Foil scrap reduction: Continuous improvement in the foil processing industry

by

Kingsley Mgbike

B.S., Kansas State University, 2015

A THESIS

Submitted in partial fulfillment of the requirements

for the degree

MASTER OF AGRIBUSINESS

Department of Agricultural Economics

College of Agriculture

KANSAS STATE UNIVERSITY

Manhattan, Kansas

2020

Approved by:

Major Professor
Keith D. Harris

ABSTRACT

The overall objective of the study is to provide insight as to what it takes to reduce scrap levels at a foil manufacturing plant, as well as interpret the essence of Metallizers and addressing the gaps in relation to its vitality within the foil manufacturing process. The invention of Hot Stamp and Cold Stamp foil relate to a pigmentary foil and production method thereof. The pigmentary foil comprises at least one PET membrane base, on which coloring layer material and adhesive layer material are coated orderly (Guoping 2010). The key documents essential for production and reducing pump down times in the Metallizer chambers vary by a significant margin in order to increase production. By creating Pareto charts to establish root cause of scrap accumulation, conducting a Fishbone discussion to brainstorm ideas that would effectively mitigate scrap, and host a TPM Kaizen to exercise all ideas and suggestions enhancing the process, API would be in a better position to improve the quality of the metallizer; boosting its capacity and Overall Equipment Efficiency (OEE).

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

First and foremost, I would like to thank my Lord God. Without him, I would not be alive to pursue this opportunity. I would like to thank my family for supporting me during this journey; my mother Florence, my big brother Harris, my baby sister Stacey, and especially my father, Dr. Ugo Mgbike. Growing up, my father has always had a big impact on me in my life; I strive to be like him and follow in his example. Aside from the rest of my family back home in Africa, I would also like to thank the supporting cast around me, especially the ones who were there watching over me in spirit; my Uncles Ike, Sam & Sundae, my best friend Josh Shane, my priest Father Forrest Burgett and my elementary school principal Bill King. As far as the living cast, I especially want to acknowledge my church families that I actively grew in, both South Broadway Baptist Church and Trinity Anglican Church. Without their influence & experiences to confirm the lessons my parents instilled in me, I do not know what kind of man I would be today.

I would like to extend my gratitude to all who wrote acceptance letters on my behalf, providing me the support and credibility necessary to be a part of this program, LeAnn Zinn, Jim Shipman and my undergrad advisor, Dr. John Unruh. He placed me on the right track to acquire my bachelors after transitioning from the pre-med field at my hometown university. I am grateful to possess the fond memories reminiscing over our athletic days and talking about sports after his Meat Science classes. In addition, I would also like to thank Dennis Tippey, Bryan Langerud and John Helwig for the insurmountable support provided during my time learning from them as coworkers from Pinnacle Foods. If not for their support, I would not have considered applying for graduate school; they saw the potential in me before I saw it in myself. Following, I would like to thank the head administrator, Dr. Allen Featherstone, for accepting my application and allowing me to take part in this program with my cohorts of the MAB 2020 class. I would like to thank Dr. Keith Harris, not only for his exemplary leadership as my major professor, but also his guidance about life as a good friend.

CHAPTER I: INTRODUCTION

1.1 Background

The demand for both Hot Stamp (HSF) and Cold Stamp (CSF) foil, also referred to as pigmentation foil, has remained consistent with consumer-packaged goods retailers. The foil is used to enhance the product appeal and provide a new medium to market customized products for pharmaceutical, cosmetics, automobile, and food processing industries. As the demand for consumer-packaged goods increased, so did the demand for colored foil. Packaging foil is sought after for its uniqueness and versatility. It is used to print detailed caricatures and improve other features of the product. Foil used in packaging of consumer goods stimulates innovation and generates new ideas to market products that in turn allow businesses to acquire more value (Herbst and Hunger 2004). The benefits of foil include its malleability, strength, and ability to withstand extreme temperatures. These benefits increased growth in the foil industry and required processors to expand operations in order to keep up with demand.

Athlone Press Industries (API), also referred to as Automized Pigments Industries, has been a leading manufacturer and distributor of foils, laminates, and holographic materials which provide exceptional brand enhancement for consumer goods and printed media worldwide since 1979. With roots in the British paper industry, the company's reputation was founded on a trading history going back to the 1900s (API Group 2020). The company traded goods that eventually led them to acquiring items in relation to pigmentations and colorants. It enables customers to customize products with their preferred options. The pigmentation process provides customers with the option to choose a variety of color combinations and a spectrum of shades. The application of the pigmentation foil compliments the specific product; in essence, pigments are insoluble in some mediums yet can dissolve in others (Herbst and Hunger 2004). In the aluminum foil industry, the pigment can change the color of the reflected light as a result of selective wavelength absorption. The sparkle effect of certain pigments, such as aluminum in paint coating, is determined by the quantity of pigment added (Association 2020).

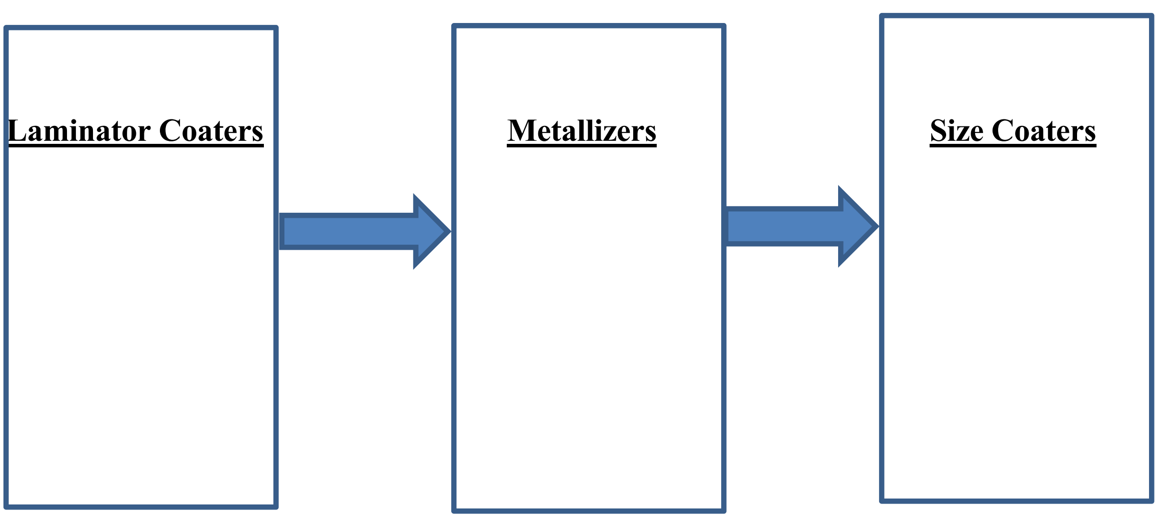
The pigmentation industry enables its customers to pursue new business in a wide range of industries. It helps customers create value, pursue other opportunities, and enhance the company's brand awareness. More than 90 percent of traditional foil stamping and embossing is primarily used for big canvases, such as car vehicles, but are notoriously known for providing life to small entities as well; i.e. footballs, wine wraps, car fuses, greeting cards, and is not recommended for printing ink colors. One of the most important properties of pigment foil is its high reflectivity of light. Visible light can reflect infrared and ultraviolet light waves. Films, foils, and laminates are substrates that are used to add holographic and metallic finishes, cartoon effects, labels, closures, and containers for many consumer brands in premium segments found in perfumery, cosmetics, confectionery, alcoholic drinks, tobacco, and healthcare industries.

1.1.1 The HSF/CSF Process

Both the Hot Stamp and Cold Stamp foil technique is a process of preparing decorated film and foils, and thermoplastic sheets of metal. Each process applies different varieties of colors to substrates or other canvases. By forming the substrate on a non-absorbent surface, the design becomes more etched and engraved. This allows the coloring material to fill in the depressions before the formation of the plastic sheet (Feuerstein 1942). Athlone uses Kaizen as its quality program. Kaizen involves statistical process controls, fishbone diagrams, and pareto optimality. Athlone used Kaizen to estimate and compare the scrap accumulated to determine the cost of the process. The statistical approach was needed to assess the progress of the objectives with respect to the enhanced production time and Sanitation Standard Operational Procedures (SSOP) revisions. The results provided the Metallizers with better pump down times, which in turn, soon became implemented into the Operator Asset Care (OAC) log for foil plants to maintain a more efficient process, creating better production runs, thereby creating high quality foil for customers with less downtime (DT) accumulated. The data was generated from API Americas, Inc. for the study.

The manufacturing process of pigmenting foil generally involves three processes: laminating, metallizing, and color coating. Laminating is a two-step process of coating the substrate with first a wax, then with lacquer. Two commonly used models for laminating are Delpro and Polytype. Next, the Metallizer applies the aluminum to the substrate. In the final step the substrate is coated with a color scheme according the customer's requirement. Figure 1.1 below displays a relevant flow chart portraying the process first hand.

Figure 1.1 Overview of API Stock Portfolio



The coating machine applies a layer of material onto a 6-20-micron Polyethylene Terephthalate (PET) membrane base. PET membrane base is dried under a temperature of 80° to 140° Celsius. This step is imperative because the physical property that measures flakiness determines how "floody" the product is. If pigment foil is considered too floody, it means the chemicals in the solvents applied at the sizing coaters are strong or there is a defect in the substrate; thus, flooding the polyester and creating blotches along the pigment. Because of the chemicals in the solvent, the blotches upset the customers and puts a damper on customer satisfaction. After applying size coating to the polyester, the foil is slit to a size that can be stored and warehoused. To provide improved multilayer pigment flakes, foils that have magnetic properties are needed to overcome or avoid conventional problems and limitations (Phillips 2001).

Some chemicals used to produce pigmented foils are listed in the Standard Operational Procedures (SOP) As stated below by Mo Guoping, are highly flammable, toxic and pose a serious health threat if used haphazardly. The SOP requires that R&D and Quality Departments to contribute to ensuring employee safety by developing procedures that detect tampering and response to dangerous situations, which involves enforcing the use of Personal Protective Equipment (PPE) and explain its importance.

As detailed further by Mo Guoping:

> The coloring layer material is prepared by grinding, mixing, wetting, and dispersing acrylic resin, ethenoid resin, mica powder, chloroprene rubber, white wax, polyethylene wax, soy lecithin, pigments, and mixed solvent. The adhesive layer material is prepared by mixing, wetting, and dispersing cellulose acetate, vinyl cellulose, polyvinyl butyral, chalking silicon dioxide, water, and ethanol mixed solvent (Guoping 2010).

This is imperative because defects created at the Metallizer can also cause harm to the size coaters and its contributions when applying the size coat.

1.1.2 The Metallizers in Manufacturing Process

The Metallizer provides the design and opacity expectations of metallic foils (AB 2017). In order to achieve a shiny metallic look, the coated substrate (polyester) is metallized. Each time the substrate is sent to the Metallizer, the shinier the appearance of the pigment foil (See first photo in Appendix A). There are conditions and concerns that might deplete the Overall Equipment Efficiency (OEE) in foil manufacturing. One prominent concern is Metallizer creases, which are classified as product defects. The foil product could meet stamp grade requirements, yet a blemish, such as a crease in the foil could put into motion the process to return the foil from a warehouse or a customer's location. Returned product causes a loss of time, goodwill with customers and increase the cost of material waste.

