent air from entering barrels. They are also created "free of burrs and flash that could obstruct fluid flow (EFD, p. 11)." The syringe *barrels* are produced with a unique and efficient internal design that allows fluid to flow without restraint. These barrels can be produced in a wide variety of styles and sizes and combine with pistons to create a precise fit in order to fill with a consistent amount of fluid (EFD, p. 11). The *pistons* "ensure uniform dispensing, prevent dripping, and eliminate waste by wiping barrel walls clean as fluid is dispensed (EFD, p. 13)."

Figure 6: Tapered Tips

Figure 7: Barrels

2.1.2 Typical Molding Complications

Injection molding has improved over the years to be able to manufacture products in bulk in a relatively quick amount of time. However, due to the inherent complexity of the injection molding process and the myriad of variable involved, there are still problems that can occur resulting in out-of-spec products. Table 4, shown in section 4.2 of this paper, lists and describes the possible problems that may be encountered, as well as the assumed causes of these problems.

2.2 Six Sigma

Six Sigma is a business initiative that was first created by Bill Smith within the Motorola Corporation in the early 1990s (Breyfogle, 1999, p. 5). The idea behind Six Sigma began years before in the early 1980s. The early ideals that paved the way for Six Sigma include quality control, TQM (total quality management), and zero defects among others. Unlike other tools, Six Sigma is a "data driven approach and methodology for eliminating defects (driving towards six standard deviations between the mean and the nearest specification limit) in any process -- from manufacturing to transactional and from product to service". It allows individuals and teams to quantify how a process is performing and measure different ways that may cause loss or defects and produce the best solutions to those problems. "To achieve Six Sigma, a process must not produce more than 3.4 defects per million opportunities" (What is Six Sigma). A Six Sigma project typically saves the company an average of six figures to the company's bottom line (Breyfogle, 1999, p. 5).

Six Sigma has two main processes; DMAIC and DMADV. DMAIC (Define, Measure, Analyze, Improve, Control) is "an improvement system for existing processes falling below specification and looking for incremental improvement" (What is Six Sigma). While DMADV (Define, Measure, Analyze, Design, Verify) deals with the development of new products or processes at Six Sigma quality levels. The Six Sigma initiative is also designed to change the culture through breakthrough improvement by focusing on innovative thinking in order to achieve aggressive goals (Breyfogle, 1999, p. 5).

2.2.1 Culture

In any organization it is important to create a culture that allows employees to feel connected to their work environment, associating their performance to the performance of the company. The culture that follows Six Sigma differs from that of any traditional business mentality in many ways, pulling on the key concept of continuous improvement while achieving financial goals. "The power of Six Sigma to create a culture of continuous improvement lies in the combination of changing the way work gets done by changing processes, plus educating people in new ways of understanding processes and solving problems" (Crom, 2000-2008). It enables workers to not only attain new tools for solving a variety or problems, but also creates new approaches to problem solving all together by examining a process in a very methodical fashion. A shift to a Six Sigma mindset, like mostly any change initiative in an organization, does not come easily and can be met with resistance. George Eckes argues that, in order to gain greater acceptance, organizational leaders must achieve four main goals:

1. Successfully demonstrate the need for Six Sigma
2. Articulately display and shape the vision of a Six Sigma culture
3. Identify and properly manage the resistance to the Six Sigma culture shift
4. Change the systems and structures of the organization to respond to Six Sigma ideals (Eckes, Six Sigma Revolution, 2001, p. 79)

One of the key differences between traditional and Six Sigma culture is in the work orientation. Opposed to the departmental flow of tasks in a traditional culture, Six Sigma focuses on process flow with the view of the customer in mind at all times. Senior and department managers are the individuals that most likely facilitate what needs to be improved in a more traditional culture, not pulling from every available resource to identify the problem. Six Sigma culture allows these managers to collect input from all different facets of the organization, including bottom-up suggestions from project leaders and team members. The team members are always a group of diverse individuals with different skill sets to allow for the best possible brainstorming sessions and innovative solutions. Six Sigma allows the individuals working on the floor to interact with the managers through these teams to express where the improvement work needs to happen.

Table 2: Differences between traditional and Six Sigma cultures

Aspects of Culture	**Traditional**	**Six Sigma**
Work orientation	Departmental, functional and/or task	Process flow and customer-output related
Who defines what needs improving	Senior managers and department managers	Senior and department managers plus bottom-up suggestions from project leaders and team members
Leadership for improvement	Functional managers or designated project leaders	Champions and improvement specialist (Belts)
Who has skills to develop and implement solutions	Specialists (e.g., engineers) and managers	Specialists plus project leaders, team members and managers
Improvement methods/tools used	The most familiar ones	Common, state-of-the-art approach and tools
Degree of operator involvement	Ad hoc	Widespread through Yellow Belt training
Project management discipline related to improvement	Variable	Gate reviews at each step of DMAIC
How performance is measured	Actual versus budget	Impact on Xs (causal measures) that affect Ys (outcomes)

(Crom, 2000-2008)

In a successful Six Sigma culture, these tools and mindsets are all used with a combination of experienced team leaders and process oriented measures that are used regularly to improve and review operations performance (Crom, 2000-2008). These experienced team leaders are usually “black belt” certified and have had first-hand experience leading successful sigma projects. Steve Crom produced a comprehensive “how to” list describing what a successful Six Sigma leader needs to be able to do: How to get things done through influence and persuasion rather than formal authority, how to approach complex problems in systematic-yet-practical ways, how to manage stakeholders and their expectations, how to communicate effectively internally (with project teams and team members) and externally (with business leaders and other stakeholders), how to handle ambiguity, how to articulate a vision and convince others to join in the journey even when the path is unclear, and how to manage conflict (Crom, 2000-2008).

These managers produced by the new Six Sigma culture must not only be able to differentiate what to work on, but also lead the change that is taking place throughout the organization. From the ground up these managers must be able to embrace the Six Sigma culture and display their confidence to all the other employees. They must combine their basic knowledge and experience with the new tools and mindset following Six Sigma, including leading others through the changes taking place along with identifying which processes and products need improving.

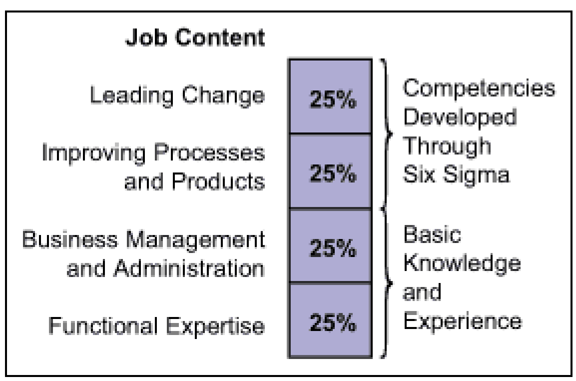


Figure* 8: *Profile of a modern manager

(Crom, 2000-2008)

2.2.2 Six Sigma DMAIC Process (Define Stage)

The first step of the DMAIC process is to define the scope of the entire project taking into account many different driving factors. After the assembly of a diverse team, including a sponsor, a black or green belt certified leader, and qualified team members, the define stage may be broken into three major parts. The sponsor, or champion, is most likely the process owner that will assist in the selection of the team and create the strategic business objectives associated with the project. This allows the team to understand what to focus on and what to avoid (Eckes, Six Sigma Revolution, 2001, p. 42). The major areas that must be approved by the project sponsor before proceeding to the measure phase, shown in Figure 9, includes the conception of a team charter, the development of a high-level process map, and identifying the customers of the project (Eckes, Six Sigma Revolution, 2001, p. 44).

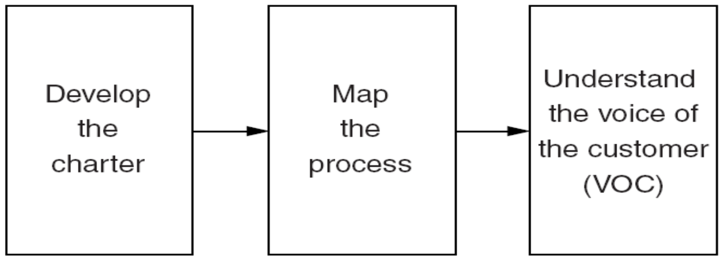


Figure** 9**: Define Step Process Flow

(Brassard, Finn, Ginn, & Ritter, 2002)

Understanding the boundaries of the project is an important step for fully defining the scope and purpose of the project, a major section of the team charter (Brassard, Finn, Ginn, & Ritter, 2002, p. 12). After determining what needs to be accomplished, the proper resources and milestones must be put in place in order for the completion of these steps to move smoothly. These steps are located within the goals and objectives, milestones, and the roles and responsibilities sections of the team charter (Eckes, Six Sigma Revolution, 2001, p. 44).

After the conception of a team charter, the process should be mapped out. The production of the high-level process map involves seven major steps:

1. Define the process to be mapped
2. Establish the start and stop points of the process (boundaries)
3. Determine the output of the process
4. Determine the customers of the process
5. Determine the requirements of the customers
6. Identify the suppliers to the process
7. Agree on 5-7 steps that occur between the start and stop points of the process

(Eckes, Six Sigma Revolution, 2001, p. 59)

After completing these seven major steps, an SIPOC (Suppliers, Inputs, Process, Output, Customers) process model can be created. This high-level process map may be considered one of the most useful techniques of process improvement because it presents a simple, “at-a-glance”, view of the work flows (Pande, Neuman, & Cavanagh, 2000, p. 186). The diagram will help provide the overall perspective of the organizational process where additional detail may be added in stages further in the DMAIC process.

Once completed, the process map provides a great visual tool to be used for the duration of the project and also helps to more specifically identify the customer's needs and requirements in relation to the specific process being improved. There are many tools that may be used to highlight these aspects of the customer, one being a CTQ, or Critical-to-Quality, tree (Eckes, Six Sigma Revolution, 2001, p. 52). Pulling from the process map that was created previously, the customers, their needs, and requirements (if any) for those needs are entered into a tree diagram. The next major step is validating these requirements with the customer themselves. This information may be gathered by performing one-on-one interviews, surveys, or focus groups. A more involved technique to validate the requirements is to "become" the customer and experience what they are first hand. This will provide perspectives that may be lost in the other interactions (Eckes, Six Sigma Revolution, 2001, p. 58). With the completion of these steps and the approval of the sponsor the project team is able to move forward from the defining stage to the measure stage.

2.2.3 Six Sigma D<u>M</u>AIC Process (Measure Stage)

The main purpose of the measure stage is the focus your improvement effort by gathering the proper information or data that is being produced in the process. During the process it is important to know how much to measure, making sure that enough data is being collected while not taking too much time collecting unnecessary amounts. (See Figure 10). George Eckes believes that many individuals overlook the importance of the measurement stage and supplies a very useful quote from Lord Kelvin on its significance:

> "I often say that when you can measure what you are speaking about and express it in numbers, you know something about it, but when you cannot measure it, when you cannot express it in numbers, your knowledge is of meager and unsatisfactory kind" (Eckes, Six Sigma Revolution, 2001, p. 70).

The major outputs that should result from this stage include data that pinpoints where the problem occurs and how often, baseline data that shows how well the process is meeting customer's demands, an understanding of how the current process operates, and a more focused problem statement (Brassard, Finn, Ginn, & Ritter, 2002, pp. 14-15).

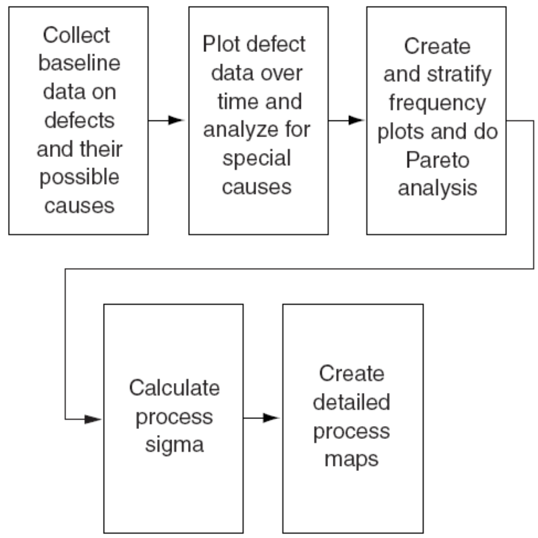


Figure 10: Measure Stage Process Flow

(Brassard, Finn, Ginn, & Ritter, 2002, p. 15)

We must determine which tools are most important to use in order gather the proper information. There is not enough time or man-power to use every tool that is available to measure the process data and the most significant should be utilized for efficiency reasons. Usually flowcharts and histograms are used to pinpoint steps in the process that do not add value. The graphs and charts also help to identify problems within the process that contribute to this non-value added time and reveals how often the problem occurs in different settings (Brassard, Finn, Ginn, & Ritter, 2002, p. 16). Pareto charts may also be chosen by the team to help display the relative importance of specific problems. This information may be used to more clearly define your problem statement that was created in the team charter.

On the more statistical side, Process Sigma can be calculated to describe the capacity of the current process that can be used to gauge your improvements after implementation (Brassard, Finn, Ginn, & Ritter, 2002, p. 16). Calculations include the product yield (Y), product cost ratio (PC), the quality productivity ratio (QRP), the capacity ratio (CR), capacity index (Cp), capacity index compared to some constant – k (Cpk). The outputs produced by these calculations will help measure the amount of variation there is in the process in relation to customer specifications (Brassard, Finn, Ginn, & Ritter, 2002, p. 204). After we are satisfied with the data that has been collected they may proceed to the next stage, the analysis stage.

2.2.4 Six Sigma DMAIC Process (Analysis Stage)

There are arguments for all of the stages to which holds the most importance; Eckes believes that the analysis stage is the most important element. The overall goal of this stage is to determine and validate the root causation of our original problem (Eckes, Six Sigma Revolution, 2001, p. 137). If the analysis process is not performed correctly the proper solutions will not be generated and the problem will persist.

The way in which the process should flow begins with the defined problem statement that was created in the previous stage. The process then moves to the potential causes that may be hindering the performance of the areas in the process that are now being examined. The next step is to organize these potential causes using tools such as fishbone diagrams. Finally, we should take the data collected in the previous stage and, using statistical tools, quantify a cause and effect relationship.

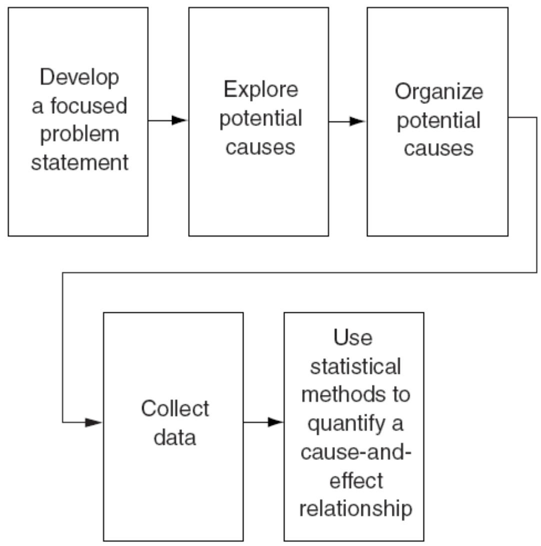


Figure 11: Analysis Stage Process Flow

(Brassard, Finn, Ginn, & Ritter, 2002, p. 17)

A simple way of analyzing the data and creating a good visual for root cause is a frequency distribution checklist. This tool takes the number of times a given event (problem) is seen in a set of observations (Eckes, Six Sigma Revolution, 2001, p. 114). By graphing this data as a bar graph a histogram is created and root causes may be further explored. Fishbone diagrams may also be used to take the raw data and analyze root causes. This tool not only allows a team to focus on the content of the problem rather than the symptoms, but also creates a snapshot of the collective knowledge around the problem. All of this builds support for the impending solutions.

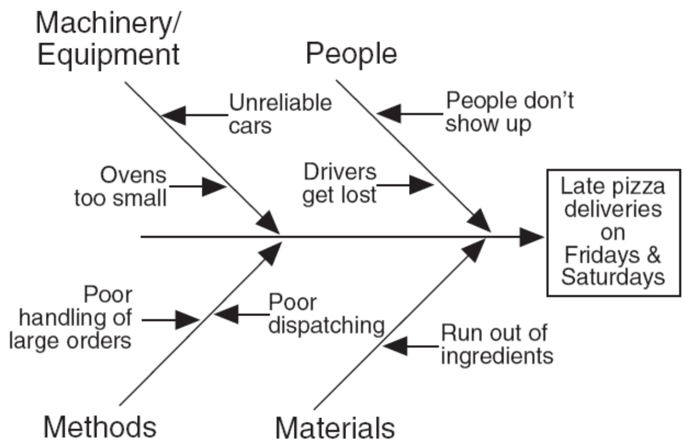


Figure 12: Fishbone Example (Pizza Delivery)
(Brassard, Finn, Ginn, & Ritter, 2002, p. 52)

Factorial experiments (full and fractional) are also good ways to determine which factors are larger contributors to variation than others (Eckes, Six Sigma Revolution, 2001, p. 171). Run charts, seen in Figure 13 are another key element in the analyze stage that monitors the performance of one or more processes over time to detect trends, shifts, or cycles (Brassard, Finn, Ginn, & Ritter, 2002, p. 221). This information allows teams to focus attention on vital changes in the process, enabling the most beneficial solutions to be created for the next stage. After calculating and drawing in the median, plot the data points collected during a specific stage of the process on the line graph. Look for points that are of concern, straying from the median on the chart and search for root causes for the deviation.

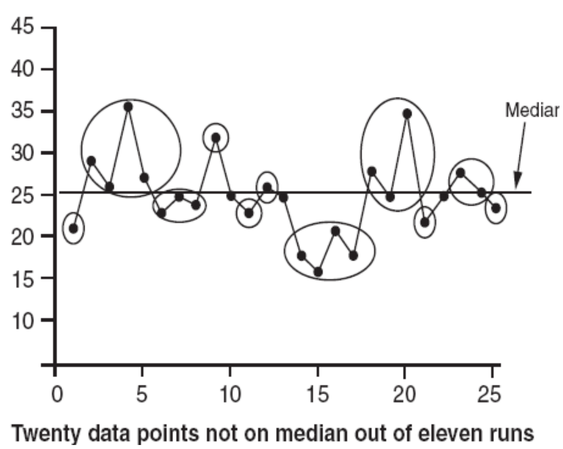


Figure 13: Run Chart
(Brassard, Finn, Ginn, & Ritter, 2002, p. 223)

There are many more tools that can be used during this stage, but the most important contributor to define the root cause begins with brainstorming. It is essential for a successful Six Sigma project team that each member has contributed, that all ideas are captured, and, through the application of the above tools, ideas are clarified and the list is narrowed down for proper solution generation (Eckes, Six Sigma Revolution, 2001, p. 137). After the analyze stage is complete, a Six Sigma project team can start selecting solutions and implementation methods to resolve the problem described during the define stage and refined in others.

2.2.5 Six Sigma DMAIC Stage (Improve/Implement)

The improvement stage will only work if the proper questions are being asked and answered amongst ourselves. Cavanagh, Neuman, and Pande argue that this may be achieved by basing everything off of four main questions:

1. What possible actions or ideas will help us address the root cause of the problem and achieve our goal?
2. Which of these ideas form workable potential solutions?
3. Which solutions will most likely achieve our goal with the least cost or disruption?
4. How do we test our chosen solution to ensure its effectiveness – and then implement it permanently? (Pande, Neuman, & Cavanagh, 2000, p. 276)

By answering these questions we want to develop, try out, and implement solutions that properly address the root causes while using data to both evaluate and carry out their improvements (Brassard, Finn, Ginn, & Ritter, 2002, p. 19). During the beginning phases of this stage there is another major brainstorming session where solutions and ideas are created and the most important are chosen to move forward to the development phase. Prioritization matrices may be one tool used to achieve the best solutions (Brassard, Finn, Ginn, & Ritter, 2002, p. 21). The criteria that are compared in this metric should be agreed upon by each team member. Pilot plans consist of simulations and preliminary data calculations to make sure that the solution is plausible before actual implementation takes place. This data will also enable us to alter, modify, or even radically change the solutions so that they are better able to be implemented (Eckes, Six Sigma Revolution, 2001, p. 202). After implementation of the solutions agreed upon, it is important to mistake-proof, or Poka-Yoke, the system as much as possible. This mistake-proofing tool corrects any problems that may cause defects being delivered to the customer. Poka-Yoke also puts special attention on the one constant threat to any process: human error (Pande, Neuman, & Cavanagh, 2000, p. 372).

Certain charts may be used to compare before and after results of the implementation. Some of those charts include histograms, Pareto, and the many different control charts. Run charts can also provide a glimpse of whether or not a solution has a real or lasting effect on the process (Brassard, Finn, Ginn, & Ritter, 2002, p.

221). By employing these tools the solutions that were implemented may be measured and the benefits may be present, both process improvements and financial savings.

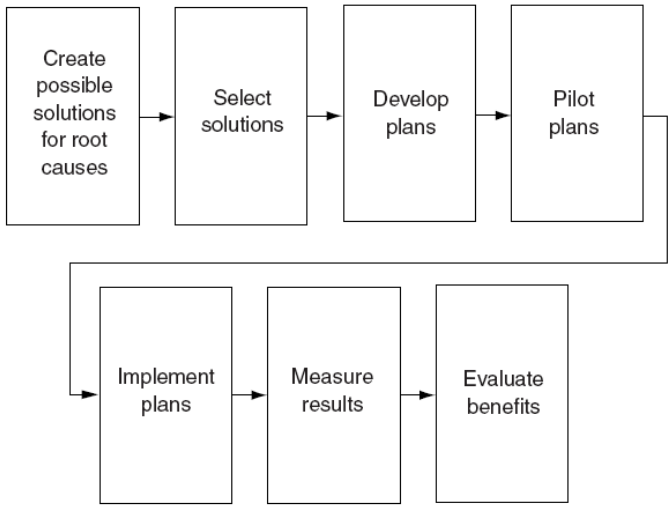


Figure 14: Improve Stage Process Flow

(Brassard, Finn, Ginn, & Ritter, 2002, p. 20)

2.2.6 Six Sigma DMAIC Process (Control Stage)

The last step in the DMAIC process is the control stage, where the gains that are accomplished in the improve step are to be maintained and future improvements are anticipated (Brassard, Finn, Ginn, & Ritter, 2002, p. 22). Standardization is very important during the control stage, making it easier to maintain the efficiency of the process no matter what the output or who operates it (Eckes, Six Sigma Revolution, 2001, p. 206). In order to achieve this standardization it is important in the control phase to produce the proper documentations of standard works. Training for the operators assigned to the new process is also needed in order to adjust to the new flow of material. Employees without formal training should be able to understand and implement the new improvements (Eckes, Six Sigma Revolution, 2001, p. 226).

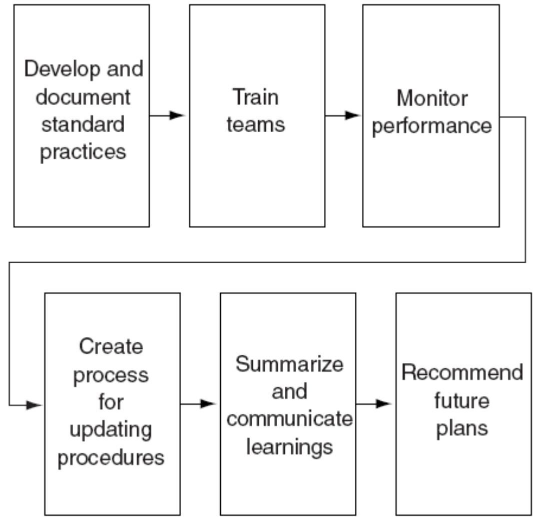


Figure 15: Control Stage Process Flow
(Brassard, Finn, Ginn, & Ritter, 2002, p. 23)

Statistical control can be maintained through the use of many different tools, such as more run charts to monitor the progress. In order to anticipate for future plans, X bar and R control charts may be calculated (Eckes, Six Sigma Revolution, 2001, p. 220). To allow management to monitor the process performance, a set of report outs should be scheduled for both monthly and quarterly reviews.