1.2 Problem Statement

The Metallizer equipment is often the source of a bottleneck in the production process. The Metallizer inability to consistently keep pace with other equipment creates downtime for the company. When producing pigmented foil, daily scrap defects increase by 7-9 percent, but Metallizer creases account for more than 50 percent of the accumulated scrap. An example of Metallizer creases can be found in the second photo of Appendix A. High levels of defects suggest there is a failure in the production or design process of the aluminum foil, which might be traced to the operational procedure or the Metallizer equipment. This study poses the following research question: Will applying primary focus to the Metallizers reduce scrap accumulation for manufacturing plants in the foil industry?

1.3 Objectives

The overall objective of the study is to provide insight as to what it takes to reduce scrap levels at a foil manufacturing plant, as well as explaining the roles Metallizers play in addressing the problem. The specific objectives are as follows:

1. To obtain a better understanding of Metallizers and functionality of other equipment involved in producing foil
2. To establish the frequency of cleansing the equipment and revise sanitation methods
3. To influence foil manufacturing plants to prioritize high-level maintenance tasks to be performed during Total Production Maintenance (TPM) Kaizen event

Since the beginning of 2019, API Foils, Inc. has maintained stagnant scrap levels as high as 25 percent due to lack of training and tribal knowledge. In the middle of the year 2019, API scrap levels have been stagnant at 20 percent as depicted in Table 1.1 below. The facility's General Manager set a goal to reduce scrap levels by 5 percent in 30 days. For change to truly be effective and measurable, several variables had to be taken to consideration: qualifications/skillset for Metallizer job, document creations/revisions, responsibility and accountability enforced on all shifts, and collaboration among shop floor operators.

Table 1.1 API Mid-Year Scrap Summary

API Americas, Inc.

Scrap Summary by Day

Month of July 2019

				Week 4									
	Week 1	Week 2	Week 3	7/21/19	7/22/19	7/23/19	7/24/19	7/25/19	7/26/19	7/27/19	Week 4	Mtd	
Hot Stamping Foils													
Scrap Value $	$ 13,626	$ 47,402	$ 11,873	$ -	$ 737	$ 13,002	$ -	$ 4,689	$ 6,853	$ -	$ 25,282	$ 98,183	
Scrap Sq Meters	79,139	268,031	70,690	-	4,903	62,376	-	26,220	40,227	-	133,725	551,585	
Sales Sq Meters	127,779	417,748	175,848	-	14,362	88,091	39,056	16,312	33,510	-	191,332	912,707	
Scrap Percentage	38.2%	39.1%	28.7%	0.0%	25.4%	41.5%	0.0%	61.6%	54.6%	0.0%	41.1%	37.7%	
Cold Stamping Foils													
Scrap Value $	$ 1,316	$ 5,547	$ 1,988	$ -	$ 229	$ 841	$ -	$ 1,042	$ -	$ -	$ 2,112	$ 10,963	
Scrap Sq Meters	9,772	31,851	12,845	-	1,802	6,409	-	10,045	-	-	18,256	72,724	
Sales Sq Meters	96,347	222,598	71,173	-	4,065	12,422	151,432	13,529	2,729	-	184,176	574,295	
Scrap Percentage	9.2%	12.5%	15.3%	0.0%	30.7%	34.0%	0.0%	42.6%	0.0%	0.0%	9.0%	11.2%	
VMP													
Scrap Value $	$ 6,813	$ 3,060	$ 8,115	$ -	$ -	$ 9,297	$ -	$ 2,691	$ 1,477	$ -	$ 13,464	$ 31,453	
Scrap Sq Meters	38,846	13,544	39,563	-	-	40,494	-	11,897	7,247	-	59,638	151,591	
Sales Sq Meters	-	774,966	387,483	-	-	-	183,457	-	639,148	-	822,605	1,985,055	
Scrap Percentage	100.0%	1.7%	9.3%	0.0%	0.0%	100.0%	0.0%	100.0%	1.1%	0.0%	6.8%	7.1%	
Pigments													
Scrap Value $	$ 5,002	$ 4,956	$ 8,427	$ -	$ 1,090	$ 3,182	$ -	$ 1,651	$ -	$ -	$ 5,922	$ 24,307	
Scrap Sq Meters	15,637	16,515	25,596	-	4,126	7,909	-	6,485	-	-	18,520	76,268	
Sales Sq Meters	58,923	99,139	96,888	-	43,741	26,879	4,294	12,300	70,087	-	157,302	412,251	
Scrap Percentage	21.0%	14.3%	20.9%	0.0%	8.6%	22.7%	0.0%	34.5%	0.0%	0.0%	10.5%	15.6%	
HLD/HLS													
Scrap Value $	$ 17,930	$ 22,056	$ 14,767	$ -	$ 2,230	$ 6,263	$ -	$ 10,477	$ 396	$ -	$ 19,366	$ 74,120	
Scrap Sq Meters	60,018	54,308	34,782	-	5,249	13,312	-	21,053	975	-	40,590	189,698	
Sales Sq Meters	69,045	71,273	48,618	-	16,915	4,413	25,286	465	39,419	-	86,497	275,434	
Scrap Percentage	46.5%	43.2%	41.7%	0.0%	23.7%	75.1%	0.0%	97.8%	2.4%	0.0%	31.9%	40.8%	
Other													
Scrap Value $	$ -	$ 1	$ 78	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 80	
Scrap Sq Meters	-	37	655	-	-	-	-	-	-	-	-	692	
Sales Sq Meters		1,383	2,279	-	99	107	5	482	3,020	-	3,713	7,375	
Scrap Percentage	0.0%	2.6%	22.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	8.6%	
TOTAL													
Scrap Value $	$ 44,688	$ 83,022	$ 45,249	$ -	$ 4,285	$ 32,584	$ -	$ 20,551	$ 8,725	$ -	$ 66,146	$ 239,105	$ -
Scrap Sq Meters	203,413	384,286	184,130	-	16,080	130,500	-	75,699	48,449	-	270,729	1,042,557	
Sales Sq Meters	352,734	1,587,106	782,289	-	79,182	131,912	403,532	43,088	787,913	-	1,445,626	4,167,755	$ 0.00
Scrap Percentage	36.6%	19.5%	19.1%	0.0%	16.9%	49.7%	0.0%	63.7%	5.8%	0.0%	15.8%	**20.0%**	

[redacted]

Non Return Quarantine $	$ 41,492	$ 39,328	$ 48,092	$ 48,092	$ 57,416	$ 37,983	$ 48,585	$ 53,214	$ 59,712	$ 59,712	$ 59,712	$ 27,465	Change in Quarantine
Offcuts value in Inventory (Parent parts)	$ 22,044	$ 10,476	$ 12,040	$ 12,040	$ 12,389	$ 11,918	$ 12,061	$ 12,307	$ 12,307	$ 12,307	$ 12,307	$ 3,011	Change in Offcuts
Unaccounted for Scrap	$ -	$ -	$ -	$ -	$ (7,512)	$ (512)	$ (2,818)	$ 26	$ 5,083	$ (13)	$ -	$ 11,416	Total Unaccounted for Scrap

1.4 Outline of Thesis

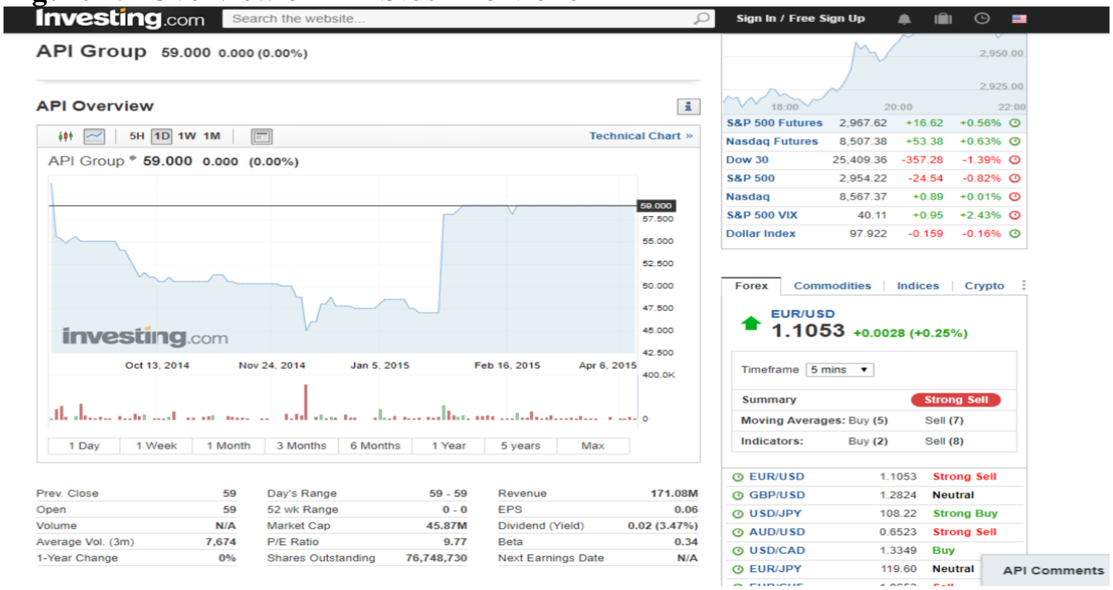
The thesis provides a background information, facts, and data analysis as well as any further opportunities for research regarding. Chapter I provides the background over the industry. Chapter II includes the literature review to provide a context of the research problem. Chapter III provides a description of the methods and data used at API to address the specific issues related to the high scrap levels caused by creases. In Chapter IV, the analysis is presented and estimation methods are used to achieve the empirical estimates demanded by the study. In Chapter V, the summary and recommendations emanating from the research are presented.

1.5 Contributions to Research

This research is relevant to businesses that suffer from high scrap levels, which contribute to declining profits, low customer service levels, a high cost structure, and not meeting profit expectations. A low OEE score can indicate several things, i.e. productivity enhancement, suggest room for improvement within the manufacturing process, identify opportunities to meet customer expectations, validate the equipment meeting performance specifications, etc. In essence, productivity would to have low variability in sales and cost due to the lack of pigment's attributes. Pigmented foil has multiple advantages for printing options. It can provide opportunities to use a wide range of colors, enhancing the hot stamping process and minimizing waste. The process is environmentally sound with respect to digital formatting, satisfying the ease of printing or transferring digital artwork. The production method is not complicated; the pigment foil can be transported and stored easily and can achieve patterns and wards in different colors (Guoping 2010). But, when making hot stamp or cold stamp pigment foil, a large part of the production process for the more popular styles increases the number of passes (the number of times the material must be machined) a substrate of foil is ran through a Metallizer. This study is intended help to decrease scrap levels accumulated at foil manufacturing plants. Unlike the food manufacturing industry, pigment foils do not exactly have the same benefits when being reworked in a Hazard Analysis Critical Control Point (HACCP) process.

Unused foil is left in the warehouse until another customer request a similar size or specification. For example, with a metallic ink product, a car customizing company wants to invest in 36-inch cut of foil, but the foil manufacturing company only provides 34-inch and 40-inch cuts due to limited cutting sizes because the model of the splitter is vintage. The foil company would have to make the 40-inch cut and trim the excess four inches off that would be stored in the warehouse for a different company. API Americas generates $171M annually (Investing 2014); therefore, with scrap levels fluctuating between 26-28 percent, to eliminate half of that alone would amount to $24M in cost savings. Figure 1.1 below displays a chart of the overview for the API profile providing the revenue and other stock data; interpreting the basis of financial efficiency for scrap (Investing 2014). The cost savings or the waste risk have an impact on the stock price of $5,750, which suggest how inefficient the plant's performance coincides with its low stock price; a proper demonstration of how imperative it is to decrease waste.

Figure 1.2 Overview of API Stock Portfolio



Source**:** (Investing 2014)

The pigment industry is busy competing with the digital formatting industry; in other words, pigment foil will become less of a fad and digital formatting will be on the rise, slowly becoming the new face of the print industry due to its simplicity within the process and how much easier it is to apply to other products than it would be to utilize pigment foil. Each process is different and achieves different tactile and visual effects on certain products, *i.e.* presentation folders, business cards, and more. In comparison to pigment foil stamping, digital raised foil stamping involves no dyes, explaining why its production cycle time is fast.

Because traditional foil stamping and embossing has that classic appeal and certain look, it can apply its own character to any customized products. The expenses of making a high caliber product is costly; creating foil product with all the material invested and profit off most of it in sales is still not feasible because not the whole product was sold. Remember the previous example where the customer needed a 36-inch cut of foil, requiring an excess of four inches of cut scrapped sitting in a warehouse waiting for another customer. An example is displayed in the fourth picture of Appendix A; depicting accurately how foil is resized to satisfy customer needs. The two half rolls on top sit in a warehouse while the rest ships to the customer.

Although, foil stamping on hot or cold stamp pigments is an affordable and traditional way to showcase the brand, there are certain quality aspects overlooked, such as the metallic shine of the foil contrasting with the matte weave for the linen; small details like that must be taken into account as well. API Americas, Inc. struggled with stamp foils, they were unable to make any other pigments for customers without a recall first. Displayed in Table 1.2, API produced close to 6.3M square meters of foil, 10 percent of the monthly production would cost $143,320.40 in lost revenue. It is ultimately the tactile and aesthetic difference that matters when applying brand identity to presentation products while the differences between raised foil coating and traditional foil stamping and embossing remain quite apparent. Knowing the difference and having both to offer can help fully promote a client’s brand (Presentation Folder 2020).

Table 1.2 API Scrap Accumulation (m2) and Value ($) between all Equipment

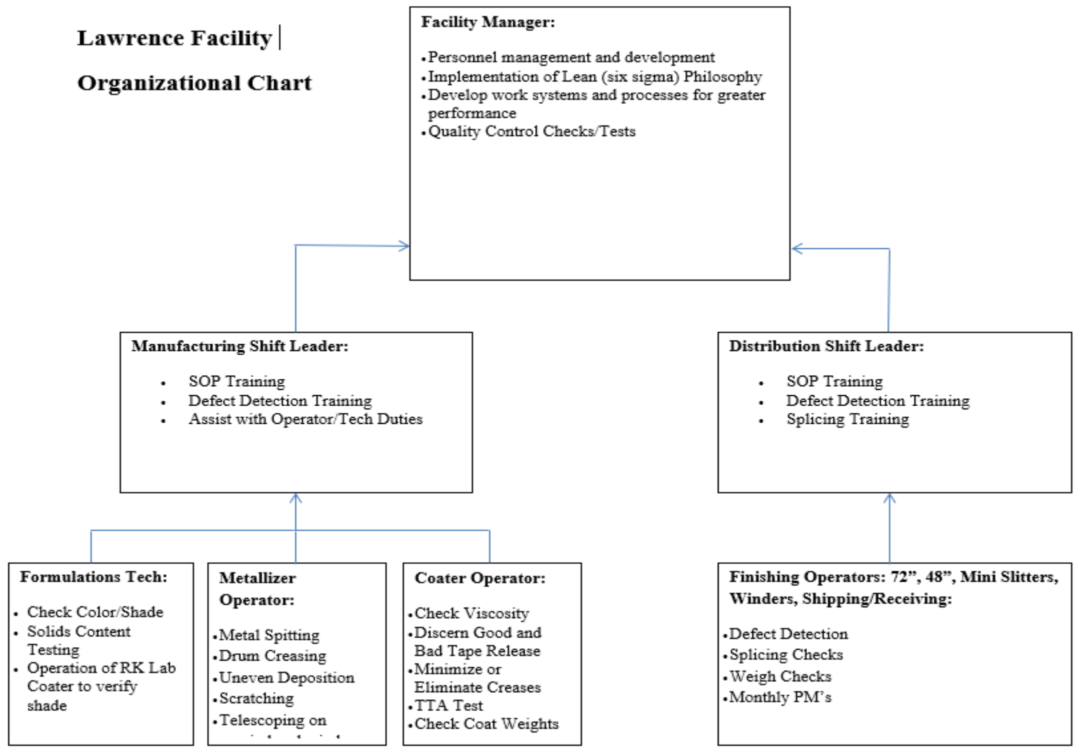
	Square Meters	Annual Revenue ($)	Annual Revenue (£)
	6,280,820	1,433,204	1,100,180
Department			
	Square Meters	Annual Revenue ($)	Annual Revenue (£)
Mix Mill	0	0	0
Coating	343,289	105,791	81,209
Embossing	52,594	25,637	19,680
Metalising	531,716	15,284	11,733
Sizing	60,158	125,195	96,104
72Slitting	655,428	113,701	87,281
VMP	515,401	107,141	82,246
Finishing	3,404,109	774,519	594,549
Manual Scrap	232,187	70,695	54,268
Other	0	0	0
Cust Return	485,939	95,239	73,109

CHAPTER II: LITERATURE REVIEW

2.1 Operations Management

If manufacturing organizations are to remain competitive, they must continuously improve their levels of operating performance (Mapes 2002). The coating process has often been referred to as the application of a covering, finish, or protective layer on one or two sides of a substrate. The lamination process is the bonding together of two or more materials to form a multi-ply structure. Figure 2.1 below is the organizational chart API used for accountability purposes with all positions. To make quality product in this industry, like all others, requires a strong leadership team because as basic as these definitions make both processes sound, the simplicity may be more complicated than the definitions imply (Weiss 1977).

Figure 2.1 API Organization Flow Chart



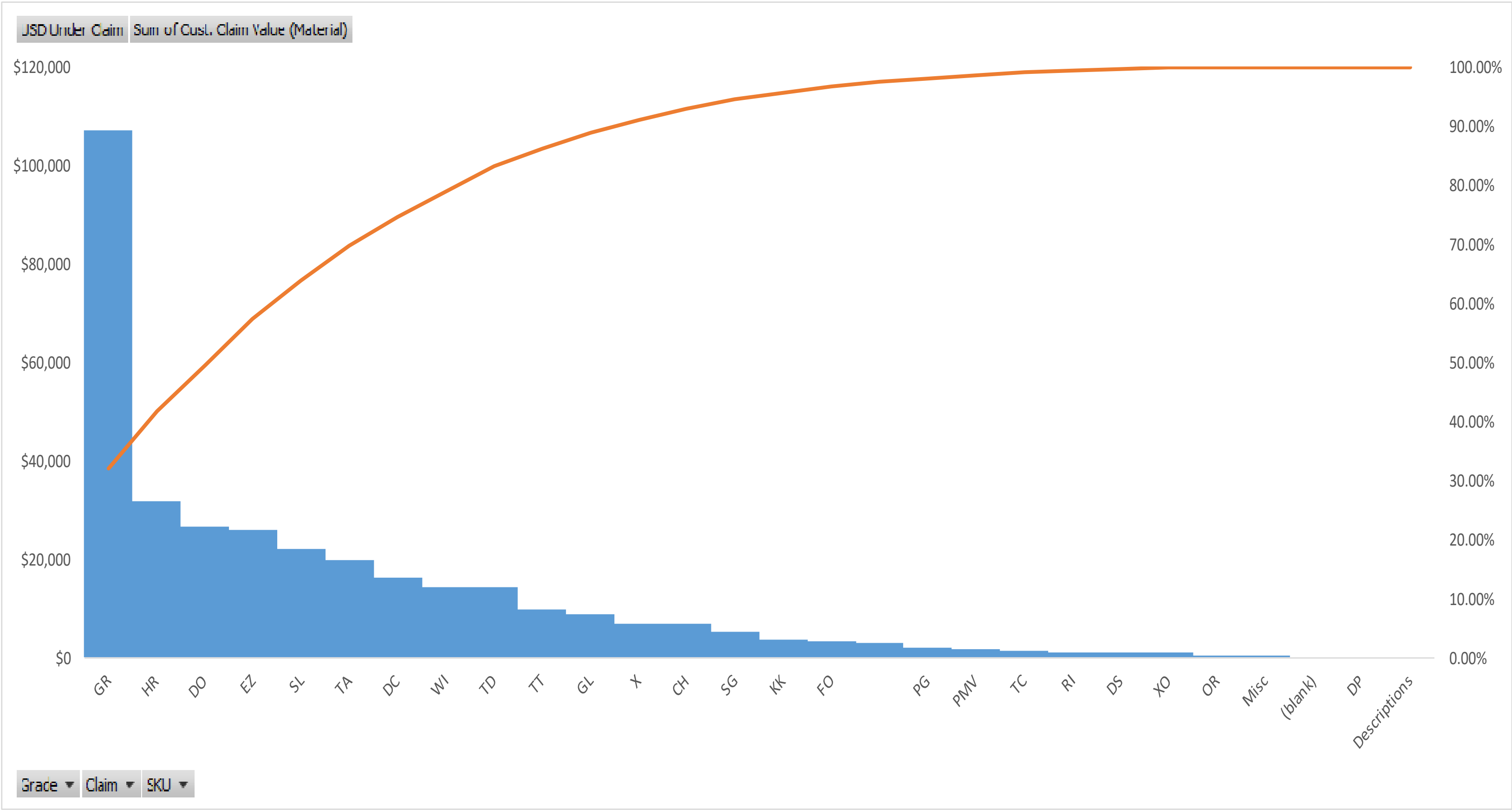
Source: (API Group 2020)

The Operations Managers must understand which key drivers are most effective at creating performance improvements in the foil industry, as well as how various the measures of each driver enhance OEE, *i.e.* safety, quality, delivery, inventory, production, etc. Identifying key drivers are most effective when attempting to achieve progress in overall operating performance; exploring relationships amongst all levels of performance in the event different operating measures are vital for the manufacturing plant to continue running (Mapes 2002). Regardless of how production flows, the plant would be ranked in its industrial category for each performance measure and categorized as either a high, medium, or low performer.

2.2 Impact on Markets

Advancements in production technology such as mobile health apps, printable medication, and the use of artificial intelligence provides food and pharmaceuticals with multifaceted advantages resulting in daily economic shifts. Thus, it is especially important for a company to anticipate market movements in order to take advantage of market opportunities and processes that create a competitive advantage. Figure 2.2 illustrates customer complaints based by grade of foil. For instance, GR recorded $107,209 in complaints and 32 percent of the summation of customer claim value. In 2019, the value and percentage of volume increased significantly with regards to the Metallizer creases creating setbacks for production; the data for the chart can be found in the first photo of Appendix B.