2.2.7 Successful Companies with Six Sigma

Motorola was the very first business to set the standards for Six Sigma use, inventing the concepts that many other companies have followed with great success. In the 1980's and 1990's Motorola, among others, was seeing their market share dwindling from the aggressive moves being made by Japanese competition. The creation of Six Sigma was out of necessity in order for them to stay in business. Between 1980 and 1997 Motorola's total employment has risen from 71,000 to over 130,000. They also saw five-fold growth in sales in this time frame, with profits climbing nearly 20% per year. The cumulative savings based on Six Sigma efforts measured at nearly $14 billion. Their stock price gains also compounded to an annual rate of 21.3% (Pande, Neuman, & Cavanagh, 2000, p. 7).

Another company that prospered from the implementation of Six Sigma is General Electric. GE's CEO, Jack Welch, describes Six Sigma as "the most challenging and potentially rewarding initiative we have ever undertaken at General Electric". The financial savings were seen immediately in their 1997 annual report, delivering more than $300 million to its operating income (Breyfogle, 1999, p. 5). The payoff accelerated to $750 million by the end of 1998 and some Wall Street analysts have predicted $5 billion in gains (Pande, Neuman, & Cavanagh, 2000, p. 5). GE chose to embrace the Six Sigma culture and focus most of their efforts on customers:

> “The best Six Sigma projects begin not inside the business but outside it, focused on answering the question – how can we make the customer more competitive? What is critical to the customer’s success?...One thing we have discovered with certainty is that anything we do that makes the customer more successful inevitably results in a financial return for us.” – GE CEO, Jack Welch

These are instances only two examples about how companies can improve their operations and profits from the implementation of Six Sigma. These success stories only happened because they followed the proper steps while following the ever growing Six Sigma initiative.

2.3 Lean Production

While Six Sigma tends to be strongly based on quality and defect statistics, lean techniques are driven by waste reduction and demand initiatives (Jones). The four main objectives are to improve quality, eliminate waste, reduce lead time, and reduce total costs (MacInnes, 2002, p. 3). Essentially, lean principles are taught and used in companies worldwide with the goal of gaining or maintaining a competitive advantage in the industry.

Lean production was first demonstrated during the early 1800s when Eli Whitney discovered the benefits of interchangeable parts after working with drawings, tolerances, and machine tools (Ndahi, 2006). In 1910, Henry Ford and Charles E. Sorensen created a continuous system for manufacturing the Model T automobile (Strategos-International). After several decades of success maintaining a lean automotive assembly line, people from all over the world were inspired by this new mindset. Shortly after World War II, Taichii Ohno and Shigeo Shingo set out to learn Ford’s techniques in order to apply them to the Toyota automotive production and essentially help re-build the Japanese economy. Ohno and Shingo analyzed, refined, and implemented the system—now commonly known as Toyota Production System.

Figure 16 visualizes these distinct milestones in timeline form. This new and improved system accommodated new products, reduced equipment changeover and set-up times, and eliminated excessive inventory (Bland).

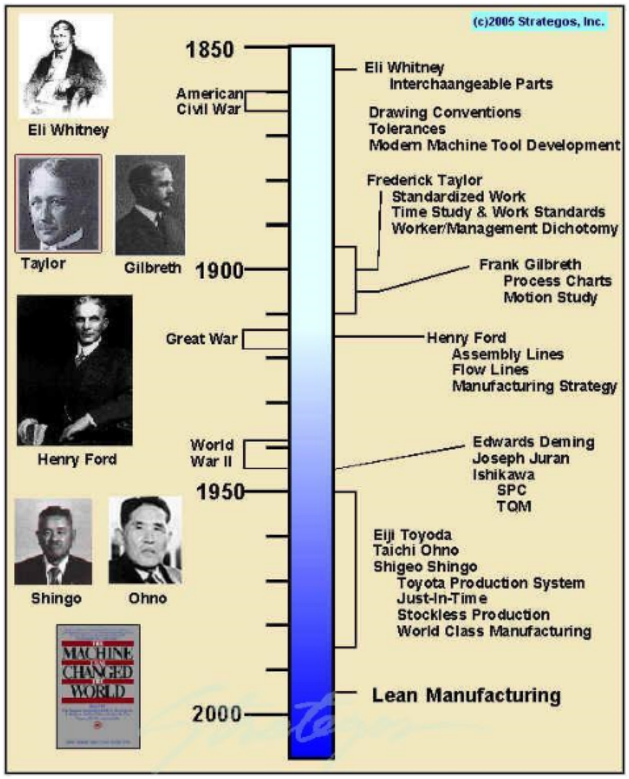


Figure 16: History Timeline for Lean Manufacturing

(Strategos-International)

2.3.1 Seven Types of Waste

In order to reduce waste in any given system, it is crucial to identify the different types of waste, as well as the potential causes and effects of each. The seven types of waste include transportation, inventory, motion, waiting, overproduction, over processing, and defects. Below each type of waste is discussed in detail.

2.3.1.1 Transportation

Any time there is unnecessary or excessive movement of materials or products within a facility, it is considered to be wasted travel. If a product must move back and forth on a production floor, it takes non-value added time and could also run the risk of damaged goods.

2.3.1.2 Inventory

Retaining a large inventory can result in a financial loss and wasted facility space. Excess raw material, work-in-progress, and finished goods that have not yet been sold to customers are all examples of supply stock (MacInnes, 2002, p. 7). While some stock helps to act as a buffer for variation between production periods, it can also be very expensive. A measure of inventory that divides annual sales by average value on hand, commonly known as “turns,” can be used to determine how well a company is managing their inventory compared to an industry average. While many firms tend to border the average turn value, companies following lean principles have turns of 200%-1000% of their industry average (Strategos-International).

2.3.1.3 Motion

Excessive motion by employees has many negative effects. The most influential consequences are wasting time and being exposed to potential ergonomic and safety hazards. One of the best methods of combating wasted day-to-day motions is to draw a spaghetti diagram in order to identify when and where there is wasted motion. With these results, it can be easier to develop a more efficient method of movement.

2.3.1.4 Waiting

Waiting, also known as queuing, occurs when production must be delayed—whether it be for 30 minutes or several days. Having a bottleneck upstream in the system or supplies on back order are both common causes of idle employees. Waiting can also be caused by poor scheduling or facility layout.

2.3.1.5 Overproduction

One of the worst types of waste is the act of producing more than what is in demand. Producing product before a customer needs it or simply producing too much of a certain product at any given time can cause a significant short-term financial loss. Typically a scheduler can forecast when and how much product should be produced on at least a daily and weekly basis; however, sometimes a random occurrence can catch a firm off-guard. This could include anything from losing power due to a storm to the stock market plummeting within a few short days (MacInnes, 2002, p. 6).

2.3.1.6 Over processing

Assigning additional work on top of the base production line process can cause various problems in a system that is essentially already autonomous. While it would likely require an extended period of time—which would hurt in a competitive environment—over processing also indicates when a system has not reached maximized efficiency. One of the most common tasks to be considered excessive processing is reworking a defective product. If the need to rework products could be reduced, a firm could save a tremendous amount of money now that they do not need more employees and their products can be shipped to customers in a timely manner.

2.3.1.7 Defects

Regardless of the industry, sub-par quality products will result in unsatisfied customers. This is why companies must pay close attention to detail of the product through an assembly line or machine production. Whether the process is producing defective parts or scrap, a company will certainly have higher operating costs due to the need to reproduce or rework product.

2.3.1.8 People

While "people" is not typically included in the seven types of waste, it is essential to note that current employees have valuable knowledge that can make a significant difference in the way a business runs. During the early 1920s, a woman by the name of Lillian Gilbreth identified that "workers are motivated by indirect incentives (among which she included money) and direct incentives, such as job satisfaction." Her studies of the motivation of workers fueled the utilization of employees' skills and opinions decades later. (The San Diego Supercomputer Center)

On the contrary, companies may be overstaffed—whether it is year-long or during an off-season—which could result in an unnecessary number of employees in the workplace. Again, required resources can typically be forecasted based on previous year success, market research, and the current state of the economy.

2.3.2 Tools and Techniques

Once waste is identified within a given process, various techniques can be considered to make further process improvements. Depending on the available resources (i.e.: employees, floor space, budget), companies can choose specific techniques that will improve the production and/or quality of the areas that initially need it the most. Upon completion of reaching set efficiency goals in those areas, focus can be shifted to not only improving the efficiency of more areas of the business but also maintaining a system that all employees understand and support every day.

Some of the most common lean approaches focus on visual management and continuous improvement. Visual management is rather self explanatory. By creating visual aids, a company can quickly detect inefficiencies and prevent future inadequate methods. Actions such as visualizing a shop layout, conducting a 5S organization event, taking set-up photos, and providing dry-erase boards to communicate progress and list queues all contribute to the initialization and maintenance of a more sustainable lean process (Korn, 2005). While there are various methods that can be used to improve a process, the most commonly used techniques are kanban, value stream mapping, and 5S organization.

2.3.2.1 Kanban

A kanban system, introduced by the Japanese, is a technique that is driven by Just-In-Time production with the goal of maintaining a minimum inventory, as seen in Figure 17. Essentially, each sector of a production line "pulls just the number and type of components the process requires" which helps to reduce any bottlenecks or idling in the system. Two types of kanban cards are typically used: a withdrawal or production-ordering kanban. A withdrawal kanban card indicates both the type and amount of a product to be withdrawn from a preceding process; however, a Production-ordering kanban card indicates the type and amount of a product that needs to be produced. Both kanban variations accomplish the same goal and can be used in many different manufacturing industries (Institute for Manufacturing).

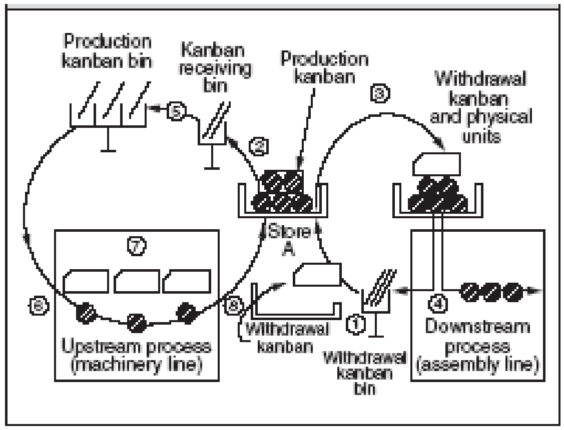


Figure 17: Withdrawal and Production Kanban Steps

(MacInnes, 2002, p. 97)

Every kanban system should have estimated timeframes in order to keep production on-schedule. One can determine the maximum time needed to produce a finished product by calculating the *takt time*.

$$\text{takt time} = \frac{\text{available daily production time}}{\text{required daily output quantity}}$$

As seen in the formula above, the takt time is strongly dependent on the customer purchase rate (Polletta, 2003). The takt time can help organize a kanban system and arrange the production in a way that is much less likely to result in wasted time or back orders.

2.3.2.2 5S Organization

A key element of visual management is 5S. This technique is often applied to a specific cell, production, or facility layout. These S's represent Sort, Straighten, Shine, Standardize, and Sustain.

1. Sort, also known as *Seiri* in Japanese, calls for eliminating any excess or obsolete equipment that may still be present in a particular layout. Leaving these items in drawers and cabinets often causes operators to take longer to find important tools or paperwork in their day to day tasks.
2. Straighten, also known as *Seiton* in Japanese, refers to arranging all tools in a place that can be easily accessible for all operators. This task may include installing hooks or labeling drawers, which will increase awareness and efficiency.

3. Shine, also known as *Seiso* in Japanese, requires the removal of trash and dirt in order to have a clean workspace. By cleaning on a regular basis, operators will have more respect for the workplace and take greater pride in their area.
4. Standardize, also known as *Seiketsu* in Japanese, documents all of the work done in the first 3 S's in order to continue best practices for the future.
5. Sustain, also known as *Shitsuke* in Japanese, is the key step to maximizing the benefits of the 5S organization event. By maintaining a standard working environment, operators can get more accomplished everyday and help the company improve its overall time-to-market efficiency. (Sugiyama)

2.3.2.3 Other valuable techniques

While implementing a kanban system or 5S organization event are both extremely helpful to creating a more efficient process, there are many other valuable techniques that should not be ruled out. Many techniques depend on the size and industry of the company.

Value stream mapping allows a company to identify where time is wasted within a given process; this technique is discussed more in the Research Methods section below. Companies also often use 'poka-yoke' which is a method that attempts to error-proof a system and "make it impossible to make mistakes" (Somanchi, 08). Figure 18 is an example of a fishbone diagram that illustrates the typical causes of process errors to look out for.

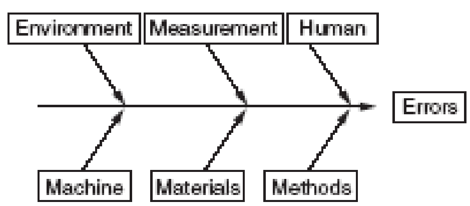


Figure 18: Causes of Error Fishbone Diagram

(MacInnes, 2002, p. 48)

Other forms of Lean techniques include autonomation and load leveling. Autonomation is a system that detects defective parts and temporarily shuts down the production line before continuing. Load leveling allows a production line to be altered based on different customers' needs. Also, working on team development and improving cellular manufacturing are both methods of being more efficient with the resources already available. This concept leads to Total Quality Management (TQM), which requires holding all employees accountable for the process efficiency, product quality, and overall success of the company. TQM is as much of a cultural mindset as it is a Lean technique (Hashmi, 2003).

Total Productive Maintenance (TPM) calls for routine equipment-maintenance activities, continuous production without interruption, and reduced emergency downtime (MacInnes, 2002, p. 107). A typical expectation is also that the same operator or team of operators is responsible for their own particular machine. Rather than fixing a machine after it breaks, TPM strives for "deterioration prevention" and "maintenance reduction" (TPM).

Lastly, a very significant Lean technique that cannot necessarily be measured is building and maintaining long-term relationships with suppliers. A company can save a lot of marketing and negotiating time and money by upholding a respectful and trustworthy relationship with a supplier or customer.

While many companies have had extreme success since adapting to Lean Manufacturing techniques, there is still potential for negative results if lean principles are taken to the extreme. As many of the Lean techniques relate to improved organization and flow, it is certainly possible to go too far. A reporter in England interviewed several disgruntled employees who had consultants who came into their offices to conduct a lean event consisting of placing tape on desks to show where everything belongs. One employee felt that the lean activities were demeaning. "They're trying to turn people into robots… Marking the desks tends to get members upset sometimes when they've got personal photographs on their desks and they have to move them around (Smith, 2007)." The simplest ways to avoid causing too much controversy would be to discuss ideas with the employees to be sure that everyone is comfortable and aware of the changes as well as benefits that they will enjoy.

2.3.3 Successful Companies with Lean Manufacturing

Over the past century, several companies have left their mark in history as crucial factors in Lean Manufacturing success stories. As mentioned earlier, Toyota and Ford were two of the first companies to apply the lean techniques to large manufacturing corporations and benefit from measurable success while doing so.

In 1994, General Motors joined Toyota to create the New United Motor Manufacturing Inc. (NUMMI) in order to implement a lean manufacturing production line at a US automotive plant. Once NUMMI was incorporated into the production system, GM's assembly hours were cut by nearly 40% and defects were reduced by two-thirds. Since this break-through, GM has continued to improve their processes by rewarding lean efforts by employees and striving for more environmentally-friendly initiatives (EPA).

Saturn also jumped on the lean bandwagon by implementing several kanban systems into their production plan. Their Spring Hill, TN automotive manufacturing plant reuses containers, which serve as indicators for when more automotive parts are needed. Also creating an electronic kanban system with suppliers has allowed for just-in-time delivery to keep waste at a minimum (EPA).

While large automotive companies like GM and Saturn have found success with Lean Manufacturing methods, plenty of smaller firms in various other industries have also made vast improvements in their processes using Lean principles. Alcoa's Howmet Castings manufacturing facilities across the world have benefited from events such as 5S and value stream mapping—increasing their productivity by nearly 50%. By providing 5S and overall lean training for all employees, all can be held accountable for steady improvements throughout the company's procedures. As local Michigan business developers have said, "In the current global economy, only the efficient will survive (Alexander, 2008)."

2.4 Research Methods

A wide variety of tools are available for use in Lean and Six Sigma implementation. Since these tools have been developed over the years by many players and they focus on achieving the common set of core ideals, the tools are so intertwined that when describing them, it is almost impossible to talk about one tool without referring to another. A good understanding of each tool is necessary in order to see how one tool is related to the next, or how a tool might be used to help solve a problem because different thinkers have used different terms for very similar things over the years. For example: in value stream mapping, the focus is on which steps add value to the customer ("value-added steps"), while Design of Experiment refers only to factors and responses. In reality, the term "step" used in Value Stream Mapping is the same thing that DOE calls a factor, and whether or not the factor adds value to the customer is called its response. Because of the different terminology it is not at all obvious that the two research methods are inseparably related until you understand what each really means. In the following paragraphs we attempt so summarize some of the most commonly used research methods and tools that engineers across the globe have developed with one goal in mind—providing a better product at a lower cost. It is important to note that many of these tools impact more than one step of the DMAIC process, and due to their intertwined nature, it is impossible to lay out all of the available tools in a neat "connect the dots" package to follow. Instead, an enlightened user will understand each of the tools available to him and pull each from his quiver as needed.

2.4.1 Brainstorming

It is a generally accepted phenomenon that a group of people interacting with each other to collaboratively solve a problem have almost always had a better outcome than the average of the outcomes of each person working on the same problem individually. This is the reason brainstorming is such a useful tool when approaching a new problem: the contributions of each person helps subconsciously cue other people's brains to think in a higher gear, and this has a multiplying affect that greatly increases the productivity of the group over the individual.

Brainstorming can be conducted in a variety of ways, some more formal than others, but some basic guidelines apply no matter what the structure:

1. Establish the purpose of the meeting: Spend a certain amount of time generating ideas surrounding a particular question or problem.
2. Do not criticize or compliment ideas as they are presented: doing so discourages the multiplying affect desired in the process.
3. Do build and expand on the ideas already presented.
4. Do not stop immediately if the flow of ideas slows down; some lulls are to be expected.
5. Record every idea presented so they can be evaluated later. Some groups find it useful to write each note on a post-it note and stick them up around the room so they can be seen and referenced.
6. After the established time has expired, or the ideas seem to have run dry, the ideas can be categorized and evaluated for quality or usefulness, depending on the situation.

Following these guidelines ensures the optimum environment for producing ideas, but still leaves plenty of room for customizing the session to the company, group, and problem being evaluated. Brainstorming can be used any time ideas are needed to proceed with a project.

2.4.2 Process Mapping

Process mapping is one method used during the define stage of a six sigma project to illustrate how a product or transaction is processed. A process map is a type of flowchart that uses symbols connected with arrows to represent visually how the parts of a process interact. A high level process map takes a "30,000 foot view" – as if viewing a process or even entire organization from an airplane. It has just enough detail to give the reader a general overview of the process or organization so they can understand where the detailed process maps that follow fit into the big picture. A Detailed Process Map, as shown in Figure 19, is just that – an extremely detailed flowchart that illustrates every step in a particular process, including a timeline, inputs, outputs, and variables that affect each step. Several levels of detailed process mapping may be required in between the high level process map and the most detailed to be useful (iSixSigma).

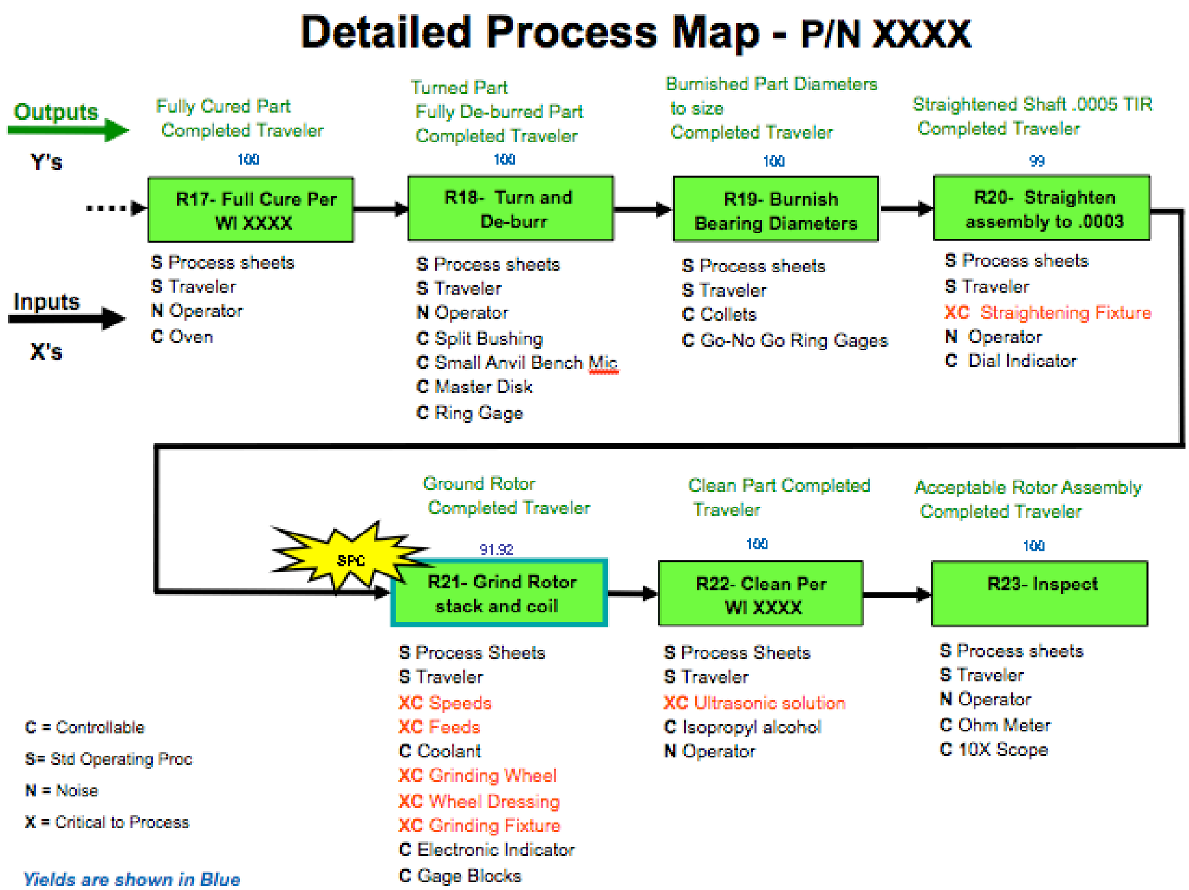


Figure 19: Example Process Map

(American Society for Quality)

2.4.3 Cause and Effect Matrix

A cause and effect matrix, also known as the C&E matrix, is used to identify and prioritize inputs that impact a set of output requirements based on their importance to the customer. It is often useful to create a process map prior to attempting to create a C&E matrix so that no factors are missed on the matrix. Arrange the outputs identified on the process map in columns, and then assign each one a rank, either relative to each other, or on a rating scale where 10 indicates an extremely important output variable and 1 indicates a minor one. Then, list every step along with its input variables in separate rows. For every input variable, place a mark in the cell that corresponds with the outputs it can affect, and carry down the assigned priority value to that cell. Now total the row and column values. The rows and columns with the highest totals are good candidates for examination, as they represent the causes and effects with the most impact on the customer (SigmaPedia).