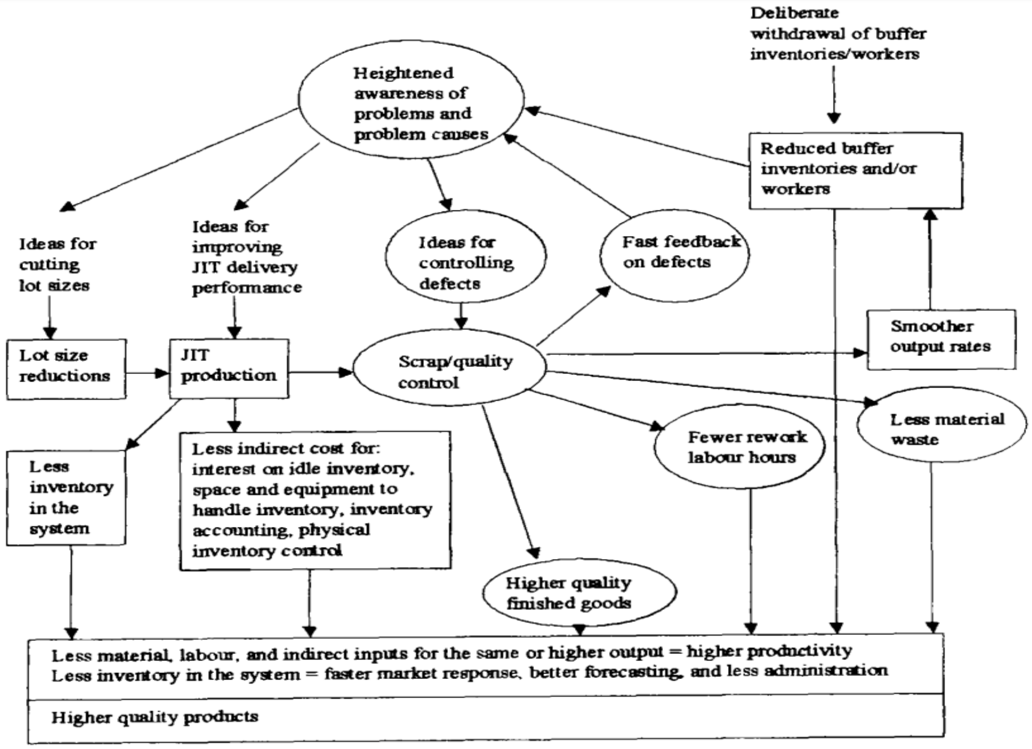
Figure 2.2 Scrap Accumulation via Consumer Complaints by Grade of Foil



(API Group 2020)

The key point to acquire from this journal that supported this study is demonstrated through Schonberger's Model below (Figure 2.3) as Total Quality Control (TQC) was blended with Just in Time (JIT) production. Scrap and/or quality control is in the middle of the diagram conducting the sequence of events. This model shows how the operating system can be improved over time. There are several performance drivers necessary to impact an industry, i.e. sales leads in a capital goods or service business, sales per square meter in a retail business, and, 'first time fix' in a maintenance business. The specific key driver observed in this study is machine downtime in a factory. The results lead to simultaneous improvements in most measures of operating performance. Industrial research, backed by the analysis of each component, is the credible source for gaining the market reports feasible for intended profit that will provide these plants with the lead towards business needs (Weiss 1977). This alludes to the fact that f land, labor, and capital are not used effectively, then the economy will stumble. If used effectively, then the economy is not the best, but balanced. When thinking about the economy, the concept becomes bigger than the people; that simply refers to the usage of labor. Without territory, one cannot expand and without profit, one cannot acquire the means nor necessities to keep the land, let alone the labor. From both a U.S. and global aspect, all three elements need to complement each other; not only to balance the economy, but also to potentially expand it.

Figure 2.3 Schonberger's Model: TQC in relation to JIT



Source**:** (Mapes 2002)

A similar study in comparison to this one is seen in Section 2.3 below by Ted Olt for scrap-based companies operate in the aluminum industry. The objective is to produce quality products that are equivalent to second-tier aluminum producers. Barmet Aluminum Corporation in Akron, Ohio operated three Hazelett casters and is knowledgeable on the quality aspect of the technology supporting the process. Hazelett castersare the source of countless aluminum products that offer the world's highest production rates at the lowest cost for rolled aluminum sheet with demonstrated energy savings and with lower emissions than other processes. Robert Park, Barmet's president, describes the company as a serious contender in the common alloy business. The methods used to categorize which mills were most successful in production are the same methods necessary to prioritize what the biggest contributors were to scrap levels.

2.3 The Aluminum Industry

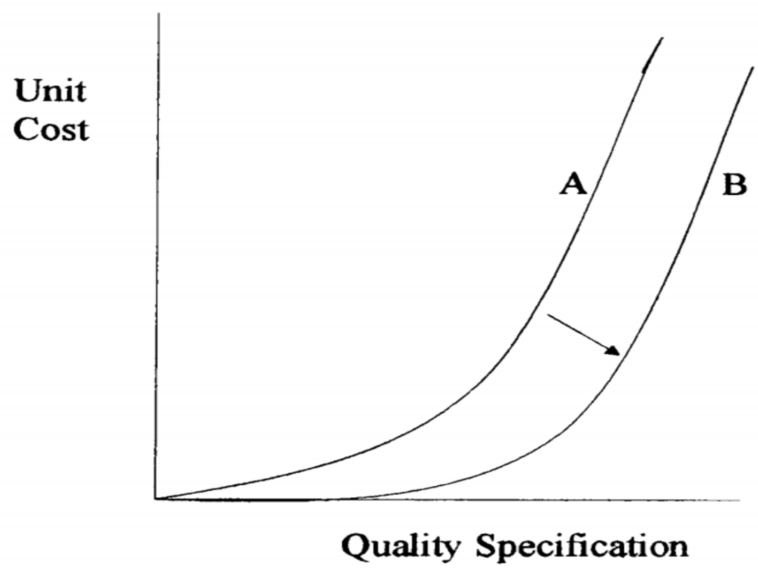
There is another industry that strives to overcome the same obstacles faced by the foil industry. The aluminum industry uses high speed continuous casters and advanced rolling mills to advance in new quality and quantity categories. According to Ted Olt, who was once the president of Nichols Homeshield in Aurora, Illinois, "the trend developing in aluminum is following the steel pattern" (McManus 1991). The scrap-based steel mini-mills started with small plants and relatively crude products, managing to work with the old equipment surrounding its vicinity and still make quality products.

This research involved 953 United Kingdom manufacturing plants. These plants had all participated in the UK's "Best Factory Awards" database during the years 1993-1996. The plants were grouped into six industrial categories. The plants in each industrial category were then ranked for each performance measure and divided into three equal-sized groups of high, medium, and low performers. The groups of high and low performers were then compared in order to identify characteristics that were statistically different for the two groups (McManus 1991).

The result of the test whether the conclusions reached based on statistical analysis could also be validated at individual plants. This in turn, set a trend when establishing a new standard for quality products; challenging the large steel mills to do the same. In this instance, the groups of high performers (mini-mills) and low performers (larger steel mills) were compared in order to identify characteristics that were statistically different between the two groups. It was noticed that the high performers put a greater emphasis on continuous improvement, involving higher proportion with the significant improvements of productivity in relation to the workforce and employee morale. The workforce became more flexible in terms of changes made to the OAC in order to maintain and preserve the condition of the equipment, including the ever so fluctuating range of tasks competent to carry out.

The database was used to test for statistical correlations and the results provided to generally support both propositions. Figure 2.4 suggests that
improvements in unit manufacturing cost, quality consistency, speed of delivery, and delivery reliability would be positively correlated between measures of these aspects of performance. The figure also suggests that the size of the product range would be negatively correlated with unit manufacturing cost, quality consistency, speed of delivery, and delivery reliability.

Figure 2.4 Unit Cost for Product Improving with Quality Specifications



Source: (Mapes 2002)

There was general support from the plant owners in each industrial category for the differences in the characteristics of high and low performing plants between both the pigment foil and aluminum industries. There was also general support for the propositions that plants achieve similar performance on unit manufacturing cost, quality consistency, speed of delivery, and delivery reliability relative to plants in the same industrial sector and that increasing the size of the product range adversely affects unit manufacturing cost, quality consistency, speed of delivery, and delivery reliability. To reiterate, the point was when a reduction in lead time is achieved, the benefits can be passed onto the customer in either the form of a reduction in the quoted lead time, improvement in delivery reliability or a combination of both; the larger the reduction in quoted lead time, the smaller improvements in delivery reliability.

The high performers exhibited less variability in their processes with greater adherence to schedule, more consistent processing times, lower scrap rates, and more reliable supplier deliveries. The results of this analysis combined with the interpretation of the literature provide a path for API to follow. Characteristics supporting high performance plants a tedious mindset constructed to show how each impact operating performance.

Regardless of the category, high and low performance plants were not significantly different in sizes, but in the volume and complexity of products made in the industry. High performance plants, however, were more than likely owned by foreign parent companies, putting a greater emphasis on continuous improvement, involving higher proportions of the workforce in this activity. Ultimately, six of the plants in the database – low performers – were visited and staff responsible for planning, purchasing, and production were interviewed (McManus 1991). It is the use of Kaizen in this context that JIT will best inform this study.

The TPM Kaizen is a strategy where employees at all levels of a company work together proactively to achieve regular, incremental improvements to the manufacturing process. In a sense, it combines the collective talents within a company to create a powerful engine for improvement. Interestingly, Kaizen as an action plan is exactly what develops Kaizen as a philosophy. When Kaizen is applied as an action plan through a consistent and sustained program of successful Kaizen events, it teaches employees to think differently about their work. In other words, consistent application of Kaizen as an action plan creates tremendous long-term value by developing the culture that is needed for truly effective continuous improvement (Vorne 2019).

Pareto Analysis, a basic decision-support process, will be used to help assess competing problems and measure the impact of reprimanding them. This technique allows a firm to focus on solutions providing the most benefit. The principle, also referred to as the 80/20 rule, was deemed by Italian economist, Vilfredo Pareto, who established the theory that 80 percent of the problems result from 20 percent of the causes, *i.e.* 80 percent of the world's problems occur from 20 percent of the world's causes. Developed by Dr. Kaoru Ishikawa at the University of Tokyo in 1943, the Pareto Chart is used in process improvement methods to identify all contributing root causes likely to be causing a problem (MoreStream 2020). This process primarily determines potential root causes of a problem, and the category of process inputs represents the greatest source of variability in the process output. Pareto Analysis identifies the problem areas or tasks that will have the biggest payoff. The tool has several benefits, including: 1) identifying and prioritizing problems and tasks; 2) helping people to organize their workloads more effectively; 3) improving productivity; and 4) improving profitability (Works 2020).

CHAPTER III: METHODS AND DATA

3.1 Equipment Analysis Supporting Manufacturing Process

To better explain the HSF/CSF manufacturing process; the coating is transferred from the polyester carrier to the hot stamped substrate by a heated die. The dies transfer the foil by pressure and temperature to the substrate; pressure and dwell time are adjustable. Stamping foils consist of coated layers on a carrier polyester film transferred by means of heat and pressure via a die onto the substrate. The die is made of metal or silicone rubber and contains the design that is to be impacted upon the substrate blocked at the vents of the Metallizer; causing buildup of aluminum to spread between the length of the rollers. There are many variations in materials and decoration effects, *i.e*. the metallic ink appeal on automobiles, holographic imagery with the NFL logos on footballs and other pigskin designs, plethora of combinations with hallmark cards, etc. The hot and cold stamp operations at API employ basic procedures and require pressure and dwell time. The carrier film transfers the decorative coating to the surface (AB 2017).