Table 3: Example C&E Matrix

(Lean Six Sigma Academy)

Rating of Importance to Customer		10	8	8														
#	KPIV	Grass Color (deep green preferred)	Thickness of Grass	Weeds (none preferred)													Total	% Rank
1	Fertilizer Type	10	10	10													260	19%
2	Watering Frequency	10	10	5													220	16%
3	Mower Height	10	7	7													212	15%
4	Fertilizer Frequency	7	10	7													206	15%
5	Watering Duration	10	10	3													204	15%
6	Cutting Frequency	7	7	7													182	13%
7	Operator Experience	3	3	5													94	7%
8	Brand of Mower	1	1	1													26	2%
9																	0	0%
10																	0	0%
11																	0	0%
12																	0	0%
13																	0	0%
14																	0	0%
15																	0	0%
16																	0	0%
17																	0	0%
18																	0	0%
19																	0	0%
20																	0	0%
Total		58	58	45	0	0	0	0	0	0	0	0	0	0	0	0		

2.4.4 Spaghetti Diagram

The spaghetti diagram is a tool used to identify wasted motion in a process. It starts with an overhead view of the physical layout of the area in which a process is completed, and traces the steps of the operators and parts as they move through the process. For more complex processes, it may be beneficial to create separate diagrams for parts vs. operators, or even for individual operators in a large factory floor. As seen in Figure 20, the lines in a completed diagram often resemble a pile of noodles, which is where this diagram got its name. It is best to start with the physical layout on paper and then physically observe a process being completed, making note of each move as it is completed. It is important to note that the diagram is intended to analyze the process, not the performer, so it is not important to note which individual operator you are observing, only the date, time, and process being observed. (NHS Institute for Innovation and Improvement, 2008)

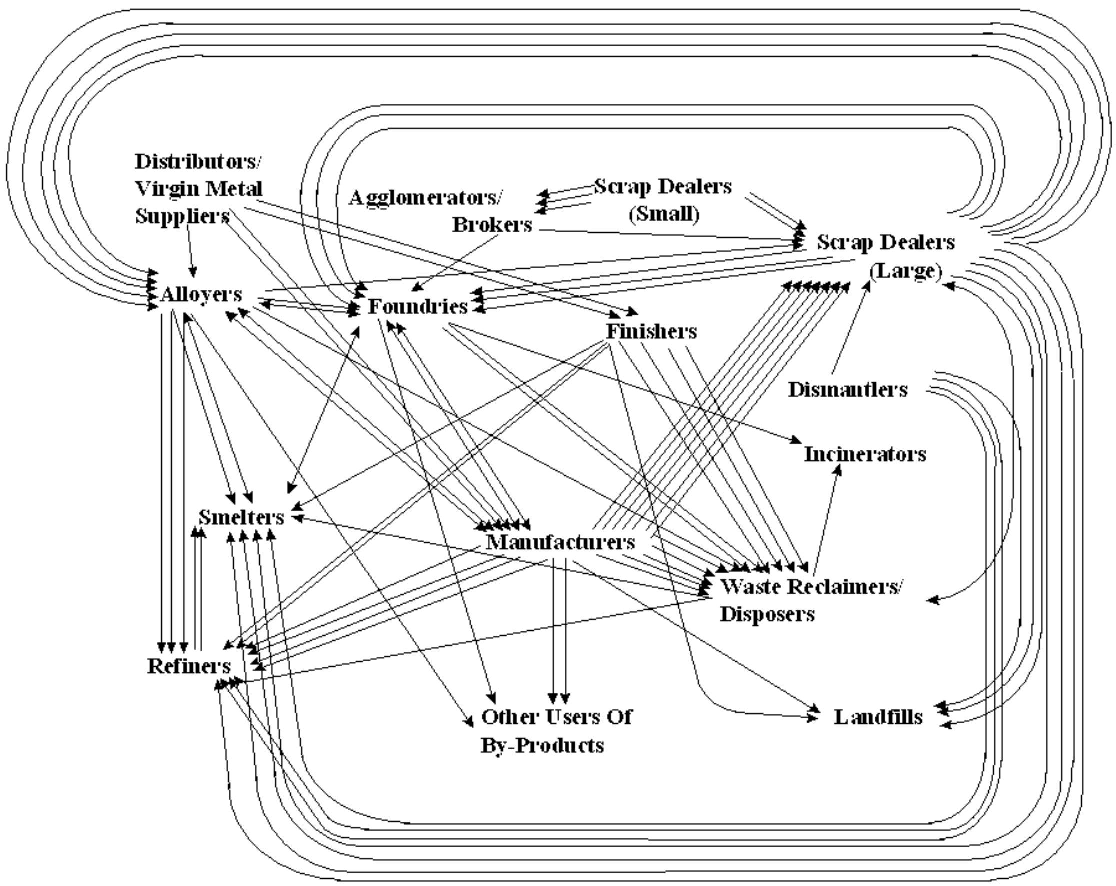


Figure 20: Example Spaghetti Diagram

(Wernick & Ausubel)

The above example is computer generated; however it is usually best to create the diagrams by hand first, and it is often unnecessary to take the time to digitize them and clean them up.

2.4.5 Statistical Process Control

Statistical Process Control (SPC) involves the use of numerous tools to statistically monitor a production process to ensure the process meets quality standards and does not shift over time. One of the main tools involved in SPC are process control charts, which are graphs which establish process control limits, and then are used over time ensure that the process stays "in control". A control chart can be created for many different types of processes and variables, using a variety of techniques depending on the variables being measured, but the purpose is the same for each- establish upper and lower acceptable limits based on in-control data and graph the process outputs against these limits to analyze the process. A process is considered in control if there are no sample points outside the established limits, most points are near the average, the points appear to be randomly distributed, and there are approximately an equal number of points above and below the centerline (Center for System Reliability).

2.4.6 Value Stream Mapping

Value Stream Mapping is a technique used to identify the flow of materials and information that is used to provide a product or a service to a customer. The purpose is to analyze the current process to determine which steps actually add value to the customer and identify which steps really just waste time and money. A future value stream map is then created by eliminating or reducing wasted steps and streamlining the value-added steps to create better flow. This future value stream map is then implemented in hopes of creating more value for the customer at a lower cost.

2.4.7 Time/Motion Studies

Time and motion studies were first performed by Frederick Winslow Taylor in the late 1800s as he strove to scientifically increase worker productivity. In a time study, an observer carefully times and records each motion or step that a worker makes while performing a standardized task. This data is used to analyze the task for efficiency, flow, and waste. Changes are suggested, the worker is retrained, and then another time study is performed to measure the effects of the process change. In one famous study, Frank Gilbreth observed a bricklayer at work, and reduced the number of motions required to lay a brick from 18 to about 5. This saved the worker time and energy, which increased both productivity and worker satisfaction.

2.4.8 Gage R&R Studies

Gage Repeatability & Reproducibility studies (or Gage R&R Studies) are used to evaluate a measurement system. These studies measure the amount of variability introduced into the measurement system by each step in the measurement system itself and compares it to the total variability observed in the process being measured. A Gage R&R study is useful for identifying an inconsistent tool or operator differences in measuring techniques, and helps establish (or identify a weakness in) the quality of the data you are collecting and using to make decisions. The lack of reliable measuring tools and techniques is the source of the old adage "measure twice, cut once." (Minitab)

2.4.9 Design of Experiments

Design of Experiments (DOE), along with ANOVA, is one of the key tools in the Analyze and Improve steps of Six Sigma. DOE focuses on carefully planning experiments to reduce the effects of random, uncontrollable variability, and determining their effects on the outcomes of experiments. DOE techniques represent the most effective method for identifying key input factors, establishing a mathematical relationship between inputs and outcomes (or responses), determining optimal input levels for the best response, and setting process tolerances. A process may have one or many inputs, such as machine settings such as pressure, temperature, and time, as well as operator inputs, materials, and environmental factors. It may also have one or many responses to each of these inputs, which can be measured and statistically analyzed. Each variable of interest (factors) are tested at various levels (settings) and their responses are measured. The purpose of DOE is to determine the most important process factors and their optimal settings. It also helps identify processes that may be less important to the final product ("non-value-added") that can be set to a more economical level than previously thought. DOE is used to determine which factors are influencing any variability identified via SPC (CAMO ASA).

Chapter 3—Methodology

The ultimate goal of the project, as already stated, was to quantify, as precisely as possible, the amounts and sources of waste and scrap in the injection molding department, identifying additional areas of study for future projects along the way. The project team used the Six Sigma DMAIC process as a guideline for the process:

- **Define** the problem, process, and stakeholders.
- **Measure** the usefulness of the current data collected.
- **Analyze** current manufacturing and documentation processes and data collection methods to identify possible ways of improving data collection.
- **Improve** the quality of available data by modifying and augmenting existing data collection methods, starting with a pilot data collection program.
- **Control** the new process by introducing formal procedures, training, and incentives.

3.1 Project Steps

In order to meet these five objectives, there were various tasks the group had to complete. Below is a detailed account of the group's step-by-step process that led to conclusions and recommendations for EFD. Figure 21 displays the general flow of the project steps.

- Determined scope and stakeholders
  - Interviewed key stakeholders— Wil Van den Boogaard, Scott O'Connell, Jeff White, and Steve Costa—to discuss key company needs, opportunities, and concerns
  - Created a schedule for deliverables
- Studied the injection molding process and EFD
  - Created flowcharts (SIPOC) and process flow diagrams (machine process)
  - Reviewed Workmanship Standards for Plastic Injection Molding Components
- Generated a baseline for molding scrap (per day/week/month/year)
  - Combined 2008 (Jan – Sept) reject report databases for four products (barrels, hubs, pistons, tapered tips)
  - Measured/estimated undocumented scrap due to changeovers, floor contamination, etc. with a pilot study
- Collected data by recording scrap for ten business days, based on time and resource availability
- Analyzed data collected/ databases using diagrams and matrices
  - Brainstormed by structuring a list of possible solutions to each specific problem identified

- Determined the most efficient methods for Process Control
  - Daily recording
  - Putting data in centrally located database

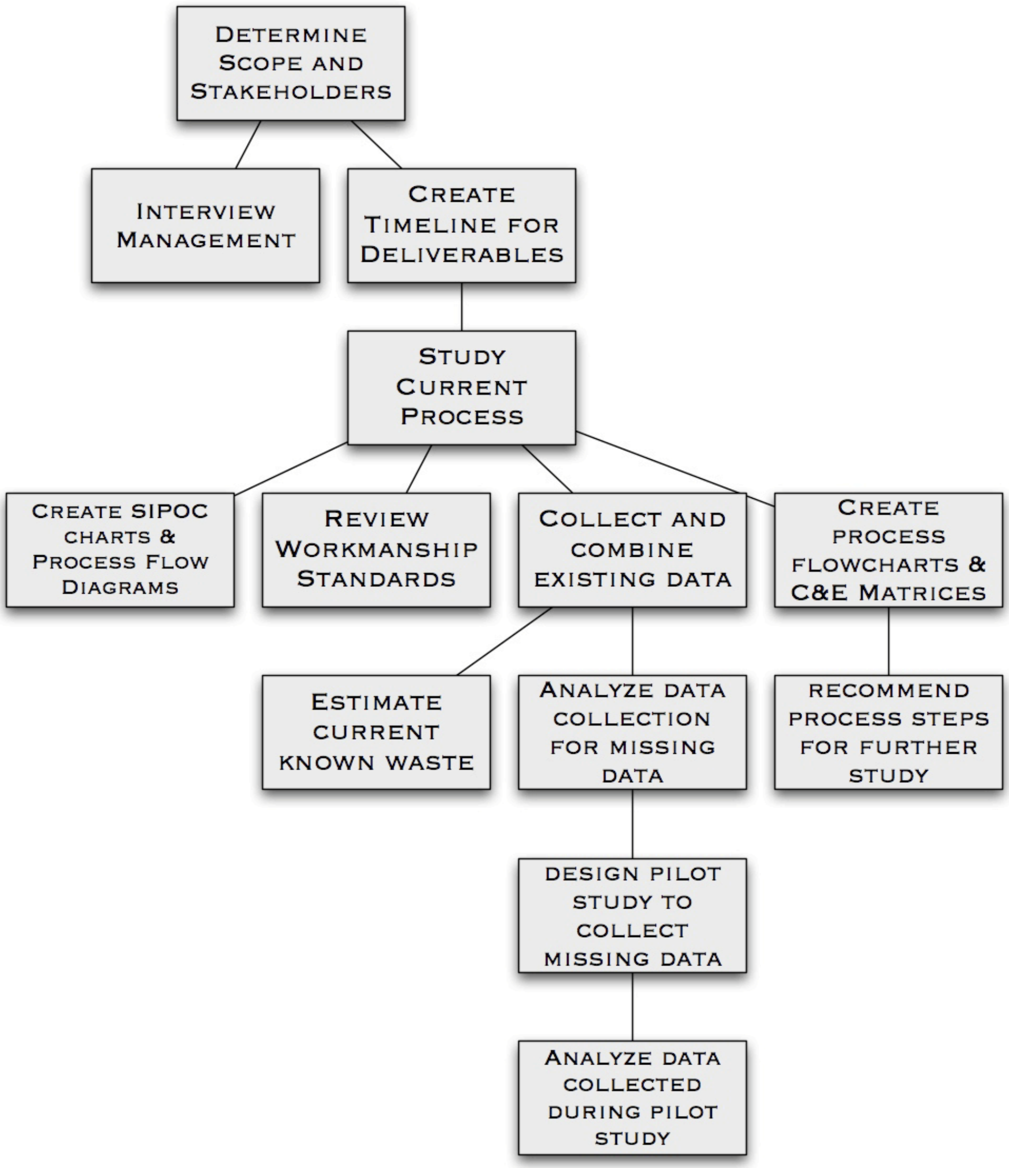


Figure 21: Steps of Project between October 2008 and March 2009

3.2 Tools Used

We used several types of Six Sigma and Lean techniques throughout the course of the project to understand existing processes, identify areas to focus on, and analyze data gathered by the company. Most generally, we followed the DMAIC thought process, using a variety of other tools at each step. Some of the tools used were:

- Cause and Effect diagram/ Prioritization Matrix
- Fishbone diagram
- Flowcharts
- Poka-yoke mistake proofing

3.3 Define

To define the project scope, the team began with a tour of the production facility and met molding manager Steve Costa. We also met Jim Radican, Quality Assurance manager, and toured his department. We met with key stakeholders, including Wil Van den Boogaard, Scott O'Connell, and Jeff White, to discuss the project scope and goals. We also began collecting materials to help us better understand the injection molding process generally and EFD's molding department specifically.

Among the materials collected were the Workmanship Standards for Plastic Injection Molding Components from the QA lab, a video tutorial on the injection molding process, and samples of each of the data forms currently used within the company. Using these materials, the group was able to create an SIPOC process flow diagram and machine process flow diagram to use as tools for analyzing sources of scrap.

The group interviewed Scott O'Connell, Industrial Engineer, and Wil Van den Boogaard, Director of Operations, and together we defined the project as a first look at quantifying scrap loss in the injection molding department. In short, Wil said he would be happy "to know what goes in and what comes out". At this time, the most precise material data available was the total amount of raw material ordered and the total quantities of product shipped; very little was accurately quantified regarding material usage between raw material and final product.

3.4 Measure

One of the first action items we identified and completed was to gather and analyze the data currently being collected. That data included the January - September 2008 Reject Report databases for each of the four products that EFD manufactures—barrels, hubs, pistons, and tapered tips and records that are currently in use by machine operators to determine when, where, and how often scrap is produced. By combining several databases, we were able to generate what we call a "baseline scrap" number which basically showed what percentage of each type of product is rejected and scrapped due to defects. This analysis is in Chapter 4.

We quickly realized that the current data does not include certain types of scrap—including waste generated during changeovers, machine startup and shutdown, and floor contamination. These sources of waste have gone almost completely unmeasured and undocumented. Identifying this gap in documentation led to the most significant portion of the project's development. After speaking with key stakeholders, we determined it would be best to develop new documentation and implement a pilot study using this documentation. Initially we hoped to do an initial test round of data collection prior to EFD's two-week shutdown period for the winter holidays, but complications with EFD's facility move required the delay of this program.

3.5 Analyze

We performed analysis on two major areas: documentation processes and manufacturing processes. For the manufacturing processes analysis, we combined our study of the injection molding department and the data already available to us to create a Cause and Effect and Prioritization matrix to determine which input variables in the process had the greatest effects on which outcomes. Before we realized the significance of the data that was not being collected, we planned on using the prioritization matrix as the basis for a pilot study in manufacturing process changes in order to increase the quality of products produced. Along the same lines, we hoped to study in detail the costs associated with running a sorting robot to sort out molds from bad cavities as opposed to shutting down the machine and repairing the defective cavities.

However, further analysis of the overall IM process and current documentation led us to believe that it was much more important to modify the documentation processes to be able to truly determine the amount of scrap generated in the department before any modifications to the manufacturing processes should be made. Making changes to the manufacturing process without first adding mechanisms for collecting the missing data might lead to false conclusions about the effectiveness of a particular manufacturing process change, and attempts at reducing scrap may be focused in the wrong areas due to incomplete starting information.

Therefore, we brainstormed possible methods of improving the current documentation processes, and this became the major focus of the project. Currently, the documentation used in the company as it relates to the IM department is very scattered and segmented. Several systems that are currently in use operate independently, and as a result, some data is duplicated while other data is missed entirely. We found that this complexity and duplicity frustrated workers and led to inconsistent data entry. After some discussion, we determined that a complete revamp of the current documentation procedures is desperately needed, but doing so would be beyond the scope and time available to the team. One of our recommendations to the company is to charter a project aimed at simplifying the current processes to take full advantage of the electronic systems already in place. Doing so will decrease frustration and increase the efficiency of operations, as well as providing more useful data for management.

In the end, we decided it would be best to develop additional concise documentation to improve the quality of the data collected through a pilot study.

3.6 Improve

Since EFD already owns a large scale designed for weight complete pallets, we decided the most efficient way to gather the missing scrap data would be to add one simple step to the material handler's job. The material handler is currently responsible for transporting all raw materials, scrap, and final product in and out of the injection molding department. By placing the scale in a central location near the entrance to the department, we could simply require the material handler to stop at the scale on every trip in and out of the department and record various weights on tracking sheets. Details of the pilot study are found in Chapter 5.

3.7 Control

In any manufacturing process it is important to ensure it is in control. Any deviations from the target must be identified and corrected swiftly. Looking specifically at data collection techniques, it is important that there be checks and accountability to ensure efficient, accurate, and appropriate data recording. Control began the moment the pilot study began. As noted in our analyses, there were some quality issues with the recording already. This was partly due to the nature of an evolving data recording program, and as the "kinks" get worked out, the quality will naturally improve.

The first step for achieving this was to establish standard work instructions to define what is expected. While initial standards were established that closely matched the data recording sheets, the process and work instructions were modified without changing the recording sheets. Updating the forms to match the new work instructions is the next step needed to control the process.

Once the standard work is defined, someone will have to check to make sure these standards are being followed. This may be the molding manager, as he already examines and handles the finished paperwork for each job. Regardless of who is responsible for this, checks need to be made to ensure that all appropriate data is recorded and additional training is provided for any operators who make frequent omissions or errors.

Also, we recommend sharing the new knowledge gained through this study with those who bear the burden of data recording. This shows the value of their extra work and helps employees gain a sense of ownership and importance, further improving the quality and usefulness of the data. This mutual sharing of knowledge from the top down as well as from the bottom up can be extremely beneficial to the company.

Chapter 4—Preliminary Analysis

In this chapter we discuss a brief overview of the injection molding department at EFD and an outline of their current process layout. We first began the preliminary analysis by inspecting the injection molding department and performing several informal interviews with the staff. We utilized several different Six Sigma tools and documentation provided by EFD to complete our overview of the injection molding department, including a tutorial video tape and also the Workmanship Standards for Plastic Injection Molding Components, a document that outlines defects that are found with products produced in the department. Examples from the Workmanship Standard document are also examined in this chapter to provide visuals of the specific problems that occur during plastic molding. Finally, the Six Sigma tools employed are discussed along with the results of the analysis.

4.1 Injection Molding Department Overview

The current layout of the injection molding department is very tight, confined to a small area of the company's facility in Lincoln, RI. This space problem will be alleviated as the company consolidates into a new building, but currently, as you enter the department, there are two molding machines running to the left and four more staggered to the right, as seen in Figure 22. The molds are stored wherever space may be found, generally located in the back of the department where maintenance is performed.

Figure 22: Injection Molding Floor

The layout has a lot more to do with packaging efficiency and the number of machines that may be placed in the area as opposed to the amount of scrap that is produced. However, the layout does play a role in set-up and changeover times, depending on the mold and its maneuverability. Considering that the layout of the department is in a transitional phase, this aspect was not researched more in-depth.

In order for a run to begin, a trained operator inputs the settings into the computer system, shown in Figure 23, used to run each separate machine. These machines are very intricate and the specific settings must be customized to each individual lot number that is used. No two lot numbers provide the same exactly consistency of virgin plastic makeup. This "tuning" that takes place results in, what the company refers to as, start-up scrap. After reviewing several different databases, we noticed that this information is not captured in any electronic database and operating run sheets are very vague on what kind of scrap and how much of it is being produced.

Figure 23: Molding Machine Central Control

There are many forms of documentation that are used to collect data within the IM department. The various documents are spread throughout several departments and are manually completed. Currently data may be duplicated or left out, which greatly reduces EFD's ability to accurately track scrap loss.

4.2 Workmanship Standards for Plastic Injection Molding Components

The purpose of this document is to serve as the baseline for how products should be approved or scrapped in the IM department. It provides photo evidence of rejected parts, highlighting the problem that has occurred for anyone who may not be familiar with it. By examining this documentation, we were able to better understand the problems that occurred at the different stages of the molding process. Figure 24 displays an example of ID flash. Any type of flash, as described in Table 4, is an excess of material left on a part after molding due to a poor "close off" condition. Excess material may be left at several places on the molded product and if any deformed "flash" product is approved the customer will surely encounter problems with their fluid dispensing, possibly destroying the relationship with the customer altogether. In this example, the fluid that is being dispensed will be backed up due to blockage from the flash.

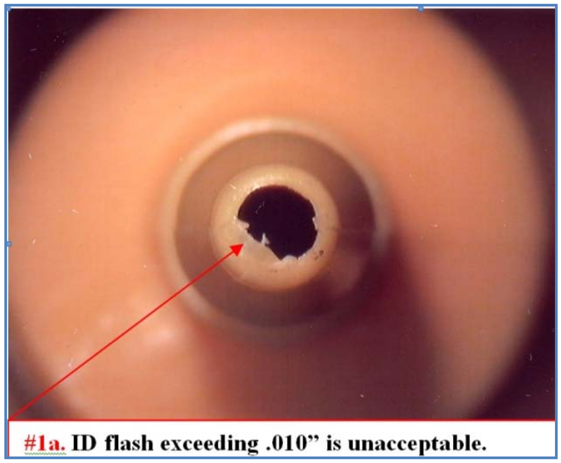


Figure 24: ID Flash Example

Another example seen in the Workmanship Standards for Plastic Injection Molding Components is found in Figure 25. This example provides a visual aid to exactly what a "short shot" may look like to a QA inspector. Again, as described in Table 4, short shots are molded parts that are not completely filled. Similarly, the material being dispensed by the customer will not be consistent because of the lack of plastic at the end of the product.

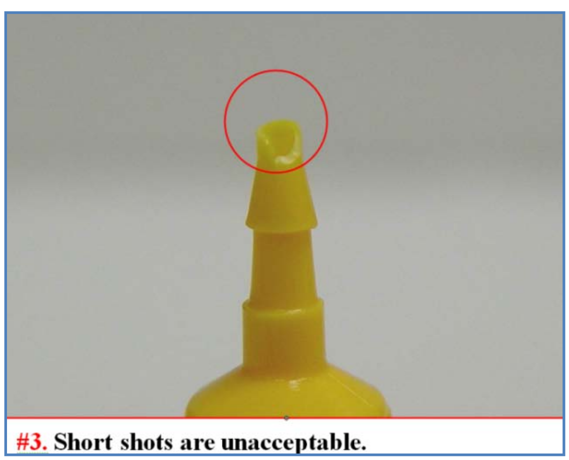


Figure 25: Short Shot Example

Due to the fact that there are many more examples in the Workmanship Standard document, we recommend referring to Table 4 for further problem descriptions. Pictures of all problems can also be found in the Workmanship Standard document.