Before understanding the complications affiliated with the Metallizers, the rest of the equipment required and their roles in the process to create pigment foil must first be interpreted. The polyester is running through multiple pieces of equipment in order to deem the product as foil. The process begins with the laminator coaters; models such as the Polytype or the Delpro. This is where the product has both the wax applied at the first coater head, followed by the lacquer at the second coater head. Depending on the product, after each pass at the coaters, the product is sent to the Metallizers and ran every two passes. Next, the Metallizer applies the aluminum to the substrate, which is melted onto the boats and sucked up by the vacuum, slowly rising to attach to the polyester on the opposite side containing wax lacquer. In the final step, the product is sent to the size coaters where the polyester receives its size coat. The sizing coaters are utilized to apply the specific color scheme based off the customer's request.

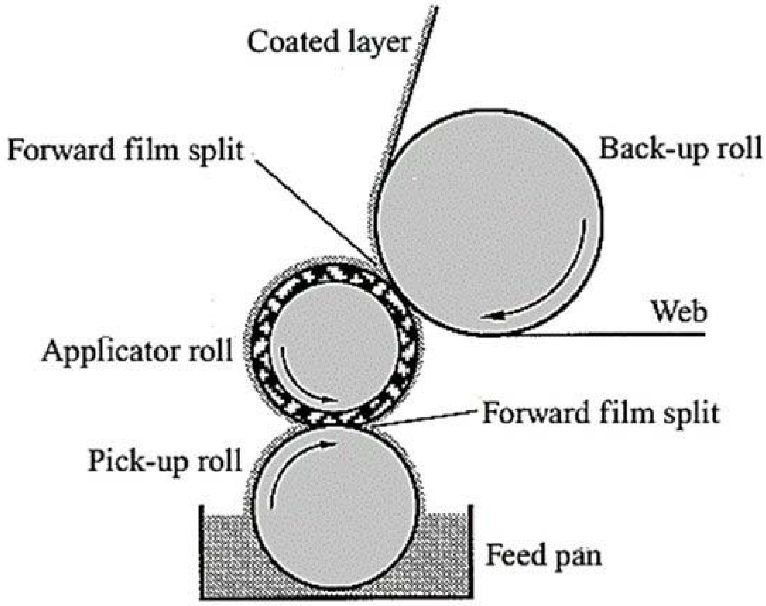
The brightness of hot stamping foils come from a layer of vacuum metalized aluminum. Pigment foils are precisely formulated blends of pigment particles, waxes, resin, solvents, and water, coated onto polyester carrier film. Almost any material with exception of glass or metal can be marked with hot stamping foil. These layers are transferred during the hot stamping process (AB 2017). This further reiterates that the literature review supports the study's objectives related to the foil manufacturing equipment. Below are the bullet points as to what will be addressed to reduce scrap levels. Kaizen was designed and conducted to arrive at these bullet points:

3.2 Methods

1. Create Pareto Analysis to establish root cause of Scrap Levels
2. Conduct Fishbone Discussion and brainstorm ideas preventing high level occurrences from Metallizer
3. Orchestrate Quality Program (TPM Kaizen) to enact strategies discussed from all aspects of research and employ resolutions that benefit production

The bow rollers are important to monitor frequently because they keep the foil running through the machine. Each roller consist of microscopic pores that not only provide the polyester film with better grip along the rotation, but also as stated in Section 3.3 of this study, makes it easier to apply aluminum on the top of the substrate throughout each pass of the polyester through the process. As referenced in Section 1.1.2, a pass refers to the amount of times the polyester is ran through the Metallizer; the more passes, the more aluminum is being applied to the substrate, meaning the more metallic the polyester becomes. Figure 3.1 shows how polyester is used in the process. As the web is pressed between the back-up roll and applicator roll, all the pores along the applicator roller are soaked with the size coat; thereby, assisting the film split as it progresses, allowing the back-up roller to gradually assist the substrate through with its set speed (550 bits per second) to wrap at the other end of the coating machine along the rewind (API Group 2020).

Figure 3.1 Rollers that Polyester roll through when receiving Aluminum or Size Coat



Source: (Zafar 2019)

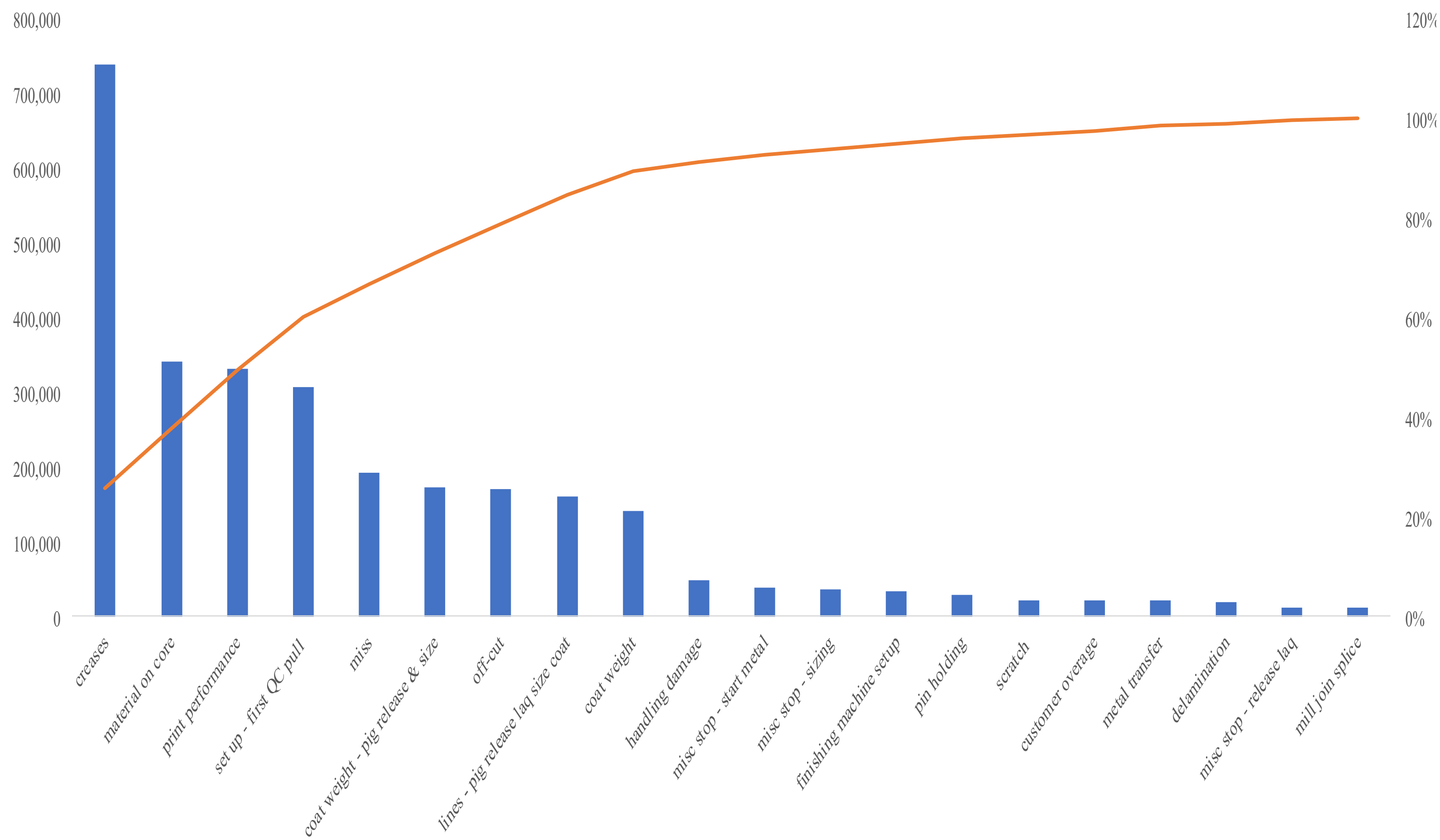
3.3 The Collaboration

Now having understood the challenges addressed with production, and the circumstances the pigment industry faces, API management understood the task at hand and gathered to discuss future projects that would take priority over production. In order to address scrap and its strain on revenue, management knew they had to approach the problem directly and confront the biggest contributor of scrap. To do this, a Pareto

Diagram was created to determine the cause of scrap. The results (Figure 3.2) from the analysis suggested that creases were the primary issue in the accumulation of scrap; data table is displayed in the second photo of Appendix C. Established below were hypothesis concocted by API management to support the methods for what would need to happen in accordance to the Kaizen plans:

1. Recreate the SSOP's with the updated modifications established from the TPM Kaizen and hold operators accountable in order to maintain quality conditions of Metallizers
2. Install the Problem Tag system and train operators on it before and after production with tool talks so issues can be quickly identified and reprimanded
3. Train all operators in new OAC and edit monthly Preventative Maintenance (PM) checklist

Figure 3.2 Level One Scrap Pareto Diagram



3.4 Data Collection

Productivity data including scrap rates were compiled from Tropos (database created by Epicore) was used to complete the first level Pareto Diagram (API Group 2020). Referring to Chapter 1, scrap levels were the number one priority for API, which led to lower operating income that played a financially devastating role in their production loss. With respect to Pareto's theory, the concept of this analysis begins with the question that establishes which cause is categorized in the 20 percent bracket: "What issues acquire the most scrap during production?"

In Chapter 1 under the HSF/CSF process, the equipment listed was in the order of the process that polyester is ran through; laminator coaters, Metallizers, and color coaters. Whenever a roll encounters a defect, it is that defected portion that gets cut out using putty knives and the role is re-spliced (third photo in Appendix A) to maintain production and to still use the remaining good polyester. The scrap is placed in a waste bin, which is moved to the weigh dump by a forklift when at maximum capacity to account for how many square meters was measured. The weigh dump is the area where scrap is taken and weighed at the scale prior to being recycled or transported to the warehouse. Tropos software calculates the measurements between equipment, product, and customer order. Data for this study was analyzed based off the quantity of square meters in relation to its origin. The approach with the Level Two Pareto Chart was similar. The polyester had the highest number of creases coming from the Metallizer. The primary focus and research revolved around the amount of scrap built up from the Metallizer chamber.

Having established from Tropos that pigment creases are the leading issue in scrap accumulation, all manufacturing equipment underwent quality checks, particularly the rollers due to its probability of crease formation. Microsoft Excel documents were created from queries based off the database to assess which piece of equipment was contributing the most to the immense scrap levels. Based on the data shown in the third photo of Appendix C, the second level scrap pareto, the Metallizer was the source of most of the creases and subsequent scrap accumulation.

The Pareto analysis confirmed that the Metallizers required the most attention because of the consistency in which product was being created and returned and the way the benchmark was established was beyond API Management’s control at this point. API knew they had to act fast and began communicating more frequent with their customers; not only to determine what defects are seen and to what extent, but also to gain the rapport they slowly lost.

The understanding of the Metallizer began to unwind as the outcome of the pigment foil shipped back to API kept aggravating customers. The data visualized from the Fishbone Diagram were all noted ideas from the meeting revolving around the Metallizer. All the ideas listed from the Fishbone in the first photo from Appendix C originated from the need to provide quality foil. The top four customers listed in Table 3.3 were of concern to API. Those companies represented 55 percent in amount of sales.

Table 3.1 Scrap Accumulation based off Customer Complaints

Row Labels	USD Under Claim	Sum of Cust. Claim Value (Material
⊞Hallmark Cards - Lawrence	$85,965	25.72%
⊞G3 Enterprises	$29,232	34.47%
⊞CCL Label - Sioux Falls, SD	$23,958	41.64%
⊞General Roll Leaf	$20,634	47.81%
⊞Sumicorp De México, S.A. De C.V.	$16,769	52.83%
⊞IIMAK IDISA S de RL de CV - México I	$14,423	57.15%
⊞Better Label and Products Inc.	$13,981	61.33%
⊞Alaniz LLC	$12,232	64.99%
⊞K Foils Ltd.	$10,006	67.98%
⊞API Hong Kong	$8,415	70.50%
⊞Multi-Color Corporation (Collotype) - CA	$7,350	72.70%
⊞RR Donnelley - NC	$7,109	74.83%
⊞Weldon, Williams & Lick	$6,720	76.84%
⊞Littelfuse Mexico Mfg	$4,868	78.30%
⊞Bic Graphic USA - MN	$4,841	79.75%
⊞Paragon Label	$4,735	81.16%
⊞A 1 Label Inc.	$4,424	82.49%
⊞Comercial Arque SA	$4,413	83.81%
⊞Custom Pak - IA [HQ]	$3,895	84.97%
⊞Olive Trading	$3,763	86.10%
⊞CCL Label - Columbus, OH	$3,722	87.21%
⊞Multi-Color Corporation (Collotype) - Ca	$3,288	88.20%
⊞CCL Label - Lumberton, NJ	$2,324	88.89%
⊞Pacific Southwest Container	$2,272	89.57%
⊞Boca Systems Inc.	$2,241	90.24%
⊞Eurostampa North America - OH	$2,127	90.88%
⊞Custom Pak - AR	$2,077	91.50%
⊞The Occasions Group Inc - FI - Roe Cres	$2,063	92.12%
⊞VisiMark, Inc.	$1,915	92.69%
⊞Diamond Packaging (Rochester)	$1,800	93.23%
⊞Euroma	$1,603	93.71%
⊞Newell Rubermaid S de RL de CV	$1,602	94.19%
⊞Spectrum Marking Materials LLC	$1,388	94.60%
⊞Wilson Sporting Goods Company	$1,368	95.01%
⊞Ideaman Inc.	$1,239	95.38%
⊞Foilmaster (Thailand) Ltd.	$1,198	95.74%
⊞Marking Systems	$1,162	96.09%
⊞ACCO Brands Corporation [HQ]	$1,132	96.43%
⊞The Occasions Group Inc - MN [HQ]	$1,123	96.76%
⊞Raypress Corporation	$1,082	97.09%
⊞Graphic Specialties Inc.	$1,058	97.40%
⊞Multi-Color Corporation - NC	$1,008	97.71%
⊞Monoflo International - NcGhee Rd VA	$731	97.92%
⊞Labels From the Heart LLC	$724	98.14%
⊞Dow Industries Inc.	$662	98.34%
⊞Jostens Inc. - Clarksville	$648	98.53%
⊞BIC Advertising & Promo Prod	$596	98.71%
⊞Pen Company of America LLC	$576	98.88%
⊞Springside Scientific	$520	99.04%
⊞TFP Universal a.s	$386	99.15%
⊞Sample Stamper	$304	99.25%
⊞Bovie Screen Process	$304	99.34%
⊞Freedom Printing	$282	99.42%
⊞E.J. Brooks Company	$278	99.50%
⊞Ennis Inc	$276	99.59%
⊞Morris Printing Group Inc.	$261	99.67%
⊞Cox Paper and Printing Co.	$199	99.72%
⊞Adstick Custom Labels	$182	99.78%
⊞Arkay Packaging Corp. (Roanoke)	$178	99.83%
⊞Embossed Creations	$85	99.86%
⊞Letterhead Press	$81	99.88%
⊞Bags and Boxes II Inc.	$70	99.90%
⊞Moquin Press	$69	99.92%
⊞Berryville Graphics - Consignm	$48	99.94%
⊟Artistic Die Mfg. Co. Inc.	$48	99.95%

(API Group 2020)

CHAPTER IV: ANALYSIS

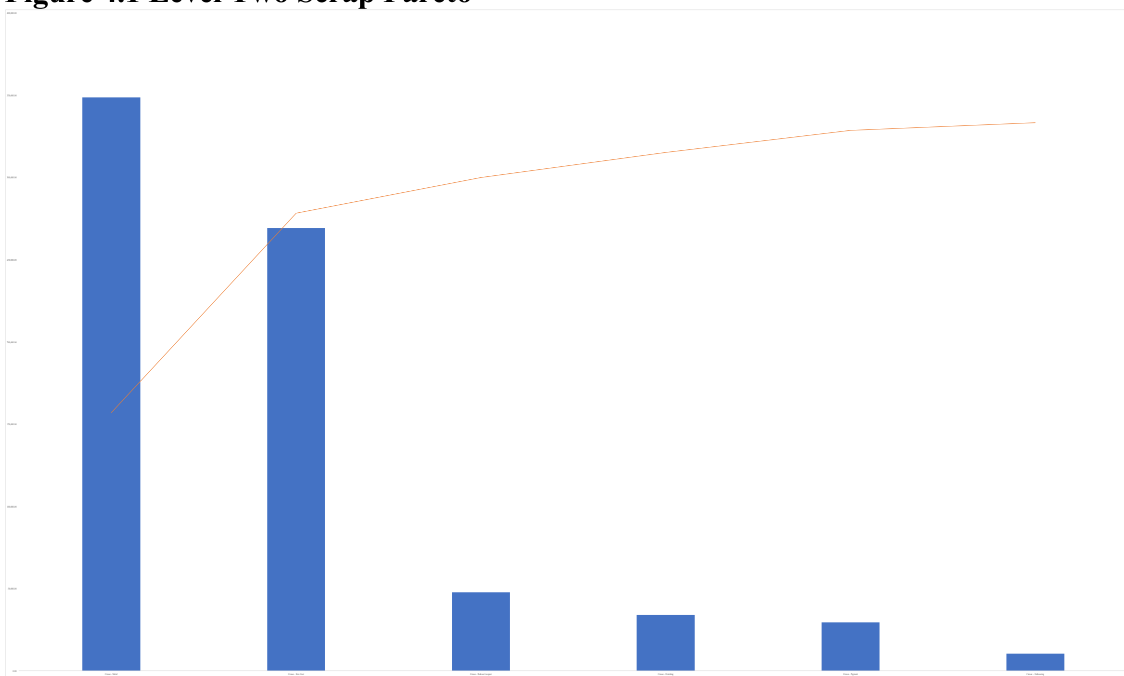
4.1 Details of Analysis

1. Better understanding of Metallizers and functionality of other equipment involved in producing foil.

Having established the primary issue with scrap accumulation as creases, senior management narrowed the search to figure out which piece of equipment created the most creases. When the data from the follow-up Pareto illustrated the Metallizer accumulating the most, management directed their primary focus to the Metallizer. The way the color coat peels from the polyester material resembled almost that of the tape test to measure the adherence of the wax lacquer to the polyester. Metallizer creases occur at any time but occur most when splices are not securely latched to each roll on both the unwind and rewind.

The QA and Research Departments on all shifts collected data from the equipment related to the Metallizer. The QA Manager assigned specialists to work with the Safety Manager to observe operator performance and behavior. This assured the operators were following the SOPs required to ensure the operators produced the desired results Current Best Approaches (CBAs). When setting the roller speeds, the results of the tension test, the splice can break depending on the speed. This test determines the durability of the roll and how much it can take before roll change. This type of defect is not only detrimental because it accounts for most of the HSF scrap percentage to date, but also because it is the most visible; customers continuously send back multiple rolls of pigment foil to the company to assess due to lack of quality of the product. In turn, this results in the loss of income from customers. In the event there is a potential correlation between operator performance and the compiled data, the follow up Pareto Diagram would help the operators to classify the amount going into the scrap bin. Figure 4.1 displays compares both observations: the creases at the Metallizer and other related equipment.

Figure 4.1 Level Two Scrap Pareto



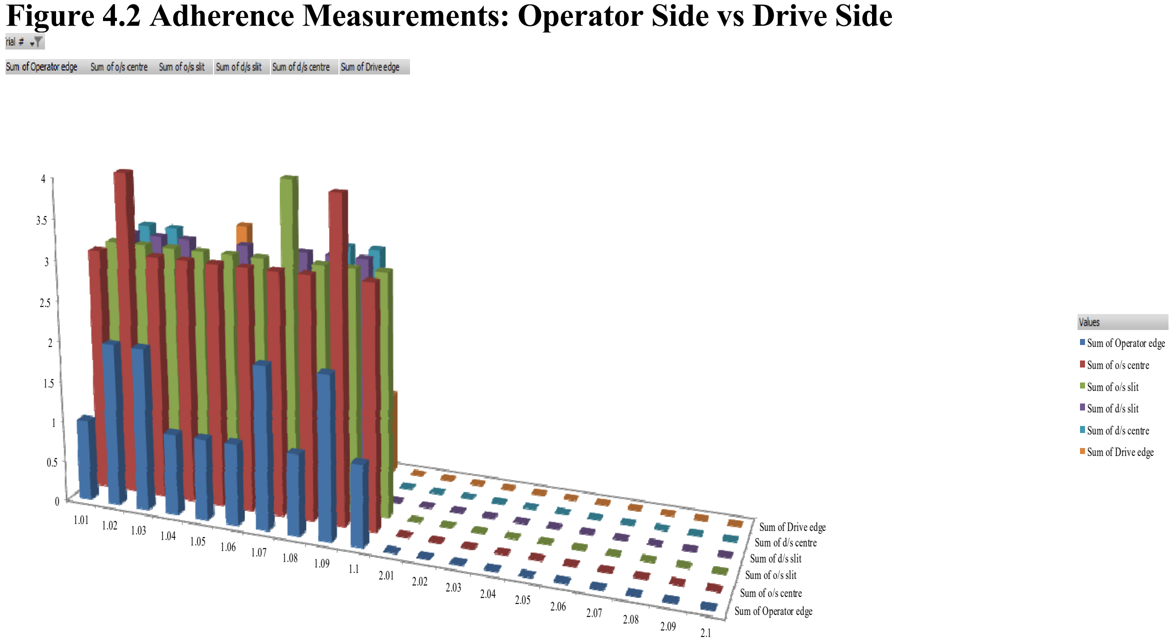
4.2 Fishbone Analysis

Fishbone Diagrams are commonly used during Kaizen events to help explain the causes and effects of quality problems. There are five key categories that ideas towards development. The top bones identify the People, Materials, and Methods while the bottom bones include issues cause by the natural environment or equipment. Management conducted a Fishbone discussion to brainstorm ways to decrease incidences of creases with pigment foil. To reiterate from the last section in Chapter 3, the first photo in Appendix C summarizes the outcome of the discussion. The top issues were tension settings on the rollers, Metallizer sanitation not accurate, possibility of incorrect scrap coding and tribal knowledge (poor training).