Table 4: EFD Injection Molded Component Problem Descriptions

Problem	***Description and Potential Cause***
Flash	Excess material left on a part after molding is due to a poor “close off” condition.
Poor Gate Breakaway	This occurs when the area in which material flows into the mold cavity is bulged, stretched, or excessively gauged.
Short Shots	Short shots are molded parts that are not completely filled.
Knit Lines	A crack or slight crevice caused by material flowing together from opposite gate directions.
Inclusions	Dark particles suspended in the material walls.
Flow Marks	Streak marks create a discolored condition that is typically visible on the outer surface of the component.
Surface Contamination	Dust or other foreign debris, which will cling to the part due to a static charge.
Grease	Grease can be transferred to the part from injection molding machine.
Inconsistent Color	A depth of color that may be inconsistent over time from part to part due to changes in raw material lots.
Bent tips	Off-center cores after cooling cause parts to bend to one side.
Mold Marks	Indentations or ridges embossed into the surface of the molded part due to irregularities in the mold cavity surface.
Off Center ID at tip (tapered tips only)	Condition caused by core either bending or shifting during injection.
Cold slug (pistons only)	A blister-like condition caused by cold material not releasing from previous gate break.
Air Bubbles (hubs only)	These are air pockets suspended within the material walls of the molded part.
Voids (hubs only)	A void is an unfilled space that exists within the material walls of the molded part.
Blush (barrels only)	A blush is a flow mark that is caused by excessive packing at the gate displaying a cloudy appearance.
Core scratches (barrels only)	These vertical lines present on the inner walls of the component are caused by a burr or nick on tooling.
Molten plastic (barrels only)	Residual plastic may be transferred to the surface of the part and is typically caused by the runner making contact with the parts.
Thread Deformation/ Smeared Threads (barrels only)	This is a flattening condition that occurs on the outer diameter of the thread.

(EFD, 2003, pp. 9,26,33,40)

4.3 Baseline Data

Several electronic databases, derived from the documentation discussed earlier, were created by Jim Radican within the QA department. There were a total of 36 different databases for overall in-process scrap production, citing specific reasons why the specific amount was expelled. We found it necessary to combine these databases into four separate databases, capturing a nine month period of in-process scrap production for four products; barrels, hubs, pistons, and tapered tips. Each of the four databases is uniform, with an exception for the types of problems that occur. As seen in Table 5, the databases include the date in which the parts were rejected, the part number, the lot number, the total quantity produced, the total quantity yield, total quantity rejected, and the specific problems associated with that product and how much of the total quantity rejected fell into that specific fault.

Table 5: Example Tapered Tips Database

Date	Part No.	Lot No.	Total Qty. Produced	Total Qty. Yield	***Total Qty. Rejected***	Short Shots	Flash	Bubbles / Voids	Grease	Contam-ination	Color Tint	Inclusions/ BlackSpec
1/9/08	7018157	4000103943	813,451	485,709	***12,052***		1,423					
1/22/08	7018297 (5122TT)	4000107308	840,615	320,729	***8,786***		8,786					
1/29/08	7018099 5116TT	4000110790	398,131	36,831	***0***							
1/30/08	7018093 5116FTT	4000112405	71,025	4,643	***16,382***	16,382						
2/4/08	7018146 5118RTT	4000112737	202,132	113,132	***0***							
2/7/08	7018157 5118TT	4000113669	435,148	249,746	***1,002***		1,002					
2/21/08	7018216 5120TT	4000115967	654,610	177,557	***47,808***						28,016	
2/22/08	7018208 5120RTT	4000115968	120,707	79,692	***1,015***		1,015					

By combining these 36 databases, we were able to calculate the weight that each problem carried with each specific product. From this information, we created four summary Pareto charts to visually display the main causes of in-process scrap for each product. This information allowed us to highlight the main causes of in-process scrap and assign the proper weight of each to C&E Matrices discussed later in the chapter. Figure 26 is a Pareto chart designed specifically for pistons. The problem that causes the most amount of scrap consists of different problems associated with the gate of the piston. The size of the piston and types of contamination that occur at different stages of the process proved to be problems that produce about 29% and 14% respectively. Figure 27 highlights four major problems occurring with tapered tips producing the most scrap; flash, damage produced by robot, short shots, and color tint. The data compiled in Figure 28 displays the main causes of scrapped hubs; short shots at around 44% and flash at nearly 30%. Finally, Figure 29 is a Pareto chart specifically outlining the causes of scraped parts for barrels. The three outlying causes are contamination at 23%, black specs at 18%, and bubbles/voids at 15%. All of these scrap numbers are a result of data collected for nine months.

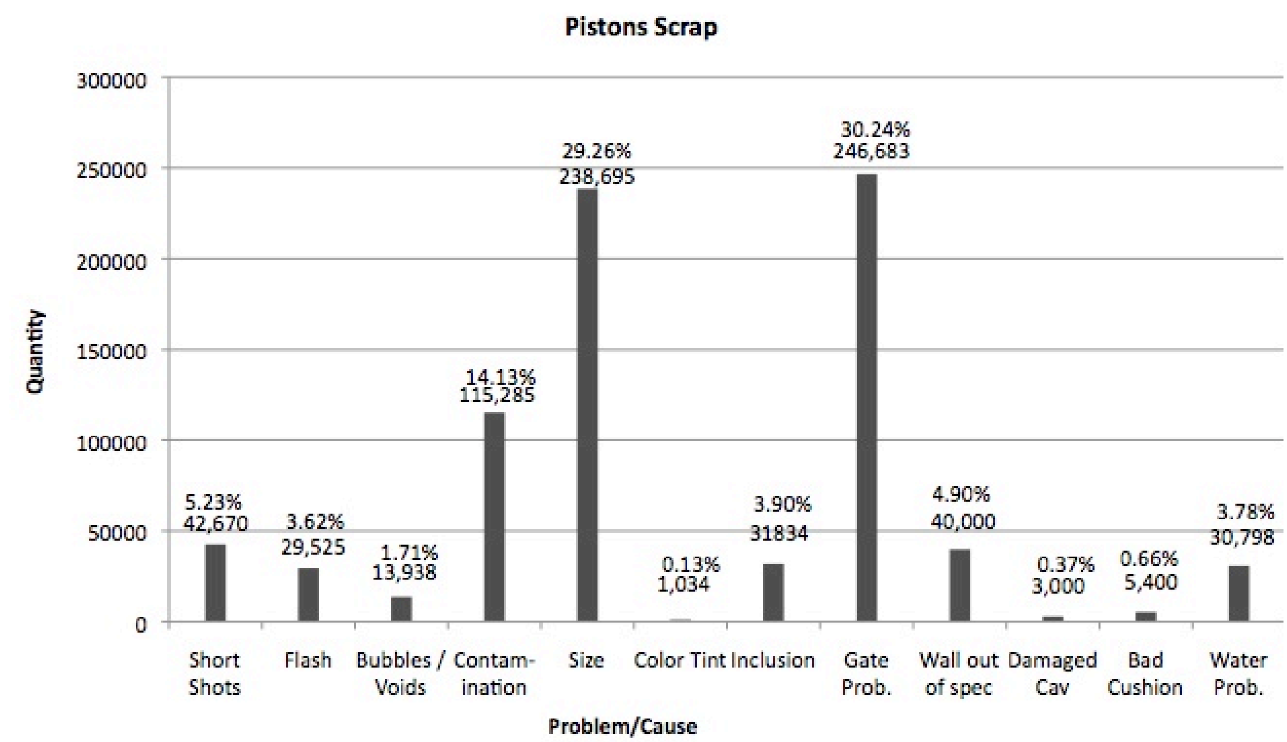


Figure 26: Piston Pareto Chart

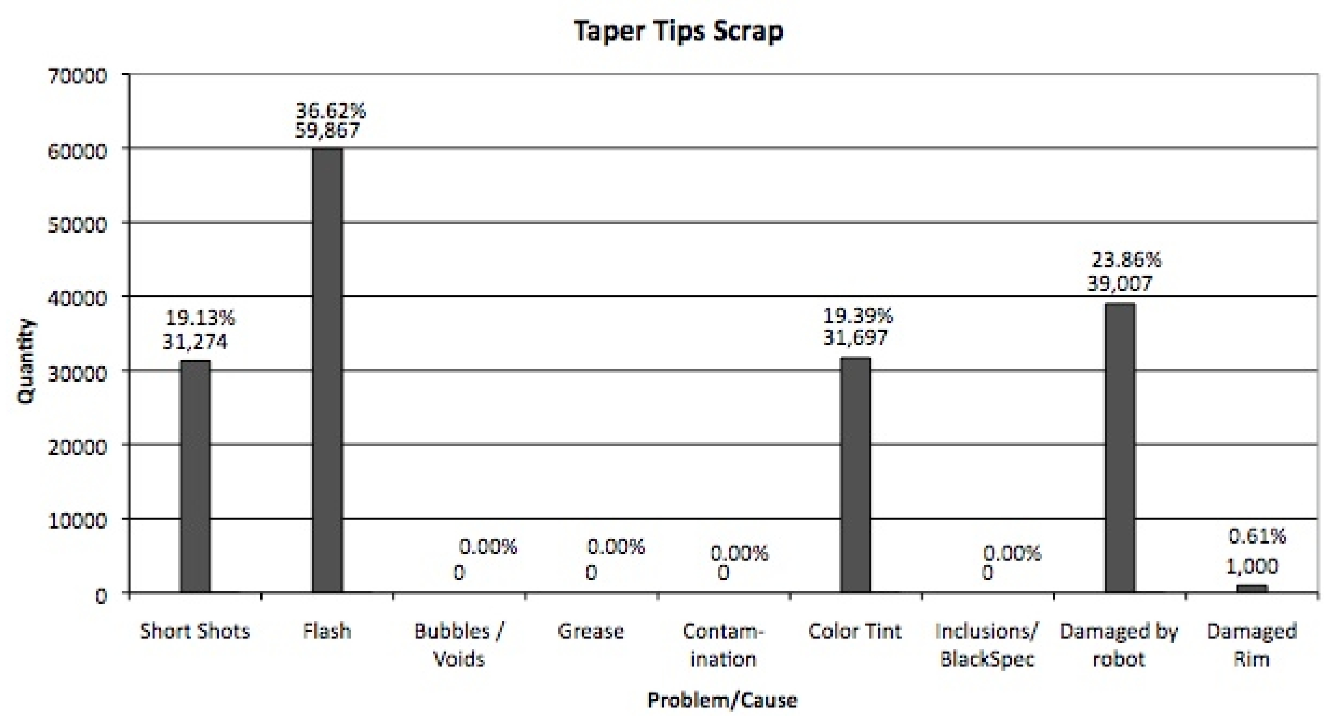


Figure 27: *Tapered Tips Pareto Chart*

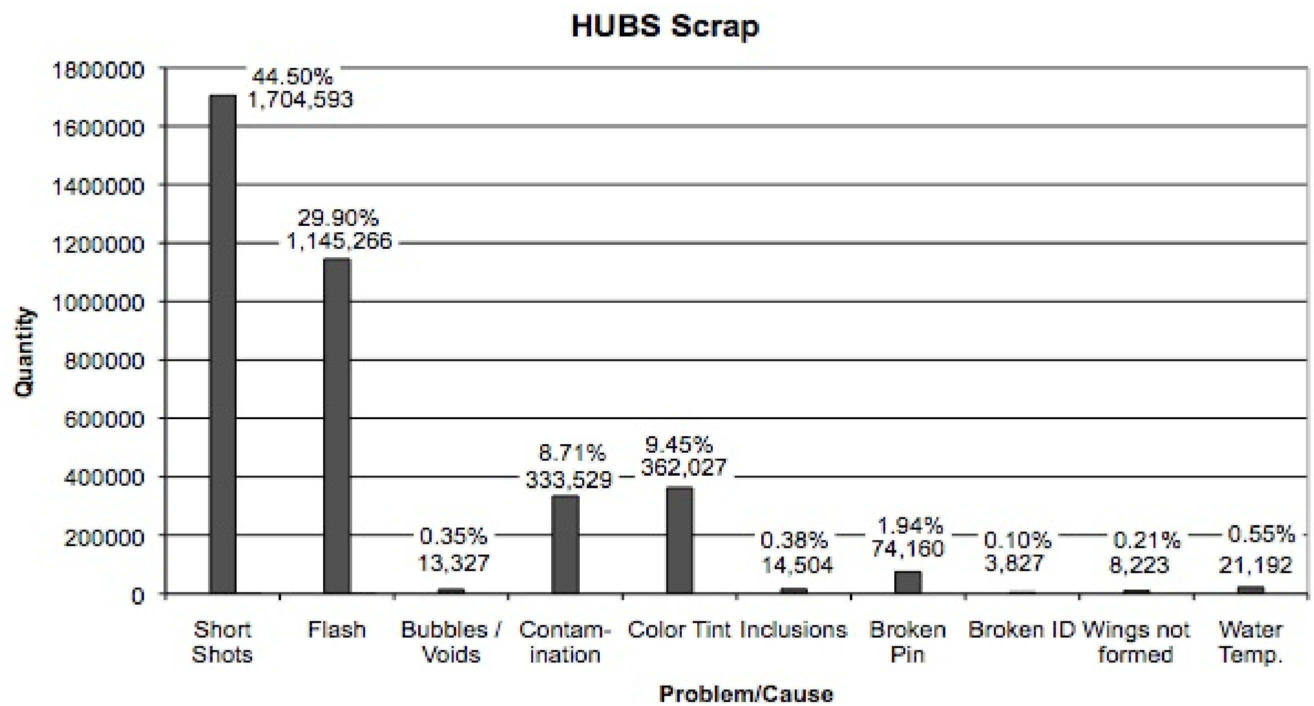


Figure 28: HUBS Pareto Chart

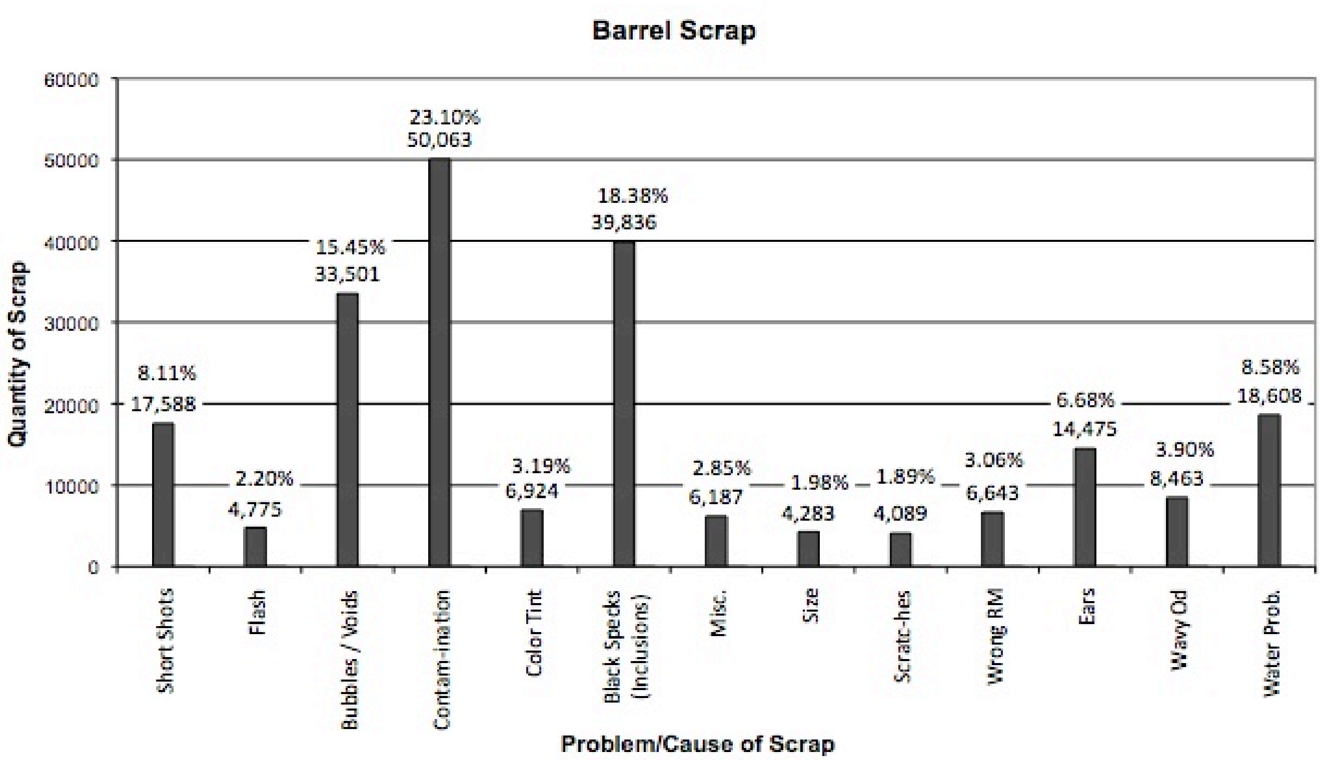


Figure 29: Barrel Pareto Chart

4.4 Waste Fishbone Diagram

Another Six Sigma tool that we utilized to determine the causes of the waste in the IM department was a 6M fishbone diagram, shown in Figure 30(McDonough, 2008). The fishbone diagram enabled us to highlight different areas that need to be improved in order to more successfully track the waste, more specifically scrap, in the IM department. Due to time constraints, we were only able to focus on certain aspects of the process while other phases may be examined in the future for even better process control.

By examining six major areas where waste may be a result, we then produced subheadings that cause that waste; the six m's consists of Management, Man, Method, Measurement, Machine, and Material. Subheadings under the Management tab which we focused on include both poor documentation and poor training for operators to record scrap. Within the Method area, causes of scrap that were chosen for focal points included the set-up scrap and the product itself. These causes were areas where the majority of scrap is produced, both from set-up configurations and in-process product QA checks. Mold problems and the purging of machines were also found to be an important aspect for us to examine more in-depth. Mold problems may cause defective parts while in production or also provide false accounts of how much product is actually produced. From these more specific causes, we were then able to determine where to allocate the remaining effort in both tracking and reducing the amount of scrap in the IM department.

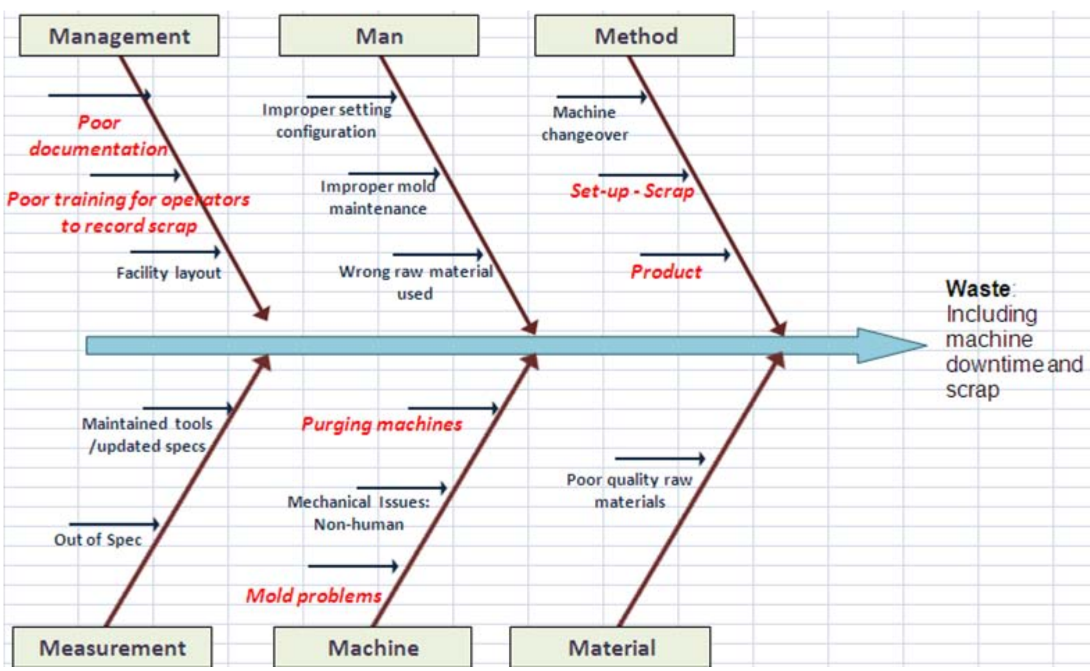


Figure 30: Waste Fishbone Diagram

4.5 Process Map

The injection molding process is described below in Figure 31. The virgin material, clear plastic pellets, are delivered in large plastic bags, stored in cardboard boxes called gaylords. The gaylords are stored in a warehouse area adjacent to shipping and receiving until they are needed for production. A material handler moves them from storage to the injection molding floor on pallets, via pallet jack, where they are carefully opened and a rigid-walled, flexible suction tube is inserted into the bag. The bag opening is kept closed at all times unless required to be opened for manual material rearrangement, which may be necessary as the material is depleted.

A vacuum moves the plastic pellets from the gaylord into a hopper on top of the injection molding machine, where a shutoff valve controls their flow into the machine's heating barrel. Inside the barrel the plastic is melted and moved along the barrel by heat from the barrel, as well as pressure and friction from the rotation of the screw. As the screw rotates, it pushes the melted plastic towards the nozzle. Once enough plastic is ahead of the screw tip, the screw stops rotation and a hydraulic system moves the screw forward, forcing the hot plastic through the nozzle and into the waiting mold.

The mold consists of at least two halves, at least one of which move back and forth with the platens, which run along tie bars, which allows the mold to be opened and closed throughout the process. The mold contains numerous identical cavities into which the plastic is injected. When the mold is closed, any plastic injected is forced to take the shape of the cavities. The mold is held clamped firmly shut until the plastic can cool and harden. Once the plastic is cool enough, the mold is opened, and ejector pins force the molded parts out of the mold.

After ejection, the parts either fall onto a conveyor belt system or are collected by a robotic system that allows additional cooling time to prevent scuffing as they fall. The parts are immediately bagged, placed into gaylords, and moved back to shipping and receiving department for final packing.

Every two hours during any given run, a batch of molded products is taken to quality control for inspection. If any inspected part does not pass inspection, the entire batch from the time of last inspection is rejected.

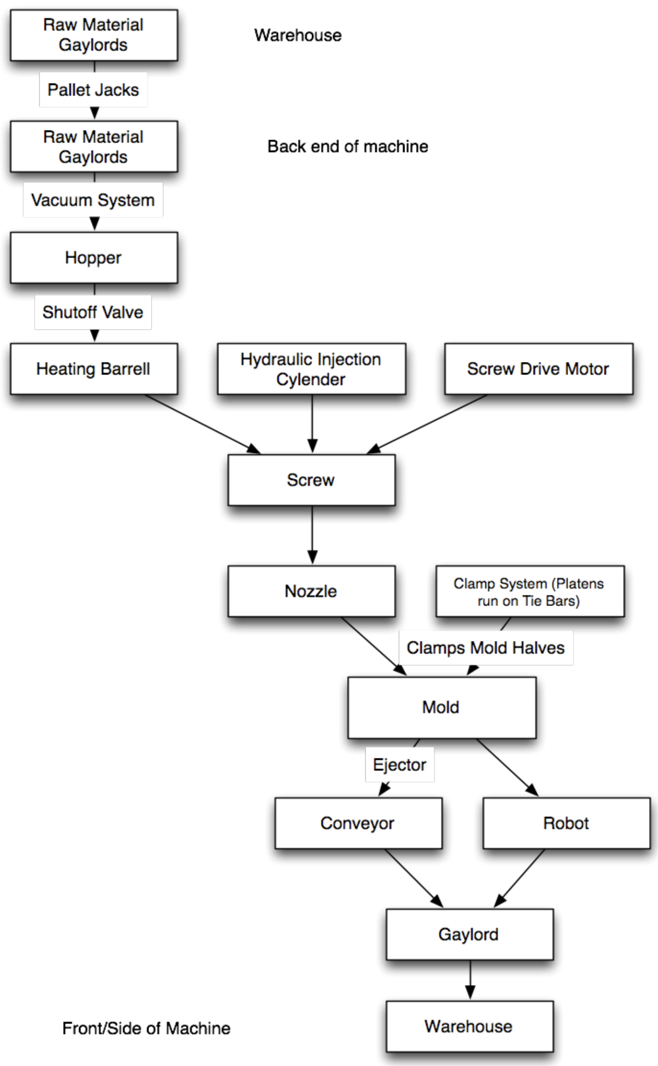


Figure 31: IM Process Map

4.6 Cause and Effect Matrices

By combining data from Pareto diagrams and information from the process map, we created C&E matrices for each category of product. These matrices help identify which steps in the molding process have the highest potential for causing rejects. By designing future studies around this data, EFD can focus on the "big hitters" first, ensuring that time and money spent studying and revising the process is cost effective.

We created these C&E/prioritization matrices using the January-September 2008 Reject Reports for all four of the products supplied to us by Scott. By looking at the "Total Relative Score" column, one can determine which process step and function has the most potential for impact on scrap. Table 6 shows that the raw material storage step likely causes the most scrap for barrel production. Table 7 shows that the nozzle step likely causes the most scrap for hub production. Table 8 shows that the nozzle step likely causes the most scrap for piston production. Lastly, Table 9 shows that the nozzle and mold/clamp step likely causes the most scrap for tapered tip production.

Table 6: EFD Injection Molding Prioritization Matrix: Barrels

	Rating of Importance	8.11%	2.20%	15.47%	23.10%	3.19%	18.38%	1.98%	1.89%	3.90%	6.68%	8.58%	
		Short Shots	Flash	Bubbles/Voids	Contamination	Color Tint	Black Specs	Size	Scratches	Wavy Od.	Ears	Water Problem	Total Relative Score
Process Step	Function									?? ??			
Raw Material (in Gaylords)	Raw material storage				23.10%	3.19%	18.38%					8.58%	0.5325
Vacuum System	Raw from gaylord -> hopper				23.10%	3.19%	18.38%						0.4467
Hopper	Feed into screw				23.10%	3.19%	18.38%						0.4467
Heating Barrell	Heat (multiple zones)	8.11%		15.47%									0.2358
Screw	Move and heat plastic	8.11%		15.47%									0.2358
Nozzle	Injection of plastic into mold	8.11%	2.20%	15.47%									0.2578
Mold/Clamp	Part Molding/Cooling		2.20%					1.98%					0.0418
	Part Ejection								1.89%		6.68%		0.0857
Conveyor	Move to packaging				23.10%		18.38%		1.89%				0.4337

Table 7: EFD Injection Molding Prioritization Matrix: Hubs

	Rating of Importance	44.50%	29.90%	0.35%	8.71%	9.45%	0.38%	1.94%	0.10%	0.21%	0.55%	
		Short Shots	Flash	Bubbles/Voids	Contamination	Color Tint	Black Specs	Broken Pin	Broken ID	Wings not formed	Water Problem	Total Relative Score
Process Step	Function											
Raw Material (in Gaylords)	Raw material storage				8.71%	9.45%	0.38%				0.00%	0.185
Vacuum System	Raw from gaylord -> hopper				8.71%	9.45%	0.38%					0.185
Hopper	Feed into screw				8.71%	9.45%	0.38%					0.185
Heating Barrell	Heat (multiple zones)	44.50%		0.35%								0.449
Screw	Move and heat plastic	44.50%		0.35%								0.449
Nozzle	Injection of plastic into mold	44.50%	29.90%	0.35%								0.748
Mold/Clamp	Part Molding/Cooling		29.90%									0.299
	Part Ejection				8.71%		0.38%					0.091
Conveyor	Move to packaging				8.71%		0.38%					0.091

Table 8: EFD Injection Molding Prioritization Matrix: Pistons

Process Step	Function	Short Shots	Flash	Bubbles/Voids	Contamination	Color Tint	Black Specs	Size	wall out of spec	Gate Problem	Bad Cushion	Water Problem	Total Relative Score
	Rating of Importance	5.23%	3.62%	1.71%	14.13%	0.13%	3.90%	26.29%	4.90%	30.24%	0.66%	3.78%	
Raw Material (in Gaylords)	Raw material storage				14.13%	0.13%	3.90%					3.78%	0.1816
Vacuum System	Raw from gaylord -> hopper				14.13%	0.13%	3.90%						0.1816
Hopper	Feed into screw				14.13%	0.13%	3.90%						0.1816
Heating Barrell	Heat (multiple zones)	5.23%		1.71%				26.29%	4.90%	30.24%	0.66%		0.6903
Screw	Move and heat plastic	5.23%		1.71%				26.29%	4.90%	30.24%	0.66%		0.6903
Nozzle	Injection of plastic into mold	5.23%	3.62%	1.71%				26.29%	4.90%	30.24%	0.66%		0.7265
Mold/Clamp	Part Molding/Cooling		3.62%					26.29%	4.90%	30.24%	0.66%		0.6571
	Part Ejection				14.13%		3.90%						0.1803
Conveyor	Move to packaging				14.13%		3.90%						0.1803

Table 9: EFD Injection Molding Prioritization Matrix: Tapered Tips

Process Step	Function	Short Shots	Flash	Bubbles/Voids	Contamination	Color Tint	Black Specs	Damage by Robot	Damaged Rim	Total Relative Score
	Rating of Importance	19.13%	36.62%	0.00%	0.00%	19.39%	0.00%	23.86%	0.61%	
Raw Material (in Gaylords)	Raw material storage				0.00%	19.39%	0.00%			0.1939
Vacuum System	Raw from gaylord -> hopper				0.00%	19.39%	0.00%			0.1939
Hopper	Feed into screw				0.00%	19.39%	0.00%			0.1939
Heating Barrell	Heat (multiple zones)	19.13%		0.00%						0.1913
Screw	Move and heat plastic	19.13%		0.00%						0.1913
Nozzle	Injection of plastic into mold	19.13%	36.62%	0.00%						0.5575
Mold/Clamp	Part Molding/Cooling	19.13%	36.62%	0.00%						0.5575
	Part Ejection				0.00%		0.00%		0.61%	0.0061
Conveyor	Move to packaging							23.86%	0.61%	0.2447

These matrices will be very valuable for projects following ours. Since we will be quantifying scrap in various locations, the next step will be to identify the causes and determine potential ways to reduce the scrap produced during runs. The process steps with the highest total score should be the functions that are analyzed first.

Chapter 5—Pilot Study Program

Our initial background research on-site with EFD exposed the fact that there are many data sheets traveling between different departments at one time collecting similar sets of data. The inefficiencies of the paper trail make it very difficult for anyone to break down the data that has been captured and make use of its content. Switching between electronic databases and older paperwork also make it extremely difficult to combine similar scrap related data that has been spread across different departments. We have found that there has been little attempt to adjust old materials or introduce new ones that would consolidate paperwork across departments and streamline the scrap tracking.

EFD's current paperwork across three divisions; Process Control, Injection Molding management, and Quality Assurance was inspected to provide justification for the pilot study. This justification was followed by a round of brainstorming sessions with key individuals at EFD to minimize the impact of the study on the workers. We then created several new tracking sheets, followed by three sessions of revisions. The data collection program for EFD to follow was implemented between Monday, January 26th and Monday, February 9th and accounted for ten business days. The main objective of the pilot study was to provide EFD with the groundwork to generate proper scrap amounts and highlight areas that produce the most significant amount, allowing for future projects within our recommendation section to be successful.

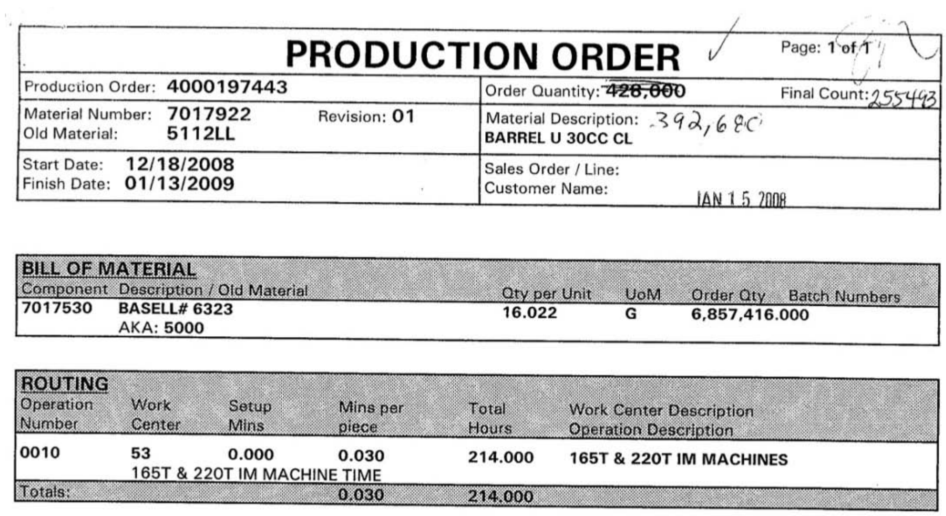
Ultimately, we recommend the creation of an electronic system incorporating all data. This database would allow for partial automation and a single point of entry for machine operators and end users of the data, decreasing data recording overhead and increasing data quality. The following section outlines this process we followed. For our full list of recommendations based on findings, please refer to Chapter 6.

5.1 Justification for Pilot Study

Existing documentation is currently generated and analyzed by three main groups: Production Control, Injection Molding management, and Quality Assurance. Each group produces a packet of materials for every job that meets the basic needs of that group's responsibilities. The following is a breakdown of what these packets include and what key data each packet records:

5.1.1 Production Control

When the kanban system calls for new production of a particular part number, the production control coordinator prints a production order, Figure 32, from SAP. It is Process Control's job to initiate the paperwork for a work order out of SAP. This is the only computer-generated form in this packet. It is divided into three sections. In the first section it lists the production order number and order quantity, part number and description, estimated start and finish dates. This section is also used to manually record (by hand) the final count of parts placed into inventory. The second section is the bill of materials for this part number. It lists the specific amounts and types of raw materials used for the job. Currently the method used to determine the quantity of material used per unit is inconsistent between parts. Some parts' BOMs include a scrap factor for setup time, floor scrap, rejects, etc., while others do not. This means that SAP's estimate for raw material to be used cannot be used to determine scrap levels, and adjustments must be made to the SAP records to account for the actual amount of raw material used for a job after the fact. Finally, the production order contains a routing section which estimates the actual production time that should be required to complete the job. Again, some of the routing information contains setup times while some does not. However, the time per piece is considered to be accurate.



PRODUCTION ORDER Page: 1 of 1

Production Order: 4000197443	Order Quantity: ~~428,000~~ Final Count: 255493
Material Number: 7017922 Revision: 01 Old Material: 5112LL	Material Description: 392,680 BARREL U 30CC CL
Start Date: 12/18/2008 Finish Date: 01/13/2009	Sales Order / Line: Customer Name: JAN 15 2008

BILL OF MATERIAL

Component	Description / Old Material	Qty per Unit	UoM	Order Qty	Batch Numbers
7017530	BASELL# 6323 AKA: 5000	16.022	G	6,857,416.000	

ROUTING

Operation Number	Work Center	Setup Mins	Mins per piece	Total Hours	Work Center Description Operation Description
0010	53 165T & 220T IM MACHINE TIME	0.000	0.030	214.000	165T & 220T IM MACHINES
Totals:			0.030	214.000	

Figure 32: SAP Production Order

Also included in the production control manager's packet is a "Process Tally Sheet", Figure 33. Its purpose is to track the final product as it goes into inventory. The first section for production floor recording is used to record each time parts are boxed. It lists the box number, date, shift, quantity of parts in the box, total quantity completed up to that point, the name of the person boxing the pieces. The second section for warehousing / data is used when warehousing personnel place the pieces officially in inventory. They take four or five boxes at once, verify their contents, and record the total quantity placed in stock along with the date and initials of the person entering the stock into SAP.

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Process Tally Sheet									
Production Floor						Warehousing / Data Entry			
Box	Date	Shift	Box Qty.	Qty. Comp.	Name	Verified by:	Qty. put in stock	Date put in stock	Entered by:
1	1/5/09	1	7140	7140	KK	AP	7,140	01/05/09	MD
2	1/5/09	2nd	7140	14280	B.D.				
3	1/5/09	2nd	7140	21420	B.D.				
4	1/5/09	2nd	7140	28560	B.D.				
5	1-5-09	3RD	7140	35700	B.T.Jr				
6	1-5-09	3RD	7140	42840	B.T.Jr	AP	35,700	01/06/09	MD
7	1/6/09	1	7140	49,980	SC				
8	1/6/09	2	7140	57,120	B.D				
9	1/6/09	2	7140	64,260	WS				
10	1/6/09	2	7140	71,400	WS				
11	1-6-09	3RD	7140	78540	B.T.Jr.				
12	1-6-09	3	7140	85680	B.T.Jr.	AP	42,840	01/07/09	MD
13	1/7/09	1	7140	92,820	SC				
14	1/7/09	2	7140	99,960	WS				
15	1/8/09	2	7140	107,100	WS				
16	1-8-09	3RD	7140	114,240	B.T.Jr	AP	28,560	01/[illegible]/09	MD
17	1/8/09	1	7140	121,380	SC				
18	1/8/09	1	7140	128,520	SC				
19	1/8/09	2	7140	~~135,640~~	WS	135.660			
20	1/8/09	2	7140	~~142,780~~	WS	142.800			
21	1-9-08	3RD	7140	~~149,920~~	B.T.Jr	149.940			
22	1-9-09	3RD	7140	~~157,060~~	B.T.Jr	AP	42,840	01/09/09	MD
23	1-9-08	1st	7140	164220	JW				
24	1/9/09	1	7140	171360	KK				
25	1/9/09	2	7140	178,500	WS				
26	1/9/09	2	7140	185,640	WS				
27	1-10-09	3RD	7140	192780	B.T.Jr.				
28	1-10-09	3	7140	199,920	B.T.Jr	AP	42,840	01/12/09	MD
29	1/12/09	1	7140	207,060	KK				
30	1/12/09	1	7140	214,200	SC				
31	1/12/09	2	7140	221,340	WS				
32	1/12/09	2	7140	228,480	WS				
33	1-12-09	3RD	7140	235620	B.T.Jr				

Raw Mat'l. Lot #: HJ25BCC06 Part Number: 5112LL Lot Number: 4000197443

Figure 33: Process Tally Sheet

The last form included in this packet is a Production Rejection Report, Figure 34. Its purpose is to summarize the quantity of parts rejected for quality issues. It lists the date, quantity, shift, tech inspector, and reason for rejection. The reasons a piece may be rejected are found in the Workmanship "Standards for Plastic Injection Molding Components" manual. Once all the forms in this packet are completed, they are returned to the production control manager for filing and analysis.

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Production Rejection Report **Part Number :** 7017922 **Lot Number :** 4000197443

Date	Quantity	Shift	Tech/ Inspector	Yield (Y)	Scrap (S)	Reason for rejection
12/23/08	300	2nd	B.D.	✓		Set-Up
"	8	2nd	EA		S	Black specks
1-5-09	49	1ST	MM		S	Black Specks.
1-5-09	29	2nd.	DS.		S	Grease, Black specks.
1/5/09	32	3rd	MM.		S	Grease, Black speaks
1/6/09	25	1ST	MM		S	Grease / Black Specks
1-6-09	30	2nd	EA		S	" " "
1-6-09	47	3rd	mm		S	Scratches, Black specks, Grease.
1-7-09	225	1st	MM		S	Black Specks.
1-7-09	37	2nd.	DS.		S	Black specks.
1-7-09	11	3rd	mm		S	" "
1-8-09	22	1ST	MM		S	Black Specks
1-8-09	25	2nd	EA		S	" "
1-8-09	19	3rd	mm		S	" "
1-9-09	31	1ST	MM		S	Grease / Black Specks
1-9-09	34	3rd	mm		S	" " "
1-12-09	41	2nd.	DS.		S	Black specks.
1-12-09	28	3rd	mm		S	" "
	1003					

QUA-13-04-F003, Rev. A, 01-04-07

254490

703

Figure 34: Production Rejection Report

5.1.2 Injection Molding Management

The next group of data recording sheets is used internally in the injection molding department by the management. The first, Figure 35, is an 11x17 graphing sheet that gets posted prominently on each machine to visually track production per shift. When a job is started, the shift doing the setup records the part number, shift number doing the setup, setup start time, the time the mechanical portion of the setup is completed, and the time the first piece is submitted to quality assurance for approval. When setup is complete, production graphing is started. The expected shift production is calculated based on the SAP time required to complete a single part. Then the appropriate quantity scale is chosen and highlighted, along with the target shift production line. The shifts spent doing setup produce no product, so their quantities are graphed at zero. From there on out, each shift marks the quantity they produced on the graph. This provides a concise graphical representation of the progress of the job and allows the operators to quickly see if there is a major problem affecting production. Any time the job is shut down or major adjustments are needed, the graph will be visibly affected, and notes are made in the "Comments" section as to what went on. The comments section also shows the machine number and how many cavities were running for this job.

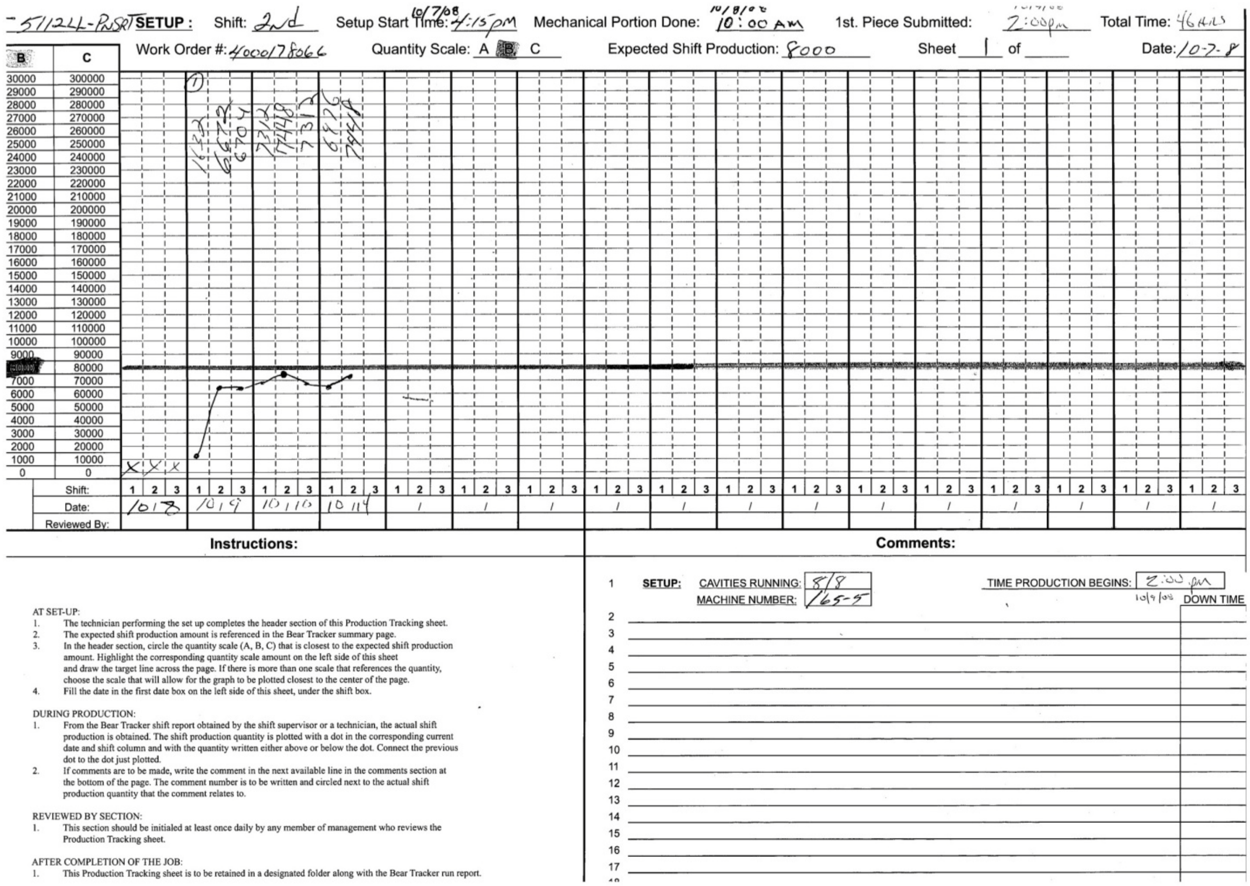
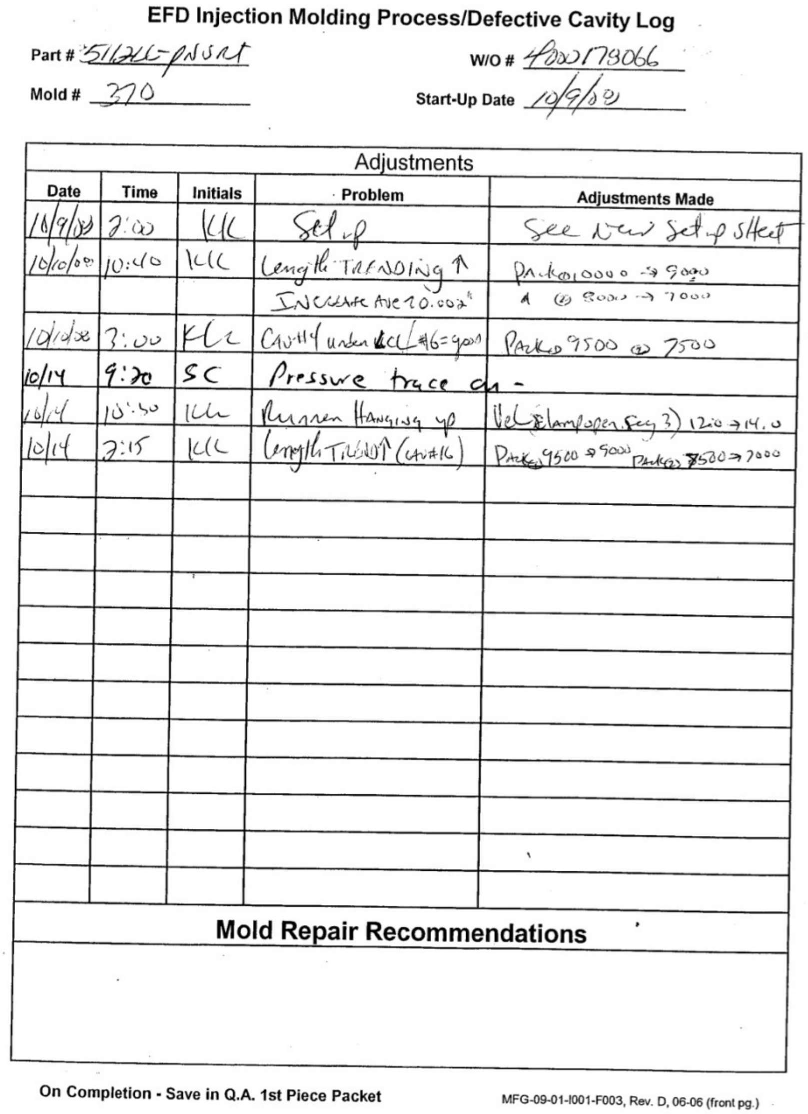


Figure 35: Injection Molding Process Graph

The second form in this packet, also manually recorded, is Figure 36, "EFD Injection Molding Process/Defective Cavity Log." It lists the part number, work order number, mold number, & startup date. The first section is for machine technicians to record the date and time they observed a problem, what the problem was, and what adjustments to the machine settings they made to correct the problem. The second section of this form is for recording any time a cavity is closed for a quality problem that cannot be adjusted out. There is also a freeform comments section for the technician to make any recommendations for mold repairs.