4.3 Fishbone Results

Management observed the top ideas from the fishbone discussion. In relation to the tension settings on the rollers, the QA specialist coordinated with the Maintenance Department to conduct test trials with varying degrees of tension to observe any fluctuation of the polyester feeding into the rollers. Figure 4.2 shows the data comparison. The red bars suggest more adherence is applied to the splice, which stables the polyester upon contact with the rollers. The front blue or back orange bars is where creases are most likely to appear, which indicates the process is vulnerable to splitting from the operator and drive side edges when ran through the Metallizer.

Figure 4.2 Adherence Measurements: Operator Side vs Drive Side



2. Establish the frequency of cleansing the equipment and revise sanitation methods to make enhanced process sustainable for other foil manufacturing companies.

Due to the inaccuracy of the cleansing process with the Metallizer, management worked to recreate the SSOP and apply all changes to the OAC guide and Problem Tag system as well; examples of each are depicted in both the second and third pictures of Appendix D. A routine cleaning regiment is needed to ensure the equipment functions efficiently. That is, minimizing the boats covered with excess slag so chamber runs at optimum functionality in Appendix A. The revised SSOP is necessary to abide by when cleansing the boats, the last photo in Appendix D portrays what the standard of clean looks like for the copper boats.

To minimize the chances of incorrect scrap codes entered in the system, the number of codes were reduced from more than 60 to 15 codes.

Tribal Knowledge, if not shared or passed down accurately, can adversely impact the business performance. The operator must reach a point of operating the equipment with the help of a trainer or mentor. All the veteran operators worked during A and B shifts while the inexperienced operators worked during the C and D shifts. A diverse mix of senior and junior operators during all shifts would help communicate the best practices among the operators.

4.4 Kaizen Analysis

3. Influence foil manufacturing plants to prioritize high-level maintenance tasks to be performed during TPM Kaizen event.

A seven-day Kaizen event was conducted to restore both Metallizers to a condition that would improve OEE. This includes a decrease in times of pump downs and web breaks; reducing the amount of Metallizer creases by 50 percent through equipment restoration and preventative maintenance (PM) routine implementation. The two Metallizers at API have been identified as the constraints impacting multiple value streams;

Vacuum Metallized Pigments (VMP), Hot Foil, Holographic, etc. The following below were objectives established for the TPM Kaizen to gain understanding of this defect occurrence:

- Replace the tension motor for bow roller and booster pump number 2 on the Metallizers upon arrival of replacement during Kaizen
- Install bow roller for the Generalized Vacuum Equipment (GVE) Metallizer and inspect tension motor for bow roller during Kaizen
- Interpret the roller wiring correctly with help from the motor repair shop and reinstall Metallizers during Kaizen

The run times for both Metallizers combined are less than 50 percent. The Bobst Metallizer is the workhorse for VMP while the GMV runs the other SKU's. The Bobst K5000 series Metallizer showed many signs of accelerated deterioration during production with a low average OEE scoring of less than 40 percent. There is one vacuum booster pump which is inoperable, a bow roller tension motor which is inoperable, much deterioration of the equipment, much contamination of the bearing journals and other areas. This equipment is a capacity constraint even at full effectiveness.

CHAPTER V: CONCLUSION AND RECOMMENDATIONS

5.1 Kaizen Results

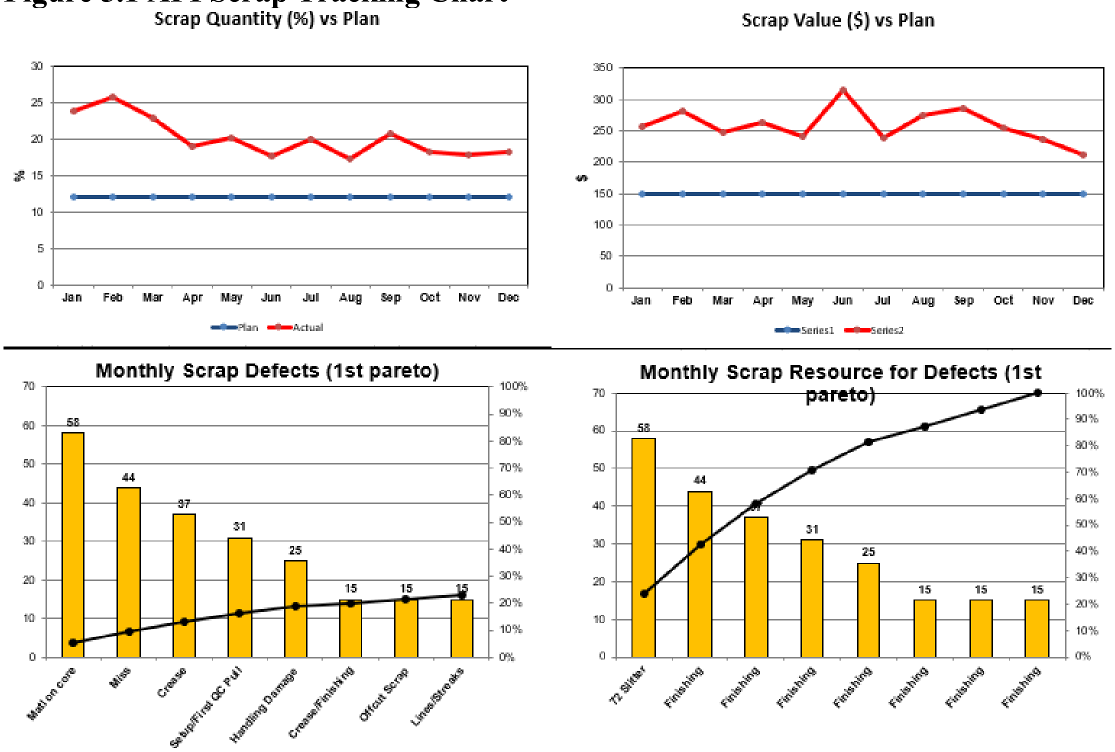
The study results were not enough to reach the company goal to reduce the level of scrap to levels to 10 percent. Although, Kaizen turned out to be successful and effective; the results covered a short period of time. Average pump down time before the TPM Kaizen was 31 minutes. After the Kaizen, the average pump down ended at 15 minutes; resulting in a significant improvement. Average vacuum loss frequency during pump down before TPM Kaizen was 1 for 2. Average vacuum loss frequency during pump down time reached 0. Average square meters scrapped for creases before the TPM Kaizen equaled 192,000 square meters per month. With the improvements made to pump down times, scrap accumulation decreased by 14 per cent following the tests and was sustained throughout that week of testing; amounting to a total accumulation of 123,000 square meters the following month, which was a 36 percent reduction.

5.2 The Outcome

Will applying primary focus to the Metallizers reduce scrap accumulation for manufacturing plants in the foil industry? As stated in Chapter 4, the equipment is a capacity constraint even at full effectiveness. Some takeaways to discuss from the study are how imperative Metallizers are during production and all the care programs needed to maintain production. There is high demand for metallic foil to enhance the appeal of packaged products. It is difficult for wholesalers to provide the foil at the rate that customers request for their customizations. Since foil can be applied to multiple canvases and substrates, API's have a number of packaging and packing options.

Downtime on a Metallizer is costly. It is imperative that all the methods stated in the documentations is applied to the Metallizer held to a standard that allows for quality foil to be created and distributed. Figure 5.1 portrays a better illustration to pair the context to; scrap levels impacted sales at API even prior to this 2019 sales.

Figure 5.1 API Scrap Tracking Chart



(API Group 2020)

The Kaizen changed the company's culture. It reinforced the awareness of operators to maintain and monitor equipment and helped to codify the tribal knowledge that would others misplaced or lost. This suggest the importance of SOP, SSOP CBA processes required need updating at a frequency. This would help to onboard new hires in the ways of help improve productivity.

The advantages of implementing the Kaizen resulted in the more output from the diffusion pumps, which in turn, created excellent coat uniformity and deposition quality for the aluminum to be applied onto the polyester. It also allows the drummer roller to increase process speed, acquiring aluminum at a rapid rate. The cons consist of timing with repairs and lack of attention to the equipment. Lack of compliance towards the guidelines in the documentation resulted in accelerated equipment deterioration, creating costly repairs that are not expected to happen so sudden.

When maintaining the Metallizer equipment, the best practice is to adhere to a routine maintenance program and to be ready for the more common failures. A closer look into the schematics, there were key parts to the Metallizer that maintenance confronted API Management about aside from the rollers; the chamber, valves, pumps, feedthroughs, gauges/electricals, and more. If not abided by methodically, then scrap can easily take over in the next coming years.

5.3 The Chamber

Chamber leaks can occur from the chamber due to abuse or poor housekeeping. It is important to wash the door gasket with a soft brush or fresh cloth each cycle in order to get rid of any dirt of debris or metal flake, breaking the gasket. Also, examine gaskets weekly for outward cuts because they can cause drips. Keep gasket lightly greased with vacuum grease and replace at regular intervals or if gasket becomes brittle. By checking safety interlocks and emergency vacuum breaks, proper operation is ensured. In addition, cleaning the porthole after each cycle prevents hard to clean (HTC) buildups. Prevent use of caustics because they trap water; avoid the usage of abrasives, these cloud the porthole overtime. A plastic louver is recommended to keep portholes sanitized.

Excessive layers of deposits inside the chamber hold water vapor and increase the gas load of the chamber leading to longer pump downs and discovered parts. The drip trough must be cleaned frequently and clean the floor of the chamber daily. Strip the inside of the chamber and the carriages on a regular basis. A Metallizer going daily for continuous 8-hour shifts should be cleansed every month, *i.e.* caustic, wire brushes, sandblast equipment, etc. Upon completion, the caustic residue should be thoroughly rinsed and dried completely avoiding discolored parts. All feedthroughs and ports should be sealed to avoid contamination with blast media, caustic or deposition residue. If feasible and applicable to manufacturing process, removable shields, and liners for the chamber would be preferred due to chemicals worked with and its elements; boron nitride or graphite discharge coatings can be used to coat tidy surfaces, making them easier to clean (Service 2020).

5.4 The Valves

Valves should be kept clean and in working order. For optimum success, inspect all airline oilers are properly adjusted and filled to insure enough lubrication of air cylinders. Check high vacuum valves weekly for amassed chips that prevent valves from completely closing; if necessary, wipe the entire plenum area clean with soft solvent. On a monthly basis, raise the high vacuum valve and remove the oil which has accumulated under the valve and on the sides of the diffusion pump to about the level of the pump's top jet. Afterwards, disassemble the valves every six months to cleanse and inspect for wear; all valve seals must be replaced annually (Service 2020).

5.5 The Pumps

The mechanical pump is dependent on airtight seals within its own moving parts. Oil, providing the tight seal, lubricates the moving parts and holds water and debris in suspension. Many mechanical pump problems can be solved simply by flushing the pump and replacing the oil; checking oil levels daily also helps. Proper usage of the pump's gas ballast will minimize contamination from water vapor. When replacing oil, operate the pump until oil is hot, then drain and rotate the pump, expelling any trapped oil. Recommended maintenance for mechanical pumps includes replacing exhaust valve springs, exhaust valve discs, the solenoid valve, the spring, and O-ring seal in the gas ballast check valve and pump every six months. All the belts must be checked as well. Check and drain the oil mist separator and check the input and output temperatures on its water-cooling loop if pump is so equipped.