EFD Injection Molding Process/Defective Cavity Log

Part # 51624-INSRT W/O # 4000178066

Mold # 370 Start-Up Date 10/9/08

Adjustments				
Date	Time	Initials	Problem	Adjustments Made
10/9/08	2:00	KLC	Set up	See new Set up sheet
10/10/08	10:40	KLC	Length TRENDING ↑	Pack@1 0000 → 9000
			INCREASE AVE ↑ 0.002"	4 @ 8000 → 7000
10/10/08	3:00	KLC	Cavity under LCL #6=900	Pack@ 9500 @ 7500
10/14	9:20	SC	Pressure trace on -	
10/14	10:50	KLC	Runner Hanging up	Vel (Clamp open Seq 3) 12.0 → 14.0
10/14	2:15	KLC	Length TRENDING ↑ (Cav#16)	Pack@ 9500 → 9000 Pack@ 8500 → 7000

Mold Repair Recommendations

On Completion - Save in Q.A. 1st Piece Packet

MFG-09-01-I001-F003, Rev. D, 06-06 (front pg.)

Figure 36: IM Process/Defective Cavity Log

The third sheet used within the molding department is generated by the computerized tracking system that is integrated with the molding machines. The system is called “Bear Tracker”. The bear tracker report, Figure 37, lists the machine, part number, raw material used, the number of cavities in use, job start and stop dates, job runtime, job downtime, number of parts made, job parts rejected, average job cycle time, and job efficiency. In many cases, operators do not input all of the necessary data for this report to be useful. For example the job parts rejected field is frequently zero according to bear tracker even though the production run report lists rejected parts. This is one example of where having multiple places to record the same data leads to mistakes or omissions in recording and inconsistent, unreliable data. Bear tracker is also capable of performing much more complicated analysis, but the system has not been leveraged to its potential at this time.

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machine	cavities in use	job start date	job stop date	job runtime	job downtime	job parts made	job parts rejected	job avg cycle	job avg efficiency
5112LL-PNSRT / 8000 EXP. PROD									
165-5	8	06Oct2008	15Oct2008	162:15:47	101:05:35	56672	0	82.46	34.93%

Figure 37: Bear tracker report

5.1.3 Quality Assurance

The third and final group of forms is generated and used solely by the quality assurance department. These forms are shown in Appendix A. The three major forms in this group are: “First Piece Inspection”, “Shrinkage Inspection”, and “Process Control Record.” The first piece inspection form is a detailed quality report on the first pieces submitted to QA after setup is done. If these parts are accepted, production goes on without immediate adjustment. The inspector may have comments about quality issues that require adjustment even if the issues were not significant enough to reject the parts. The shrinkage inspection report is necessary for some parts, such as barrels, whose internal diameter is critical to the functioning of the part. As the plastic cools, it shrinks, changing critical dimensions. While the majority of the shrinkage happens within the first few minutes after molding, the parts continue to shrink for approximately 30 days. To ensure quality parts, the QA department tracks shrinkage of parts for one hour and twenty-four hours. If parts pass both of these shrink tests, historically they will also pass the 30-day shrink test. Finally, the process control record is updated approximately every two hours during a production run, when a sample of parts is taken to QA for inspection. These inspections are carefully documented to ensure consistent product quality throughout the production run and give feedback to the operators about any adjustments that need to be made.

While much of the data recorded in the QA packet is not directly relevant to material usage, the process and outcome is extremely important. First, the inspection process requires removal of parts produced from the production process. These samples are not returned to inventory after inspection: they are scrapped instead. Currently the impact of these samples on the amount of material used and perceived scrap amounts is not known, and may or may not be accounted for in the bill of materials in SAP. Therefore it is important to start recording the exact amounts of material that is scrapped for the QA department’s inspections. Secondly, the outcome of the QA inspection is critical to the amount of scrap for any given job. If a quality problem is identified and is not able to be adjusted out of the process, an entire batch of pieces will have to be scrapped. Even with as frequent a sampling as every two hours, this can mean a significant number of pieces.

It is clear that each department has some individual recording and monitoring needs, while many of these needs are shared between two or more departments. As a result, some documentation requests information that is duplicated or should be available elsewhere. Other data, such as the amount of material used during machine setup, startup, shutdown, purging, floor scrap, regrind produced or reused, etc., is not recorded at all. The goal of this pilot study is to collect this data without adjusting the current documentation in use. A future redesign of the existing documentation to minimize duplication of efforts, include all relevant data, and take advantage of electronic systems is recommended.

5.2 Brainstorming

After performing preliminary analysis of the current documentation and identifying the missing data areas as previously discussed, we decided it would be best to develop additional concise documentation to track these data. We recognize that adding even more manually-recorded, paper-based tracking sheets exacerbates the documentation-complexity problem we identified in Chapter 3, but feel that it is a necessary step to take prior to a documentation redesign program. Ultimately, an electronic system incorporating all data would allow for partial automation and a single point of entry for machine operators and end users of the data, decreasing data recording overhead and increasing data quality.

With this in mind, we toured the production facility to identify possible data recording methods to minimize the impact of the pilot study on the machine operators and material handlers. By following the path that materials take through the department, we noted that all materials enter and exit through the same doors and that all the missing data could be collected by the materials handler as he brings materials to and from each machine. All that is needed is to record the weight of each gaylord or barrel each time it is moved to or from the department. Since the injection molding department already owns a pallet scale that was not in use, we decided to set it up as a weigh station just inside the main entrance to injection molding, shown in Figure 38 and Figure 39. By placing the weigh station near the entrance already used by material handlers, the impact will be minimal: a brief stop to weigh and record the contents of any container going to or from any machine.

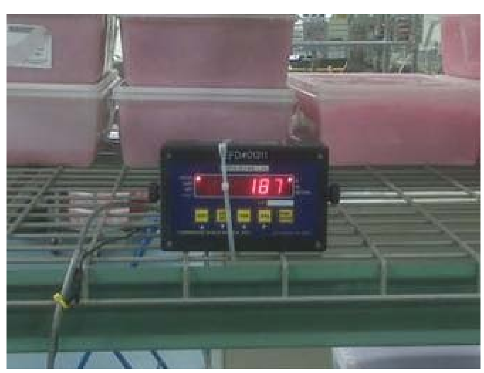

Figure 38: Weigh Station Pallet Scale Display

Figure 39: Weigh Station in Injection Molding Department

5.3 Tracking Sheets

Initially we created three tracking sheets. The first sheet tracks raw materials, startup scrap, runners, and final product for a specific production run. This sheet will stay with the production order packet currently kept on a clipboard at the machine. The second sheet, which is clipped onto each new gaylord of regrind produced, follows that container until it is emptied and records where all of the regrind is used. Finally, the floor scrap data collection sheets are meant to track floor scrap that cannot be linked to a specific job or material.

Training notes and reminders were also written in order to ensure that all three shifts weighed and recorded data accurately and uniformly. After meeting with several stakeholders and getting initial approval of the documents, the group hoped to perform a test run of the pilot study for seven days prior to EFD's two-week winter holiday building shutdown. The goal of this test run was to determine whether or not our data recording sheets included all the necessary fields and also to see if these documentation methods would be feasible as a daily routine for machine operators and material handlers. Due to scheduling conflicts and limited staffing, the test run was postponed. With this delay, we took the time to reevaluate the pilot study plans and make necessary changes for the start-up in early 2009.

Figure 40 represents the first draft of the job-specific scrap data collection sheet (page 1 of 2). This sheet goes on the job clipboard, which hangs on the side of the injection molding machine, and is to be filled out by the materials handler every time materials move to or from the machine.

Job/Requisition Number: ________________ Part Number: __________________

Record the date, time, and weight of each movement in appropriate columns.

	Gaylord/Barrel #	Date/Time	Weight In[1]	Weight Out[1]	Net Weight[2]
Raw Materials	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				
	10				

	Date/Time	Weight In[1]	Weight Out[1]	Net Weight[2]
Scrap prior to 1st piece submitted				
Runners				
Runners → Trash[3]				
Runners → Regrind[4]				

Figure 40: Work Order Materials Tracking Sheet, version 1

Figure 41 represents the first draft of the floor scrap data collection sheet. This sheet will be located at the weigh station in a pouch located next to a designated trash can or gaylord. Anyone who cleans up any type of floor scrap should empty the scrap into a gaylord or trash can and record the date and time of this transaction.

Gaylord/Trash Can #	Date/Time	
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
	Total	
	Gaylord/Trash Can Weight	
	Conveyance Accessories	
	Total Floor Scrap	

Figure 41: Floor Scrap Data Collection Sheet, version 1

Figure 42 represents the first draft of the regrind recording sheet. One sheet is attached to every gaylord with material going into storage in order to capture how much material is reground and scrapped. The material handler is expected to stop at the weigh station before putting the gaylord in storage so that this sheet can hold the most updated information regarding the amount of material inside. Appendices B, C, and D display all three tracking sheets in full.

GROSS WEIGHT OF MATERIAL & CONVEYANCE OUT OF INJECTION MOLDING ______ LBS

- ______ Gaylord Weight

- ______ Other accessories (pallet jack, etc.)

MATERIAL ONLY: ______ LBS

Part #	Date	Time	Weight In	Weight Out

WEIGHT OF MATERIAL OUT/ TRASH ______ LBS

- ______ Gaylord Weight

- ______ Other accessories (pallet jack, etc.)

TOTAL REGRIND SCRAP ______ LBS

Figure 42: Regrind Recording Sheet, version 1

In order to illustrate the flow of material in the injection molding department, we created a process flow diagram, Figure 43. Each step is color-coordinated based on which scrap tracking sheets should be used to record the relevant scrap data. This diagram was meant to confirm our understanding of the process and give employees a visualization of where scrap should be weighed.

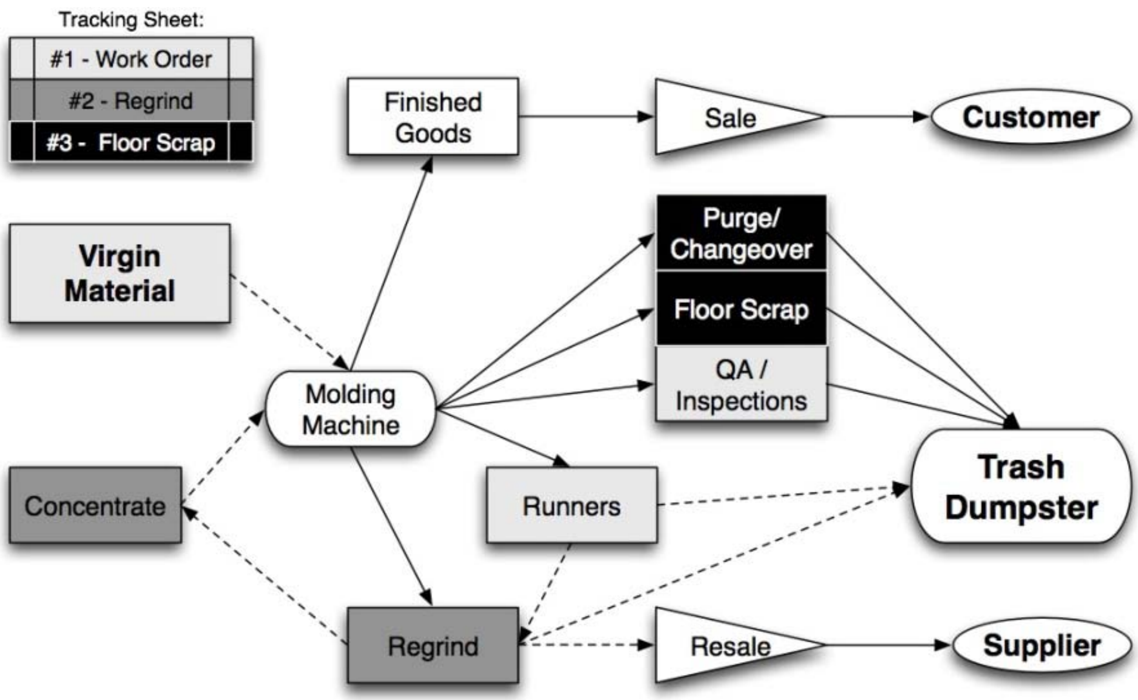

Figure 43: Process Flow Diagram

Upon meeting with the various stakeholders in mid-January (see Appendix E for the meeting minutes), the tracking sheets were revised prior to the start of the pilot study program. The initial floor scrap tracking sheet was combined with the job-specific scrap tracking sheet, shown in Appendix F, in order to condense the necessary information into one sheet. The regrind scrap tracking sheet was reformatted to be more uniform with the job-specific scrap tracking sheet, shown in Appendix G.

We also created standard work instructions for each of the scrap tracking sheets in order to specify how the data collection and recording should take place on a daily basis. By offering detailed instructions, employees can be sure that the data is collected consistently and accurately over the three shifts to produce reliable data. The goal of all of the revisions was to help walk employees through the recording process, one step at a time, and keep the process simplified in order to keep all on board.

5.4 Implementation of Pilot Study

Our meeting with the stakeholders confirmed that everyone was on board with the program that we developed and all were ready to begin recording that evening. We provided several copies of the tracking sheets along with the standard work instructions associated with each and brought them into the injection molding department to be sure that they are readily available for each new job. The two-week pilot study was slated for Monday, January 26th until Monday, February 9th and accounted for ten business days.

Almost immediately the employees decided to limit data collection to save on manpower by eliminating several sections of the forms. The tracking sheets were modified to focus on material coming in (raw and regrind) and material going out (trash), rather than recording details regarding what happens to material once it is already "in the system." Floor scrap and un-ground runners were combined (Appendix H), and regrind tracking was limited to recording the weight of any unused regrind just prior to it being thrown away, shown in Appendix I. However, the sheets were not formally revised: The tracking sheets already on hand were implemented using new standard work instructions written by the molding department manager.

The new standard work instructions were condensed into one sheet. Instead of having three step-by-step work instruction sheets, one sheet is used to specify what employees should record before, during, and after each job. This serves as a checklist and makes it less likely that an employee will leave out crucial steps to the scrap data recording process. However, as noted below, since the original sheets were used with new standard work instructions, there was some confusion about what was to be recorded and where.

5.5 Analysis

Despite the adjustments made to the pilot study materials and the standard work instructions, data was still obtained that provided some interesting results. Due to several obstacles that the project encountered, discussed later in Chapter 6, only three job runs were able to be tracked through the 26th of January and the 9th of February. The jobs all ran on the same machine and produced essentially the same part. The work order numbers ended in 2185, 4762, and 3390, for the first, second, and third jobs, shown in Appendices K, J, L, respectively.

For some jobs, not all of the required data was recorded. On the first Job, no floor scrap/runner weights were recorded. The second job did not include any information on setup scrap or quality assurance scrap, while the third job was completed. Also, due to EFD's changes to the pilot program, the weight of regrind produced for each job was not directly recorded. However, we make the assumption for the purposes of this analysis that any raw material not otherwise accounted for went into regrind. This assumption is not ideal and should not be relied upon; however given the data available to us it is the only way to proceed. Also, the quantity of pieces produced by the job was recorded instead of the weight. Therefore we must rely on the unit weight according to SAP for our calculations.

The first job is summarized in Figure 44 and used 2442 pounds of raw materials and produced 1530 lbs of finished goods, which account for approximately 63% of the raw material used. Setup and quality assurance data accounted for approximately 1% each, and floor scrap was not recorded for this job. The remaining 35% is assumed to be runners that were reground for later use.

The second pilot study job is summarized in Figure 45 and used 1791 lbs of raw materials. Finished goods account for 75% of raw material use, with floor scrap & un-ground runners accounting for 5%. Setup scrap and quality assurance samples were not accounted for, so the remaining 20% is assumed to be runners that were reground for later use.

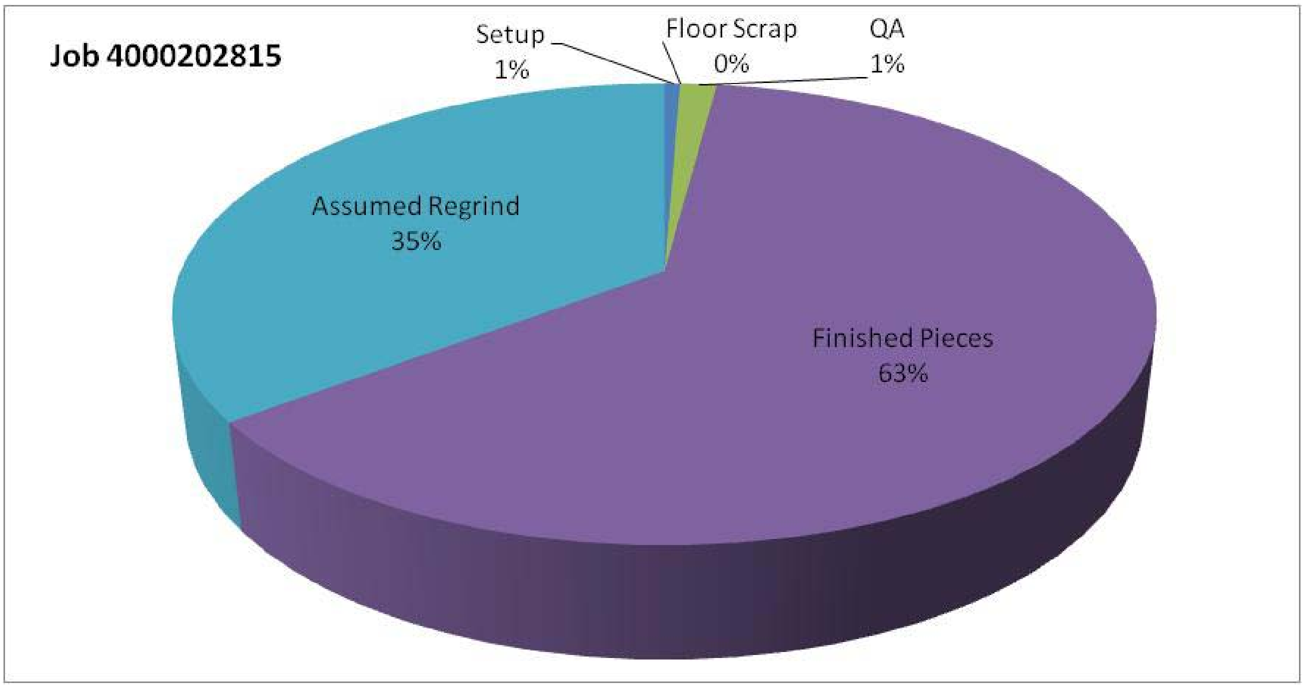

Figure 44: Pilot Study Job 1 Results

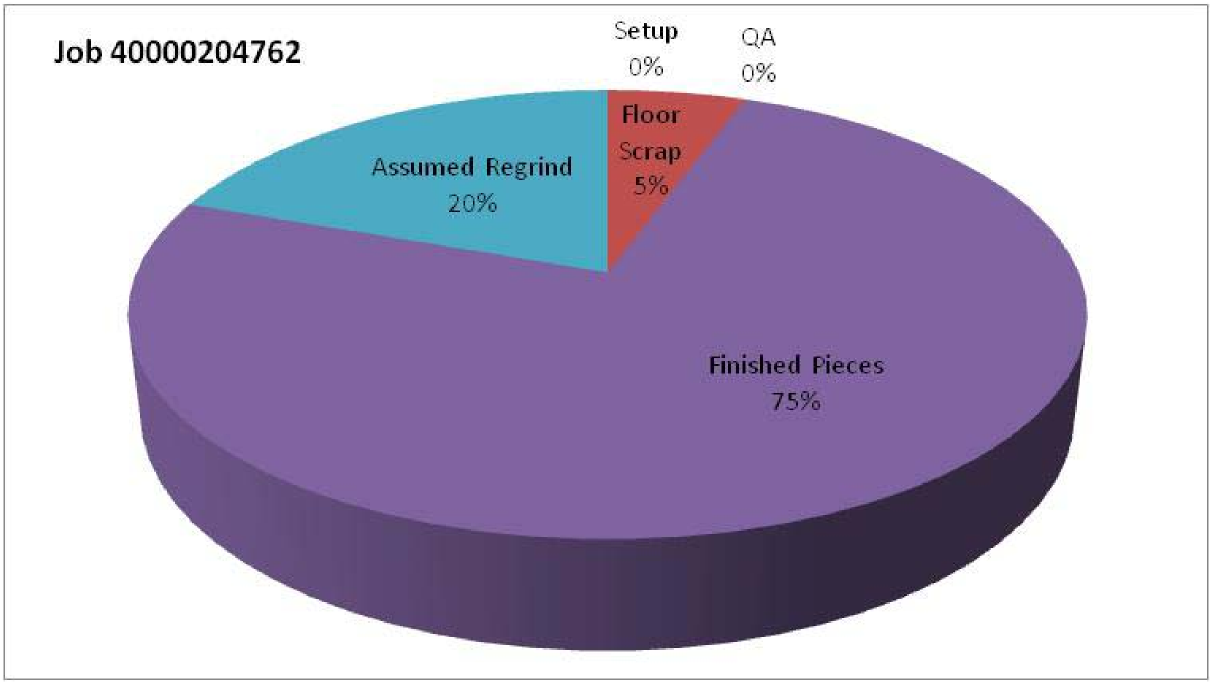

Figure 45: Pilot Study Job 2 Results

The third and final pilot study job is summarized in Figure 46 and used 2702 lbs of raw materials. 65% is accounted for in finished goods, 3% in floor scrap & un-ground runners, 1% in QA scrap, with setup accounting for only 2/10ths of a percent. The remaining 31% of raw materials is again assumed to have been reground.

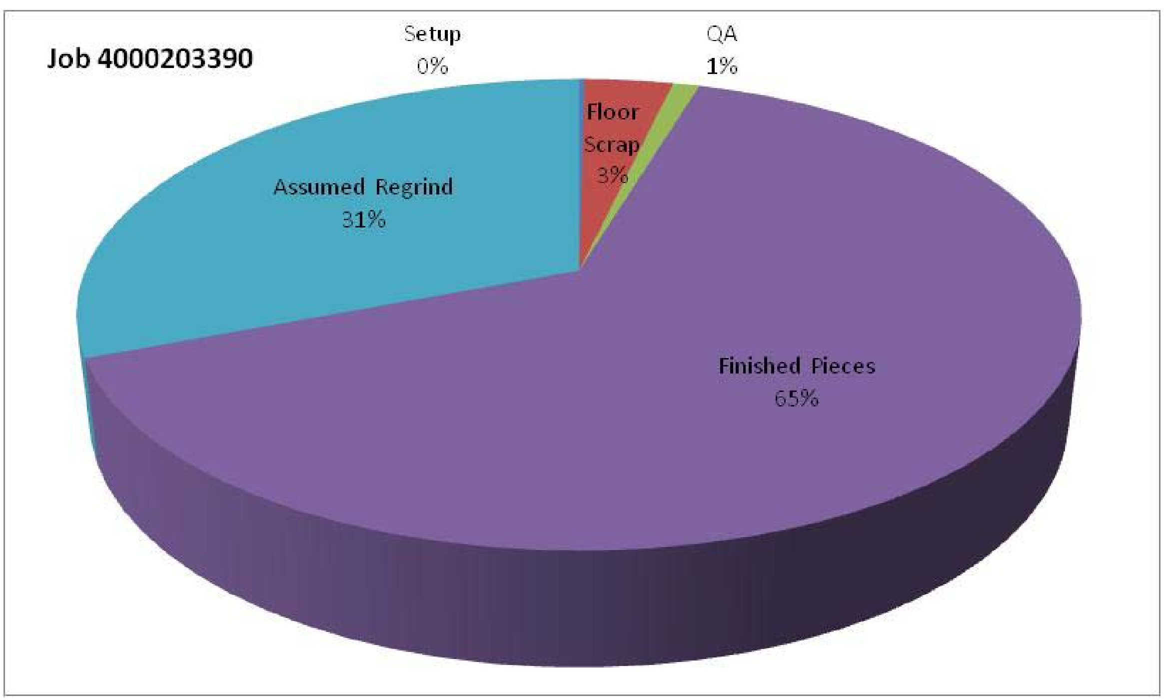

Figure 46: Pilot Study Job 3 Results

Combining the data from these three runs gives us a summary of the pilot study findings, shown in Figure 47. Overall, finished pieces accounted for 66% of material usage, followed by regrind at 30%, floor scrap at 3%, QA at 1%, and setup at only 3/10ths of a percent. While the data is not as complete as we would like, it shows some important information not previously known to the company. Specifically, the fact that on three small jobs, floor scrap accounted for 3% of waste was previously unknown. Also, the fact that 31% of the raw material produces regrind and not product could affect management decisions about how regrind is handled, stored, and used.

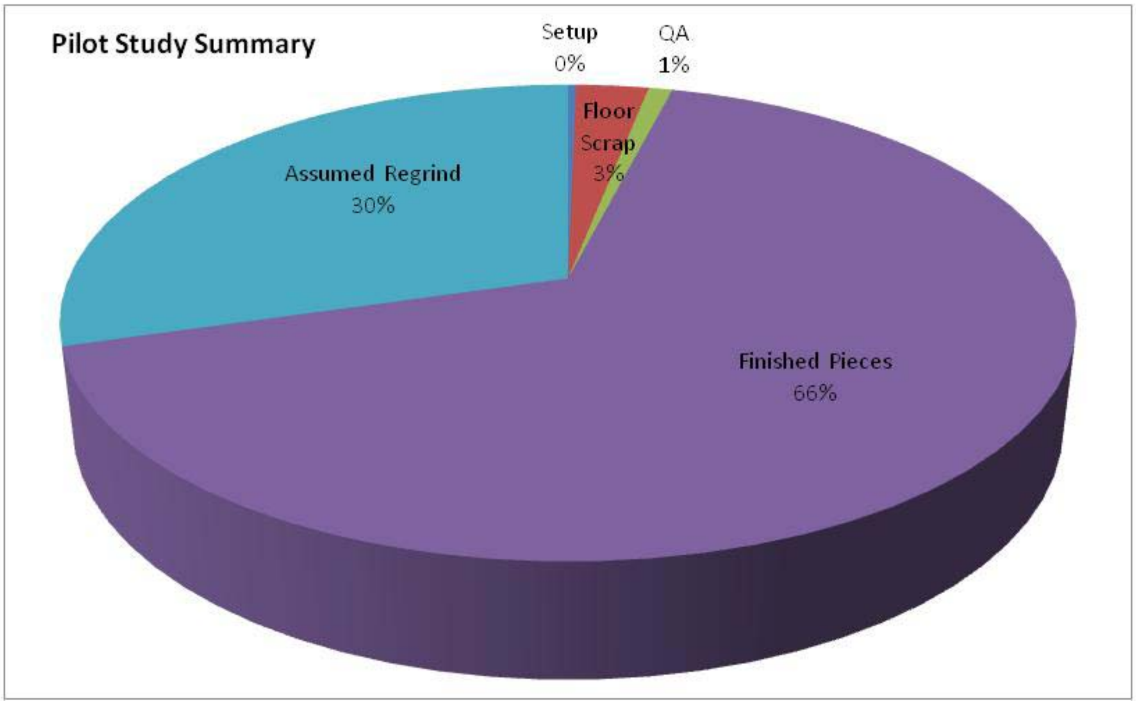

Figure 47: Pilot Study Findings Summary

It is important to note that all final products from these three jobs were marked as accepted. This means that our study provides no information on rejected product and cannot be used to study scrap due to defects at this time. Assuming the study is continued, it would become useful for this purpose when such data is collected.

We hope that the data shown here, although not vast, will provide EFD with enough incentive to continue to revise the program and collect the scrap data. In order to be successful we recommend either implementing the full pilot study and recording all data or revising the data collection sheets to help employees properly utilize the recoding sheets. Utilizing the information collected on these forms will help EFD identify areas of further study to reduce each category of scrap and ensure that regrind is handled and used wisely. More complete data will also help revise product bill of materials to allow for easier accounting of material use and inventory.

5.6 Extrapolated Findings

Given the very small sample size, any extrapolated data will have significant limitations and should not be relied upon. Not only is the sample size very small, as previously noted, the data recording was not particularly accurate. In addition, different part numbers will yield different percentages of scrap in different categories, further changing the findings. However, we feel it is a useful exercise to perform some basic extrapolations to illustrate the importance of continuing this study in order to gain a larger sample size.

Table 10 summarizes the data collected in this short pilot study and the associated costs in dollars. The number of shifts each job spanned was estimated based on the dates and times recorded on the pilot study recording sheets. Raw material is assumed to cost approximately one dollar and twenty cents per pound. For the three jobs involved in this pilot study, approximately $8,300 was spent on raw materials, of which approximately $330 was one type of scrap or another. In addition, almost $2500 worth produced regrind.

Table 10: Pilot Study Data – Monetary Values

Pilot Study Data							
Job #	# shifts	Raw Material ($)	Setup ($)	Floor Scrap ($)	QA ($)	Finished Pieces($)	Assumed Regrind ($)
2815	6	2,442	15	-	35	1,530	862
3390	7	2,702	6	92	28	1,743	834
4762	5	1,791	-	100	-	1,340	351
Total	**18**	**6,935**	**21**	**192**	**63**	**4,613**	**2,047**
	Per Pound	Raw Material ($)	Setup ($)	Floor Scrap ($)	QA ($)	Finished Pieces($)	Assumed Regrind ($)
Cost	$ 1.20	$ 8,322.0	$ 25.3	$ 230.4	$ 75.0	$ 5,535.1	$ 2,456.2
		Total Setup, Floor Scrap, & QA Scrap		$ 330.7			

Table 11 shows the data extrapolated over 11 machines operating around the clock for a period one year. The multiplication factor is based on number of shifts available in one year given three eight-hour shifts over 365 days. (Multiplication factor = 1095 divided by the number shifts in sample). This multiplication factor is used to extrapolate the rest of the data to the period above. Again, keeping in mind the limitations of the extrapolation listed above, we can see that in one year the department might spend $5.57 million dollars on raw materials of which $221,000 is accounted for by scrap and $1.66 million of which was reground.

Table 11: Extrapolated Data

Extrapolated : 24/7 Production for 1 year using 11 machines							
Job #	* Factor	Raw Material ($)	Setup ($)	Floor Scrap ($)	QA ($)	Finished Pieces($)	Assumed Regrind ($)
2815	*2008*	4,902,315	30,313	-	70,263	3,071,341	1,730,398
3390	*1721*	4,649,370	10,324	158,306	47,320	2,998,395	1,435,025
4762	*2409*	4,314,519	-	240,900	-	3,228,337	845,282
Total	*669*	4,640,671	14,119	128,480	41,823	3,086,583	1,369,665
	Per Pound	Raw Material ($)	Setup ($)	Floor Scrap ($)	QA ($)	Finished Pieces($)	Assumed Regrind ($)
Costs	$ 1.20	$ 5,568,805	$ 16,943	$ 154,176	$ 50,188	$ 3,703,900	$ 1,643,598

Since regrind creation accounts for such a significant source of spending, we recommend implementing some method of tracking how and where it is used. At one extreme, all regrind could immediately be sold back to the manufacturers to recover some of the cost of creating it. At the other extreme, all regrind could be used in production to reduce expenditure on virgin material. However, using regrind in production produces more runners which are then reground. This "second generation" regrind can be used again, creating product + "third generation" regrind. At some point using reground-regrind begins to be blamed for quality problems, specifically related to contamination. It also may require different machine settings to produce quality final products even if contamination is not a problem. The specifics of where the quality issues come up are not known at this point and require further study.

Finally, to quantify total scrap in one year in the injection-molding department, we took the in-process rejection report from January 2008 to September 2008 and extrapolated its findings to estimate one year's worth of in-process rejections and added it to the pilot study's extrapolated scrap amount. Not considering wasted regrind, total scrap and rejections account for almost $522,000 per year just in materials spending. Note that this dollar amount does not include any of the operator or machine time involved. These data are shown in Table 12.

Table 12: Extrapolated Pilot Study + In-Process Rejections

Total Setup, Floor Scrap, & QA Scrap	**$**	**221,306.80**
In-Process Rejections Jan - Sept 08	$	225,452.00
Extrapolated to 1 year	$	300,602.67
Total Scrap + Rejections for 1 year	$	**521,909.47**

In summary, the data recorded in this short pilot study emphasizes the need to continue collecting this data as well as the need to track the use of regrind and its effects on production. The money shown in this study as being spent on raw materials that either definitely or potentially go to waste is significant, and does not yet include any data on how much was spent handling this material. It is important for these data points to be added to EFD's regular documentation procedures and recorded in a manner that allows for meaningful interpretation for the company.

Chapter 6: Findings and Recommendations

During the first three months of working on our project, we conducted background research and became very familiar with the company's injection molding department. Although we began with a well-defined goal of reducing waste in the IM department, the scope of the project, and materials to be examined in the process shifted as the project progressed. The initial goal of the project was to provide EFD with the groundwork and recommendations to reduce costs resulting from waste produced within their injection molding department, including molding scrap and machine downtime. The project was meant to focus on overall scrap reduction utilizing Six Sigma ideals.

By researching the company's past scrap data collection sheets, we recognized the need to set up a new system involving the collection of this scrap data. We developed a data collection program for EFD to follow in order to generate the baseline of scrap production that we had previously expected to establish. The pilot study served the purpose that was intended: to provide EFD with the groundwork to generate proper scrap amounts and highlight areas that produce the most significant amount.

With the current economic conditions, the project should be vital to EFD in order to capture the correct scrap data, analyze it, and reduce the overall scrap being produced. These wasted materials can be reused or reduced to ultimately cut costs. The following sections outline obstacles that hindered the project's initial plan and the pilot study program, findings from our research, and recommendations that were generated from the findings.

6.1 Project Obstacles and Limitations

Along the way, we ran into many issues that hindered our progress. During most of the months of November and December 2008, the employees at EFD in Lincoln, RI were in the process of packing up paperwork and machinery to move to the new central location in East Providence, RI. Although this conversion from four buildings to one building would help streamline their operations, this move made it difficult for us to track down certain paperwork and understand their current data recording practices. A bottleneck was created because of the move and caused a time constraint that had not been planned for originally.

Within the pilot study plan, we also encountered the issue of determining a weighing method of the scrap material that is both accurate and time efficient. Due to the fact that the cardboard and plastic gaylords, barrels, and pallets had a large range of weights, we were initially unsure of the easiest way for employees to measure the actual weights of scrap. Time was also a factor that became even more important as the project progressed because we had limited resources to help collect the data. Through further communication with operators in EFD's IM department, we found that only the cardboard and wooden pallets were used for scrapped materials. This finding made the average weight of 69 pounds to be subtracted from the final weight to determine the total scrap weight per job.

EFD survived the first several months of the US economic recession without changing their daily operations; however, by the beginning of 2009, the company was forced to eliminate various positions and reduce hours of machine operation from 7 days to roughly 5 days in order to adjust to a decrease in the demand of their products. Our project was affected by these layoffs because we originally planned on assigning data recording responsibilities to these employees. The employees still working for EFD now must pick up the duties of the employees that are no longer available. With a larger day-to-day workload, we encountered the problem of motivating employees to complete our pilot studies and convincing them of the need to determine a baseline of scrap produced and thrown away. This data will identify the sources of scrap, help to adjust policies in order to reduce the amount of scrap, and save the company thousands of dollars each year.

In mid-January, the company changed their schedule to a 4-day work week to reduce overhead costs. Just a few months prior, EFD had been operating 24 hours a day, 7 days a week. This change in their operating schedule is a clear indicator that the shaky economy is now affecting a company that had previously been extremely successful without needing to address high scrap amounts as a top priority.

In addition to the 4-day work week, in early February, EFD reduced the production of various injection molding products due to a decreasing demand and an excess of inventory build-up. Within a few weeks, EFD had no choice but to completely shut down production in the injection molding department in order to deplete their inventory. Each of these phases of schedule changes and reduced production greatly affected our project and left us with less data to analyze than we were expecting. Fortunately, we were able to gather about one week's worth of data before these changes were made so we have come up with conclusions and recommendations for EFD to consider.

6.2 Findings

After several months of background research, on-site visits, and collaboration with EFD, we have reached various conclusions involving the injection molding department's data collection sheets, scrap production, scrap tracking, and scrap reuse methods. Our initial background research on-site with EFD exposed the fact that there are many data sheets traveling between different departments at one time collecting similar sets of data. The inefficiencies of the paper trail make it very difficult for anyone to break down the data that has been captured and make use of its content. Switching between electronic databases and older paperwork also make it extremely difficult to combine similar scrap related data that has been spread across different departments. We have found that there has been little attempt to adjust old materials or introduce new ones that would consolidate paperwork across departments and streamline the scrap tracking.

We found that a significant amount of scrap can be captured by creating and utilizing new forms of paperwork designed specifically for scrap tracking. During job number 4000204762, Appendix J, there were roughly 1,800 lbs of materials captured that went into producing either finished goods or scrap. Out of those 1,800 lbs, there were 100 lbs of floor scrap produced. This number is very significant because it shows 5.56% of the total weight going into a job leaving the department as scrap; this scrap amount had not been captured by any data sheets prior to our project. This number would be even larger if both the scrap prior to first piece submitted and QA scrap totals were recorded in the designated areas, reinforcing our conclusion that it is possible to capture scrap numbers with new forms of documentation that were previously overlooked.

Regrind is also a very significant aspect of the injection molding department that has no means of tracking. We noticed that during the job numbered 4000202815, Appendix K, the regrind material that was produced made up a significant amount of the material that the job generated. Out of the 2,442 lbs of virgin materials entering the job, 861.97 lbs went back to regrind, 1529.93 lbs toward finished goods, and 50 lbs toward floor/QA/prior to first piece submitted scrap. The 35% of materials entering this job will eventually be reused, resold, or scrapped. There is no current method set up in the IM department to capture the total amount that is being thrown away or resold. The weight of the regrind leaving the department and being reused on other jobs should be tracked through the system and connected to the original job that created it. With this information EFD will be able to assess how many times a regrind gaylord can be used to produce products that adhere to their strict specifications, how often a concentrate is formed, and what percentage of materials are used, etc.

We also found that it is difficult to introduce new forms of paperwork without providing the standard work instructions along with it. Despite the addition of the standard work instructions to the paperwork, we came to the conclusion that formal training will also be needed to ensure that the scrap tracking will be performed correctly. Some set of auditing materials must also be created in an attempt to control and monitor any new projects that will be implemented for scrap collection and tracking. Management must have a “hands-on” approach to working with the IM department to ensure that these materials are enforced.

6.3 Recommendations

By examining the past documentation that was originally used by EFD, we believe several projects can be created to reduce unsystematic activities. Due to the various areas that need improvement, we have suggested short and long-term studies and solutions to apply from the groundwork that we have provided for EFD through our project.

6.3.1 Short-term

A breakdown of the documentation, including which type of data each captures, where it is located, and who documents on it, will allow EFD to combine certain aspects of the documentation and eliminate data duplication. The positioning can also be improved by analyzing the foot traffic associated with each and the amount of times the paperwork is transferred from department to department.

Another study stemming from the pilot program includes examining the ergonomics involved in the data collection. A spaghetti diagram can be created for each data sheet along with the individuals that are filling out the information. Inefficiencies can be eliminated by repositioning certain landmarks and 5S concepts. The project will not only allow for more precise data collection, but also improve the foot traffic in the department and utilize time more resourcefully. The floor scrap that is being collected can also be broken down to track which machines produce the greatest amount of scrap. The information will highlight areas that may need a new means of conveyance or different mechanical advances. To further break down the study of floor scrap, a program can be established that tracks percentage of material being thrown away as floor scrap.

A future study can be formed that tracks the paperwork used in the pilot study through each step of recording until the job is completed. Flow diagrams can be created for the new paperwork to allow for adjustments to be made, if needed, to make for the most efficient flow of scrap tracking paperwork. Similarly, we also recommend that the paperwork be utilized to fix imperfections that may be located in the Bill of Material for each part number.

Once the tracking sheets are established more firmly in the IM department, we recommend that a new set of auditing materials be created. The materials can be introduced either by adding new sections to the tracking sheets themselves or by introducing a new set of sheets that are to be filled out before the beginning of each job. Adding new sections to the current tracking sheets would be the simplest way, adding areas for the shift in which the data recording is taking place along with the individual's initials. These new accountability sheets make it the individual's responsibility to record the data correctly, as well as management's responsibility to enforce them if neglected.

6.3.2 Long-term

The most distinct issue that we encountered was that data collection sheets were missing valuable information and duplicating others. For these reasons, we felt that the best solution to alleviate the current data tracking inconsistencies at EFD would be to consolidate all data tracking in one centralized electronic system. This database would allow for partial automation and a single point of entry for machine operators and end users of the data, decreasing data recording overhead and increasing data quality. If technology allows, this database should be linked with SAP, continually updating scrap information associated with the materials leaving the building. It is understood that this would require a great amount of resources and would come with a very high expense.

The data collected from the pilot program provided more than just insight into their current scrap production; it also presented potential future scrap reduction projects for EFD to pursue in the future. One study includes tracking the percentage of which types of materials are used, whether it is virgin material or regrind, for each individual job. This project will allow EFD to create databases tracking the specific percentage of materials used for each job, how often a product is reused, and how often this reuse and mixed percentage creates poor products (rejects). By tracking how many times the regrind can be reused to produce quality products, EFD will be able to understand when each specific batch of regrind should not be used, but re-sold to ECM.

To ensure that future scrap tracking programs run smoothly and without confusion, a formal training program should be created for employees that are directly involved in the process. The program should outline the tracking sheets that are to be utilized, examining each section and its purpose. We believe that if the employees for all three shifts experience a formal training program and gain a better understanding of the benefits associated with the program they will be more apt to put in the extra work. This training program could be established by either mandatory meetings times with the employees of each shift or even electronic training tools that could be taken at any time. We understand that the creation of electronic training equipment may not be cost effective and recommend that the initial training steps take place with face-to-face meetings. Once the training seminars are completed, the tracking sheets should be made into part of the standard daily operations of the IM department.

Once the scrap tracking sheets have been proven successful in the IM department, we recommend that the concept be used in other departments throughout the company. The machine shop and the solder area may be the other departments that can benefit from the implementation of scrap tracking. By expanding the proven methods, EFD looks to save even more money relating to scrap by reducing the overall waste produced by the company itself.

We also recommend that the cause and effect diagrams be examined to create potential future projects involving specific parts and machines. The data we captured can be manipulated and used for EFD's own cause and effect matrices as they have trained professionals that work with the molding machines on a daily basis. Some changes that may be established are fixes to machine configuration/calibration or even adjusting the concentrate of materials entering the machine, adjusting the percentages of regrind and virgin materials used. If adjustments are successful the company can save thousands of dollars in money lost to materials that would have previously been scrapped.

We have also created several recommendations that focus more on machine change over time reduction. One of these recommendations includes streamlining the machine changeover process for more efficient mold movements; possibly setting up a mechanical pulley system that includes overhead cranes that can place any mold into any machine at anytime. Training materials for operators to follow step by step when changing over specific jobs/machines should also be created. This training will allow for uniform changeover instructions across all shifts and also any new employees that may be added.

We have learned a lot from the MQP experience that spanned five months as well as working alongside EFD. One aspect that we learned from our experience is that change in any organization is extremely difficult to implement without a hands-on approach. We were not able to be on-site all the time and this made implementing the pilot study difficult for us to do during the time frame that we had. We also learned that in times of an economic recession, every company's operations, no matter how small the niche market, can be affected drastically. The economy taught our group and the company that scrap reduction should become more of a priority and should be looked at as a prime opportunity to reduce costs. As the company has had to make many adjustments to their staffing and operations schedules over the past few months, it has become increasingly apparent that in times like these, every dollar counts.

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Appendices

Appendix A: QA Department Forms (Existing Documentation)

EFD A NORDSON COMPANY **First Piece Inspection**

Part No.	Description	Dwg No.	Rev.	Set-up Tech	Date/Time
7017922	Barrel Reservoirs – ALL	7017922	01	B.D./M.M.	12/23/08 6:30 PM.

Machine	# Cavities	WO / Lot #	Raw Mat'l #	Comp. Lot #	Sht Rev: P
220-2	16	4000197443	HJ25BCC06	N/A	Date: 7/12/07

Characteristics (attributes)	Ref Mat'l	Findings
Proper color – refer to drawing.	Visual	✓ ✓
Flash all areas – Luer orifice / dome critical.	Vis. – 7X Mag.	✓ ✓
Check for core scratches and material flow marks.	Visual	✓ See note #1
No molten plastic.	Visual	✓ ✓
No inclusions or surface contamination.	Visual	✓ See note #2
No voids or sinks – base of luer thread and ears, critical.	Visual	✓ ✓
No bubbles in sidewalls – Condensed bubbles located at base of luer area and ears typical.	Visual	✓ ✓
No short shots.	Visual	✓ ✓
Check gate breakaway – not to exceed .020.	Visual	✓ ✓
Performance test – Air leak test for luer taper.	QUA-10-20-I008 for instructions	Pass
Double start threads – Refer to drawing.	Double start thread gage #00884	Pass

SAMPLING: 1piece per complete mold cycle (1 piece/cavity) for all of the above attributes.
NOTE: Reference **QUA-10-20-I001** for inspection instructions regarding the above attributes, excluding "Perform UV block test".

Parts accepted ☑ **Parts rejected** ☐

Inspector Stamp & Date
12-23-08

Comments:

1. Few cavs with med flow line - Typical.
2. 4/16 cav's with blk spec - Tech to Purge.

CAV#23 Excessive water marks - Req ADJ.

Quality Assurance Approval & Date	Engineering Approval & Date	Manufacturing Approval & Date
[signature] 7/12/07	[signature] 7/12/07	[signature] 7/12/07

Form # QUA-10-20-I001-F001 Rev A 7/00

Characteristics (variables)	Ref. Mat'l	Barrels Pg. 2 Findings
INSPECTION POINT 1 **Measure barrel I.D.** – Refer to drawing (Perform 1 hr. and 24 hr. I.D. inspections – Allow 1 hr. and 24 hr. cool time. Use same sample for both the 1 hr. and 24 hr. check. Process may continue if 1 hr. check meets requirements. Parts are to be quarantined until 24 hr. check is performed and meets requirements. Refer to "Barrel Shrink Rate Limit" chart.	**QUA-10-20-I009** for test instructions Air Gage	(Document results onto the "Data Control Sheet for First Piece")
INSPECTION POINT 2 **Luer orifice** – refer to drawing.	Gage Pins	PASS: ✓ .094+ / .096 ✗ FAIL:
INSPECTION POINT 3 4.650 **Overall length** – refer to drawing. ± .010	Digital Caliper or Height Gage	RANGE: 4.6533 – 4.6595
INSPECTION POINT 4 4.565 **Length to luer collar** – refer to drawing ± .010	Height Gage	RANGE: 4.5700 – 4.5745
INSPECTION POINT 5 .420 **O.D. of luer collar** – refer to drawing. ± .005	6 Inch digital caliper	RANGE: .4185 – .4225
INSPECTION POINT 6 .998 ± **Barrel O.D. at luer end** – refer to drawing. .003	6 Inch digital caliper	RANGE: .9990 – 1.0010
INSPECTION POINT 7 1.007 ± **Barrel O.D. at ears end** – refer to drawing. .003	6 Inch digital caliper	RANGE: 1.0060 – 1.0100
INSPECTION POINT 8 **Luer taper check**	Female Luer gage	PASS: ✓ FAIL:
Barrel impact test for impact modified material (5113AUV,LL,UV only). Allow 24 hour cool time before performing impact test. Barrels should not crack at maximum height (60 inches). Barrel impact test and hydrostatic burst test for each new lot number of mold material kept on file for reference. ***SAMPLING***: 8 random pieces from one complete mold cycle. Record AVERAGE and RANGE. Notify Supervisor and Quality Manager of any out-of-tolerance values	**QUA-10-20-1007** for test instructions.	RANGE: N/A
Perform UV block test – All barrels with UV inhibitors. Refer to drawing. 1 sample.	**QUA-10-20-1003** for test instructions.	N/A
Heat test for bloom (<u>LB BARRELS ONLY</u>): Collect and bag 4 LB barrels and submit to QA Lab for heat test.	**Instructions: Test samples @ 65 deg. C for 2 hours for bloom.**	PASS: N/A FAIL:

SAMPLING: 1 piece per complete mold cycle (1 piece/cavity). Record the **RANGE** values in the appropriate findings column. Record the cavity I.D. for any out-of-tolerance samples.

Comments:

EFD A NORDSON COMPANY

Barrel I.D. Data Control Form for Shrinkage Inspection

Part Number:	Lot Number:	Time and Date sample taken:	Time and Date sample measured:
7017922	4000197443	6:30pm 12/23/08	7:30pm 12/23/08

24 HR. ☐ 1 HR. ☑	Inspector:	Engineering spec:	Shrinkage spec:	Results:
	JO	.8920 ± .0015	.8940 – .8942	Pass ☑ Fail ☐

CHECK ONE		Luer End	Mid-section	Average
	✓			
1	17	42 / 35	61 / 22	Average: 40
2	18	42 / 28	60 / 25	Average: 39
3	19	40 / 30	60 / 25	Average: 39
4	20	32 / 34	60 / 23	Average: 37
5	21	41 / 34	60 / 23	Average: 40
6	22	40 / 35	60 / 28	Average: 41
7	23	35 / 29	57 / 21	Average: 36
8	24	38 / 30	56 / 26	Average: 38
9	25	40 / 32	63 / 25	Average: 40
10	26	35 / 34	61 / 28	Average: 40
11	27	41 / 35	63 / 24	Average: 41
12	28	40 / 31	62 / 22	Average: 39
13	29	39 / 33	60 / 19	Average: 38
14	30	36 / 30	59 / 20	Average: 36
15	31	39 / 34	61 / 19	Average: 38
16	32	43 / 36	60 / 20	Average: 40

Comments:	Grand Average:
Allowed 2/10 below spec. Past Runs history of .8939 will shrink in 30 day shrinkage	Average: .8939 Range: .0005

EFD®
A NORDSON COMPANY

Process Control Record

Part No.	7017922
Dwg # / API #	7017922
Rev.	01
WO / Lot #	4000197443
Mach #	220-2
Inspector	EA/VM/MM/DB.
Raw Material Batch #	HJ25BCC06
Component Lot #	N/A
Sheet	1 of
Sheet Rev:	L
Date:	02/10/04

SHIFT	2nd.				~~1st~~	1st.								2nd.	2nd	
DATE	12/23/08				~~12/24/08~~	1/5/09								1-5-09		
TIME	9:00 PM	9:30	10:00	11:15		8:10	8:15	8:25	8:35	9:00	11:00	12:00	1:30	3:25	5:45	6:40

Characteristics	Barrel Reservoirs – All Sizes															
Visuals - Use adequate illumination.		✓	✓				✓		Run	✓	✓	✓	✓	✓	✓	✓
No flash – luer orifice / dome critical. (7x)		✓	✓				✓			✓	✓	✓	✓	✓	✓	✓
Check thread for deformation. (7x)		✓	✓			Run	✓	DOWN		✓	✓	✓	✓	✓	✓	✓
Luer orifice - Use go/no-go gage pins.			P							P		P	P	P		P
Luer taper - Use female luer gage.			P							P		P	P	P		P
Barrel I.D. - check I.D. with go gage pin. *Critical* - Report tight fit conditions.			P	Down	~~Start~~					P		P	P	P		P
Barrel I.D. 24 hrs. check - Provide sample (2 shots) to QA lab for dimensional test.	Run						✓							✓		P

Visual sampling: Every 2 hrs. check 16 random samples from the bin/bins containing parts produced during the past 2 hrs. and 1 complete mold shot (1 pc. per cavity).

Luer orifice/Luer taper/Barrel I.D. sampling: 1 complete shot every 3 hours. Record "P" (pass) or "F" (fail). **Note** – ***Allow 1 hour cool time before testing***.

Barrel I.D. 24 hour sampling: Q.A. lab to record results on "Barrel I.D. Data Control sheet". Plot grand average value. Report out of control limit values.

Reference **QUA-10-20-I001** for inspection instructions and **ISO 594/1** for luer taper standards.

Comments:

16 cav's

Quality Assurance Approval and Date	Engineering Approval and Date	Manufacturing Approval and Date
J. Higgins 2/24/04	3/3/04	2/24/04

Form # QUA-10-20-I001-F002, Rev B, 9/01

Appendix B: Work Order Materials Tracking, version1 (page 1 of 2)

Job/Requisition Number: ________________ Part Number: ________________

Record the date, time, and weight of each movement in appropriate columns.

	Gaylord/Barrel #	Date/Time	Weight In[1]	Weight Out[1]	Net Weight[2]
Raw Materials	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				
	10				

	Date/Time	Weight In[1]	Weight Out[1]	Net Weight[2]
Scrap prior to 1st piece submitted				
Runners				
Runners → Trash[3]				
Runners → Regrind[4]				

[1] Weight is the gross weight of the container & its conveyance. Weight in is weight as container is brought to machine; weight out is weight as it is removed from the machine.
[2] Net weight = Weight Out – Weight In.
[3] Runners → Trash is any Gaylord or barrel used to for runners going directly to the trash & should be weighed pre- and post-filling.
[4] Runners → Regrind is any Gaylord or barrel used for collecting regrind, and should be weighed both pre- and post-filling.

Appendix C: Floor scrap data collection sheet, version1

Gaylord/Trash Can #	Date/Time	
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
	Total	
	Gaylord/Trash Can Weight	
	Conveyance Accessories	
	Total Floor Scrap	

Appendix D: Regrind recording sheet, version1

GROSS WEIGHT OF MATERIAL & CONVEYANCE OUT OF INJECTION MOLDING ________ LBS

- ________ Gaylord Weight

- ________ Other accessories (pallet jack, etc.)

MATERIAL ONLY: ________ LBS

Part #	*Date*	*Time*	*Weight In*	*Weight Out*

WEIGHT OF MATERIAL OUT/ TRASH ________ LBS

- ________ Gaylord Weight

- ________ Other accessories (pallet jack, etc.)

TOTAL REGRIND SCRAP ________ LBS

Appendix E: 1/26/09 Pilot study stakeholder meeting minutes

Pilot Study Meeting Minutes

Date: Wednesday, January 26, 2009
Time: 11:00 – 11:35 AM
Location: Cafeteria conference room at EFD

Attendees: Jeff White (Manufacturing Manager - Molded Products), Jim Moore (Manufacturing Manager - Electromechanical Products), Steve Costa (Molding & Tip Assembly Manager), Tom Emidy (Solder Products Manager), Dan Crane (QA Manager), Scott O'Connell (Industrial Engineer), David Byler, Nathan Griggs, Caitlin Macko

- Scott called the meeting to order and gave a brief introduction. The project team presented the pilot study proposal and related paperwork and solicited feedback from those present.
- Steve Costa expressed concern about lots of hands being involved to track all of this and potential recording problems.
- On the work order materials tracking sheet we discussed adding more lines for non-submitted product due to machine shutdowns and restarts, but decided any startup scrap beyond initial startup would just go into floor scrap.
- It was decided that the floor scrap should be tracked per job at each machine, so there will be barrels placed at each machine for collecting all floor scrap from that machine. The barrels will be emptied when full or at the end of each job, and we decided add the floor scrap tracking to the work order materials tracking sheet to simplify it.
- Purge will continue to be counted as floor scrap and should be recorded on the next job's work order tracking sheet.
- Consensus was that the team would update the tracking sheets and standard work instructions to incorporate the changes we discussed and they would be implemented for all new jobs starting after this afternoon.
- The team plans to come in to see how the implementation is going later this week and next week, and will be seeking feedback for any changes that need to be made for future data collection.

Appendix F: Work Order Materials Tracking, version 2

Work Order Materials Tracking Sheet

Refer to Standard Work Instructions.

Job/Requisition Number: ________________ Part Number: ____________________ Machine #: __________

Raw Materials In	Container #	Date/Time	Weight In[1]	Weight Out[1]	Net Weight[2]
	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				
	10				
	11				
	12				
	13				
	14				
	15				
	16				
	17				
	18				
	19				
	20				
	21				
	22				
	23				
	24				
	25				
	26				
	27				
	28				
	29				
				Total	

[1] Weight is the gross weight of the material & its conveyance (conveyance = pallet + gaylord) with the scale zeroed to . "In" is the weight as container is brought to machine; "out" is weight as it is removed from the machine. Weights include the Gaylord and pallet, but not the pallet jack.
[2] Net weight = | Weight Out – Weight In |

Work Order Materials Tracking Sheet: 2/25/09 4:11 PM – Page 1 of 3 –

Work Order Materials Tracking Sheet

Materials Out – In Process

Container #	Date/Time	Weight In	Weight Out	Net Weight
Scrap prior to 1st piece submitted				
Runners – Trash or Regrind [3] (circle one)				
1				
2				
3				
4				
5				
6				
7				
8				
			Total:	
Quality Assurance - Samples taken for inspection				
1				
2				
3				
4				
5				
6				
7				
8				
			Total:	
Floor Scrap				
1				
2				
3				
4				
5				
6				
7				
8				
			Total:	

[3] Runners are assumed to be either all trashed or all reground. Circle one or the other depending on whether the machine has a grinder or not.

Work Order Materials Tracking Sheet: 2/25/09 4:11 PM – Page 2 of 3 –

Work Order Materials Tracking Sheet

Materials Out – Post Process	#	Date/Time	Weight In	Weight Out	Net Weight	Status		
	1					Accept	Hold	Reject
	2					Accept	Hold	Reject
	3					Accept	Hold	Reject
	4					Accept	Hold	Reject
	5					Accept	Hold	Reject
	6					Accept	Hold	Reject
	7					Accept	Hold	Reject
	8					Accept	Hold	Reject
	9					Accept	Hold	Reject
	10					Accept	Hold	Reject
	11					Accept	Hold	Reject
	12					Accept	Hold	Reject
	13					Accept	Hold	Reject
	14					Accept	Hold	Reject
	15					Accept	Hold	Reject
	16					Accept	Hold	Reject
	17					Accept	Hold	Reject
	18					Accept	Hold	Reject
	19					Accept	Hold	Reject
	20					Accept	Hold	Reject
	21					Accept	Hold	Reject
	22					Accept	Hold	Reject
	23					Accept	Hold	Reject
	24					Accept	Hold	Reject
	25					Accept	Hold	Reject
	26					Accept	Hold	Reject
	27					Accept	Hold	Reject
	28					Accept	Hold	Reject
	29					Accept	Hold	Reject
	30					Accept	Hold	Reject
					Total:			

Notes:

Appendix G: Regrind Recording Sheet, version2

Regrind Tracking Sheet

In		Date/Time	Weight In	Weight Out	Net Weight
	Starting Weight				

Usage Log	Job #	Part #	Date/Time	Weight In	Weight Out	Net Weight
					Total Regrind Used	

Out		
	Unused Regrind	

Avg wood pallet + cardboard gaylord = 69 lbs. Avg plastic pallet gaylord = 41 lbs. Avg. carboard barrel = 10 lbs.

Appendix H: Work Order Materials Tracking – With EFD Markup

Simplified data collection sheet

Work Order Materials Tracking Sheet

Materials Out – In Process

Container #	Date/Time	Weight In	Weight Out	Net Weight
Scrap prior to 1st piece submitted				
Runners – Trash or Regrind [3] (circle one)				
1				
2				
3				
4				
5				
6				
7				
8				
			Total:	
Quality Assurance - Samples taken for inspection				
1				
2				
3				
4				
5				
6				
7				
8				
			Total:	
Floor Scrap				
1				
2				
3				
4				
5				
6				
7				
8				
			Total:	

★ Combine All 3 As Scrap

[3] Runners are assumed to be either all trashed or all reground. Circle one or the other depending on whether the machine has a grinder or not.

Work Order Materials Tracking Sheet: 1/26/09 2:36 PM – Page 2 of 2 –

~~Quicker~~ Easier for employees to record

Work Order Materials Tracking Sheet

Materials Out – Post Process

#	Date/Time	~~Weight In~~ Quantity	~~Weight Out~~	~~Net Weight~~	Status		
1					Accept	Hold	Reject
2					Accept	Hold	Reject
3					Accept	Hold	Reject
4					Accept	Hold	Reject
5					Accept	Hold	Reject
6					Accept	Hold	Reject
7					Accept	Hold	Reject
8					Accept	Hold	Reject
9					Accept	Hold	Reject
10					Accept	Hold	Reject
11					Accept	Hold	Reject
12					Accept	Hold	Reject
13					Accept	Hold	Reject
14					Accept	Hold	Reject
15					Accept	Hold	Reject
16					Accept	Hold	Reject
17					Accept	Hold	Reject
18					Accept	Hold	Reject
19					Accept	Hold	Reject
20					Accept	Hold	Reject
21					Accept	Hold	Reject
22					Accept	Hold	Reject
23					Accept	Hold	Reject
24					Accept	Hold	Reject
25					Accept	Hold	Reject
26					Accept	Hold	Reject
27					Accept	Hold	Reject
28					Accept	Hold	Reject
29					Accept	Hold	Reject
30					Accept	Hold	Reject
				Total:			

Notes:

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Appendix I: Regrind Recording Sheet – With EFD Markups

Regrind Tracking Sheet

In		Date/Time	Weight In	Weight Out	Net Weight
	Starting Weight				

Usage Log	Job #	Part #	Date/Time	Weight In	Weight Out	Net Weight
	Total Regrind Used					

Out		
	Unused Regrind	

Avg wood pallet + cardboard gaylord = 69 lbs. Avg plastic pallet gaylord = 41 lbs. Avg. carboard barrel = 10 lbs.

Appendix J: Job #4762

Work Order Materials Tracking Sheet

Refer to Standard Work Instructions.

Job/Requisition Number: 4000204762 ~~40002 03390~~ Part Number: 7017922 ~~7017899~~ Machine #: 220

	Container #	Date/Time	Weight In[1]	Weight Out[1]	Net Weight[2]
Raw Materials In	1	02/03 /900 Am	1400 lbs	90 lbs	
	2	02/04/ 3:30 Pm	~~1469~~ 1470 lbs	15 lbs	
B.T.Jr.	3	2-4-09		943 LBS	~~[illegible]~~
	4				
	5				
	6				
	7				
	8				
	9				
	10				
	11				
	12				
	13				
	14				
	15				
	16				
	17				
	18				
	19				
	20				
	21				
	22				
	23				
	24				
	25				
	26				
	27				
	28				
	29				
				Total	1791

Used on 5/5H-TT

[1] Weight is the gross weight of the material & its conveyance (conveyance = pallet + gaylord) with the scale zeroed to . "In" is the weight as container is brought to machine; "out" is weight as it is removed from the machine. Weights include the Gaylord and pallet, but not the pallet jack.

[2] Net weight = | Weight Out – Weight In |

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Work Order Materials Tracking Sheet

Materials Out – In Process

Container #	Date/Time	Weight In	Weight Out	Net Weight
Scrap prior to 1st piece submitted	2-3-9 9:00PM			
Runners – Trash or Regrind [3] (circle one)				
1		9Lb	89LBS	80 Lbs
B.T.JR. 2	2-4-09	9LBS	29. LBS	20 LBS.
3				
4				
5				
6				
7				
8				
			Total:	100 Lbs
Quality Assurance - Samples taken for inspection				
1				
2				
3				
4				
5				
6				
7				
8				
			Total:	
Floor Scrap				
1				
2				
3				
4				
5				
6				
7				
8				
			Total:	

[3] Runners are assumed to be either all trashed or all reground. Circle one or the other depending on whether the machine has a grinder or not.

Work Order Materials Tracking Sheet

Materials Out – Post Process

#	Date/Time	Weight In	Weight Out	Net Weight	Status		
1	2/2	7000			Accept	Hold	Reject
2	2/2	7000			Accept	Hold	Reject
3	2/4	7140			Accept	Hold	Reject
4	2/4	7140			Accept	Hold	Reject
5	2/4	7,146			Accept	Hold	Reject
6	2/4	7000			Accept	Hold	Reject
7	2/4	7000			Accept	Hold	Reject
8					Accept	Hold	Reject
9					Accept	Hold	Reject
10					Accept	Hold	Reject
11					Accept	Hold	Reject
12					Accept	Hold	Reject
13					Accept	Hold	Reject
14					Accept	Hold	Reject
15					Accept	Hold	Reject
16					Accept	Hold	Reject
17					Accept	Hold	Reject
18					Accept	Hold	Reject
19					Accept	Hold	Reject
20					Accept	Hold	Reject
21					Accept	Hold	Reject
22					Accept	Hold	Reject
23					Accept	Hold	Reject
24					Accept	Hold	Reject
25					Accept	Hold	Reject
26					Accept	Hold	Reject
27					Accept	Hold	Reject
28					Accept	Hold	Reject
29					Accept	Hold	Reject
30					Accept	Hold	Reject
				Total:			

Notes:

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Appendix K: Job #2815

Work Order Materials Tracking Sheet

Refer to Standard Work Instructions.

Job/Requisition Number: 4000202815 Part Number: 5712LL Machine #: 220

was not Record

	Container #	Date/Time	Weight In[1]	Weight Out[1]	Net Weight[2]
Raw Materials In	1	1-26-9/9:55 PM	1485	69	-1416
	2	1/27/ ?	1400	374	-1026
	3				
	4				
	5				
	6				
	7				
	8				
	9				
	10				
	11				
	12				
	13				
	14				
	15				
	16				
	17				
	18				
	19				
	20				
	21				
	22				
	23				
	24				
	25				
	26				
	27				
	28				
	29				
				Total	-2442

[1] Weight is the gross weight of the material & its conveyance (conveyance = pallet + gaylord) with the scale zeroed to . "In" is the weight as container is brought to machine; "out" is weight as it is removed from the machine. Weights include the Gaylord and pallet, but not the pallet jack.

[2] Net weight = | Weight Out – Weight In |

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1/26/09

Work Order Materials Tracking Sheet

Materials Out – Post Process

#	Date/Time	Weight In	Weight Out	Net Weight	Status		
1	1/26		7000 PCS		Accept	Hold	Reject
2	1/27		7000 PCS		Accept	Hold	Reject
3	1/27		7000 PCS		Accept	Hold	Reject
4	1/28		7000 PCS		Accept	Hold	Reject
5	1/27		7000 PCS		Accept	Hold	Reject
6	1/27		7140 PCS		Accept	Hold	Reject
7	1/27		7140 PCS		Accept	Hold	Reject
8	1/28		7140 PCS		Accept	Hold	Reject
9					Accept	Hold	Reject
10					Accept	Hold	Reject
11					Accept	Hold	Reject
12					Accept	Hold	Reject
13					Accept	Hold	Reject
14					Accept	Hold	Reject
15					Accept	Hold	Reject
16					Accept	Hold	Reject
17					Accept	Hold	Reject
18					Accept	Hold	Reject
19					Accept	Hold	Reject
20					Accept	Hold	Reject
21					Accept	Hold	Reject
22					Accept	Hold	Reject
23					Accept	Hold	Reject
24					Accept	Hold	Reject
25					Accept	Hold	Reject
26					Accept	Hold	Reject
27					Accept	Hold	Reject
28					Accept	Hold	Reject
29					Accept	Hold	Reject
30					Accept	Hold	Reject
				Total:			

Notes:

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1/26/09

Work Order Materials Tracking Sheet

Materials Out – In Process

Container #	Date/Time	Weight In	Weight Out	Net Weight
Scrap prior to 1st piece submitted	1/26/09	0	15.1 lbs	15.1 lbs
Runners – Trash or Regrind [3] (circle one)				
1	0			
2				
3				
4				
5				
6				
7				
8				
			Total:	
Quality Assurance - Samples taken for inspection				
1	35 lbs			
2				
3				
4				
5				
6				
7				
8				
			Total:	
Floor Scrap				
1	0			
2				
3				
4				
5				
6				
7				
8				
			Total:	35 lbs

[3] Runners are assumed to be either all trashed or all reground. Circle one or the other depending on whether the machine has a grinder or not.

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Appendix L: Job #3390

Work Order Materials Tracking Sheet

Refer to Standard Work Instructions.

Job/Requisition Number: 4000203390 Part Number: 5112AVX Machine #: 220

Raw Materials In

Container #	Date/Time	Weight In[1]	Weight Out[1]	Net Weight[2]
1	1/28 1st	526 lbs	0	
2	1/28 2nd	952 lbs	0	
3	1/29 1st	1092 lbs		
4	1/29 1st	Minus	70 lbs	− 70 lbs → A
5	1/29 2nd	minus	12 lbs	− 12 lbs
6	02/02 2nd	1,059 lbs	14 lbs	− 14 lbs
7	2/02 2nd	1045	30 lbs	− 30 lbs
B.T.JR. 8	2-2-09 3RD		17 LBS	− 17 LBS
B.T.JR 9	2-2-09 3RD		19 LBS	− 19 LBS
B.T.JR 10	2-2-09 3RD		20LBS	− 20LBS
B.T.JR. 11	2-2-09 3RD		20LBS	− 20LBS
B.T.JR.	Put BACK	49	LBS	LEFT OVER.
13				
14				
15	Gaylord 5 lot #6		774 lbs	
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
			Total	

A used on ST134H

B used on [illegible]

---

[1] Weight is the gross weight of the material & its conveyance (conveyance = pallet + gaylord) with the scale zeroed ~~to~~. "In" is the weight as container is brought to machine; "out" is weight as it is removed from the machine. Weights include the Gaylord and pallet, but not the pallet jack.

[2] Net weight = | Weight Out – Weight In |

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Work Order Materials Tracking Sheet

Materials Out – In Process

Container #	Date/Time	Weight In	Weight Out	Net Weight
Scrap prior to 1st piece submitted	1/28	6 lbs		
Runners – Trash or Regrind [3] (circle one)				
1	1-28-9	9LBS	39 lbs.	
2	1-28-9	9 lbs		
3	1/29/09	9 lbs	34 lbs	
4	2/3/09	9 lbs	23 lbs	
5				
6				
7				
8				
			Total:	
Quality Assurance - Samples taken for inspection				
1	27.50			
2				
3				
4				
5				
6				
7				
8				
			Total:	
Floor Scrap				
1				
2				
3				
4				
5				
6				
7				
8				
			Total:	

[3] Runners are assumed to be either all trashed or all reground. Circle one or the other depending on whether the machine has a grinder or not.

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Work Order Materials Tracking Sheet

Materials Out – Post Process

3RD

#	Date/Time	Weight In	Weight Out	Net Weight	Status		
1	1/26/09	41 lbs	7,140 pcs		Accept	Hold	Reject
2	1/28/09		7,140 pcs		Accept	Hold	Reject
3	1/28/09		7,140 pcs		Accept	Hold	Reject
4	1/28/09		7140		Accept	Hold	Reject
5	1/28/09		7140		Accept	Hold	Reject
6	1/29/09		7,140 pcs		Accept	Hold	Reject
7	1/29/09		7,140 pcs		Accept	Hold	Reject
8	1/29/09		7,140		Accept	Hold	Reject
9					Accept	Hold	Reject
10	2/3/09		7140		Accept	Hold	Reject
11					Accept	Hold	Reject
12					Accept	Hold	Reject
13					Accept	Hold	Reject
14					Accept	Hold	Reject
15					Accept	Hold	Reject
16					Accept	Hold	Reject
17					Accept	Hold	Reject
18					Accept	Hold	Reject
19					Accept	Hold	Reject
20					Accept	Hold	Reject
21					Accept	Hold	Reject
22					Accept	Hold	Reject
23					Accept	Hold	Reject
24					Accept	Hold	Reject
25					Accept	Hold	Reject
26					Accept	Hold	Reject
27					Accept	Hold	Reject
28					Accept	Hold	Reject
29					Accept	Hold	Reject
30					Accept	Hold	Reject
				Total:	71400		

Notes: S112AUY

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