The diffusion pump has no moving parts, which makes it rather easy to maintain. Check sight glass monthly for potential loss of fluid. Note that slight discoloration of the oil does not affect its performance. A more thorough check should be performed at least annually. Check inlet and outlet water temperatures, including the proper cooling water flow. Make sure to inspect the functionality of the heaters; occasionally the pumps will need cleansing. By no means, expose scorching silicone oil to oxygen or its protective gear. It is important to scrub down the jets and interior with alcohol or acetone and allow to dry. Clean any traps, baffles, and cold caps above the pump and be mindful of damaged O-rings (Service 2020).

5.6 Feedthroughs, Gauges, and Electricals

For stationary feedthroughs, check fittings every six months for tightness and leaks. If feedthroughs contain moving parts, check bimonthly for tightness and leaks. If necessary, lubricate with high vacuum grease. Keep a separate gun for high vacuum grease to avoid contamination. Check electrical feedthroughs for tightness and insulation. Check faces of electrical contacts in chamber for pitting and warpage. Replace or reface as needed. If spring loaded, check springs for fatigue or loss of temper.

For gauges and electricals, check for corrosion and tightness of all electrical connections every six months. It is important to check vacuum gauges annually for enough calibration. This can be done by replacing the gauge with one known to be properly calibrated or by employing a gauge calibration service company (Service 2020).

5.7 Miscellaneous

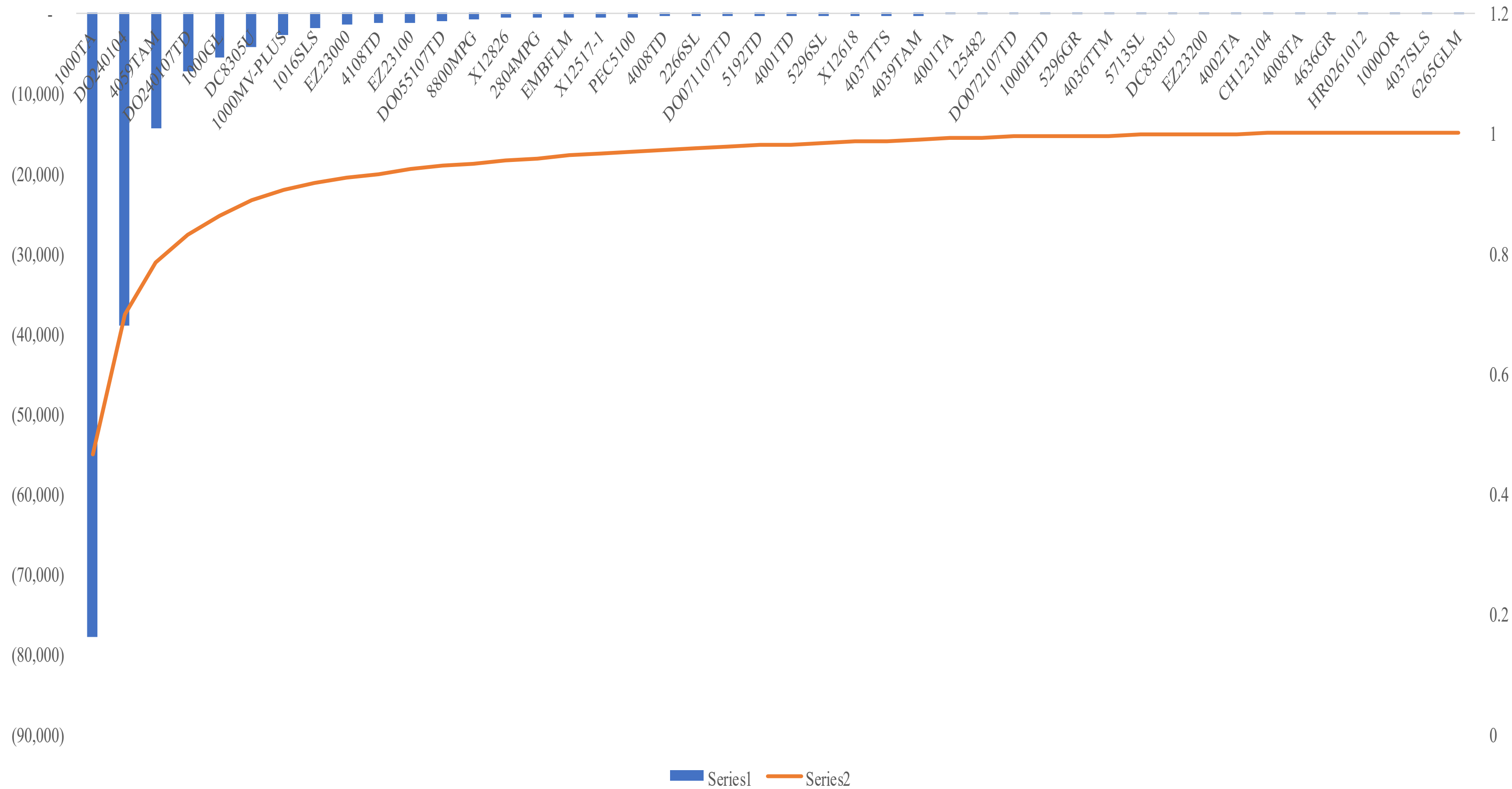
Remove filament posts annually and sand contract areas with fine sandpaper to remove oxidation and deposits. Replace worn filament post hardware; adjust for proper spacing and alignment. Also, stocking spare parts are mission critical; especially those replaced frequently or hard to acquire. Some suggestions include: pump fluids, vacuum grease, rubber sheet for quick fixes, belts, gaskets, hose clamps, fuses, control panel lights, vacuum sealant paint, filament posts, door gaskets, and bus cables. Acquiring in bulk and used suggestively with each formulation, as a bonus, will keep cycle times and scrap occurrences to a minimum (Service 2020).

5.8 The What-Ifs

One thing I would have taken into consideration with this study is the possibility of conducting compare analysis of the Metallizer. By comparing data, the creases from the second highest accumulator in scrap (material left on the core) or even the third highest contributor (print performance) and contrasting the data with the standard. Although, Metallizer creases had the highest impact in scrap, there may very well have been a correlation amongst all three top categories, and an effective solution to perhaps remedy all three categories simultaneously. Something else I could have investigated would have been to see which commodity created the most Metallizer creases and analyze that specific foil from the specific wax/lacquer applied at the laminator all the way to the end of the process at the size coaters. Figure 5.3 provides an example of how to assess which commodity accumulated the most offcut scrap, which is another defect aside from Metallizer creases.

Based upon the results of the study, we can expect the impact Metallizers have on the foil manufacturing process to always be of priority. The quality of the Metallizer equipment relies solely on the condition that management dictates the operators keep it in, whether through informative documents to assist operators or successful TQC programs. To impact the condition of the Metallizers is a team effort; although, it comes with their job description, maintaining the quality is not just operator managed. The accountability starts with management and then progresses to the team, in which, management spreads that level of accountability to the operator who converts that to his or her responsibility in order to be well versed with the equipment. In conclusion, companies succeed based on how well they apply and educate their principles to the operators who feed off their guidelines, allowing them to lead by example and take on more promising roles in the future that would possibly allow them to be role models in the industry.

Figure 5.2 Offcut Scrap Measurements assessed by Commodity (SKU #)



REFERENCES

AB, Point Scandinavia. 2017. *Hot-Stamp Decoration.* 3 25. http://www.pointscandinavia.com/en/hot-stamping-technique/.

API Group. March 19. https://apigroup.com/.

Association, The Aluminum. 2020. *Pigments and Powder.* 3 19. https://www.aluminum.org/industries/processing/pigments-powder .

Feuerstein, Kurt. 1942. *Espacenet.* February 17. https://worldwide.espacenet.com/publicationDetails/biblio?FT=D&date=19420217&DB=EPODOC&locale=&CC=US&NR=2273700A.

Guoping, Mo. 2010. *Pigment foil and Method of Preparing the same.* May 12.

Herbst, Willy, and Klaus Hunger. 2004. *Industrial Organic Pigments.* Hoffheim, Germany: Wiley-VCH Verlag GmbH & Co. KGaA.

Investing. 2014. *API Overview.* March 13. https://www.investing.com/equities/api-group-plc.

Mapes, John. 2002. *Performance Trade-Offs in Manufacturing Plants.* Cranfield, England: Cranfield University.

McManus, George. 1991. "Small Aluminum Companies Speed Up, Spread Out." In *Small Aluminum Companies Speed Up, Spread Out.* 22. ProQuest LLC.

MoreStream. 2020. *MoreStream.* https://www.moresteam.com/toolbox/fishbone-diagram.cfm.

Phillips, Roger W. 2001. *Multi-Layered Magnetic Pigment and Foil.* 4 27. https://patents.google.com/patent/JP2009119875A/en.

Presentation Folder, Inc. 2020. *Digital Raised Foil vs Foil Stamp Emboss.* http://blog.presentationfolder.com/design-tips/raised-foil-folders/.

Service, Midwest Tungsten. 2020. *Midwest Tungsten Service*. www.tungsten.com.

Vorne. 2019. *Lean Production*. https://www.leanproduction.com/kaizen.html.

Weiss, Herbert L. 1977. *Coating and Laminating Machines.* Milwaukee, Wisconsin: Converting Technology Company.

Works, Emerald. 2020. *Mindtools.* January 1. https://www.mindtools.com/pages/article/newTED_01.htm.

Zafar, Muhammed. 2019. *Mathematical Analysis of the Coating Process over a Porous Web Lubricated with Upper-Convected Maxwell Fluid.* May 12. https://www.mdpi.com/2079-6412/9/7/458.

APPENDIX A

Copper Boats above the Hearth (Trough) melting Aluminum Wires

Example of Metallizer Creases and Impact on Foil Product

Correct Way to Splice New Full Roll to Old One to Maintain Production

Example of Customer Foil (Bottom Full Rolls) and Scrap (Top Half Rolls)

APPENDIX B

Scrap Accumulation via Consumer Complaints by Grade of Foil

Row Label	USD Under Clain	Sum of Cust. Claim Value (Materi
GR	$107,209	32.08%
HR	$31,821	41.60%
DO	$26,517	49.54%
EZ	$25,856	57.27%
SL	$21,999	63.86%
TA	$19,770	69.77%
DC	$16,376	74.67%
WI	$14,422	78.99%
TD	$14,322	83.27%
TT	$9,688	86.17%
GL	$8,890	88.83%
X	$6,805	90.87%
CH	$6,720	92.88%
SG	$5,387	94.49%
KK	$3,604	95.57%
FO	$3,252	96.54%
	$3,112	97.47%
PG	$2,091	98.10%
PMV	$1,603	98.58%
TC	$1,388	98.99%
RI	$1,128	99.33%
DS	$1,058	99.65%
XO	$1,041	99.96%
OR	$99	99.99%
Misc	$35	100.00%
(blank)		100.00%
DP	$0	100.00%
Descriptions		100.00%
Grand Total	$334,194	

APPENDIX C

Ideas Generated from Fishbone

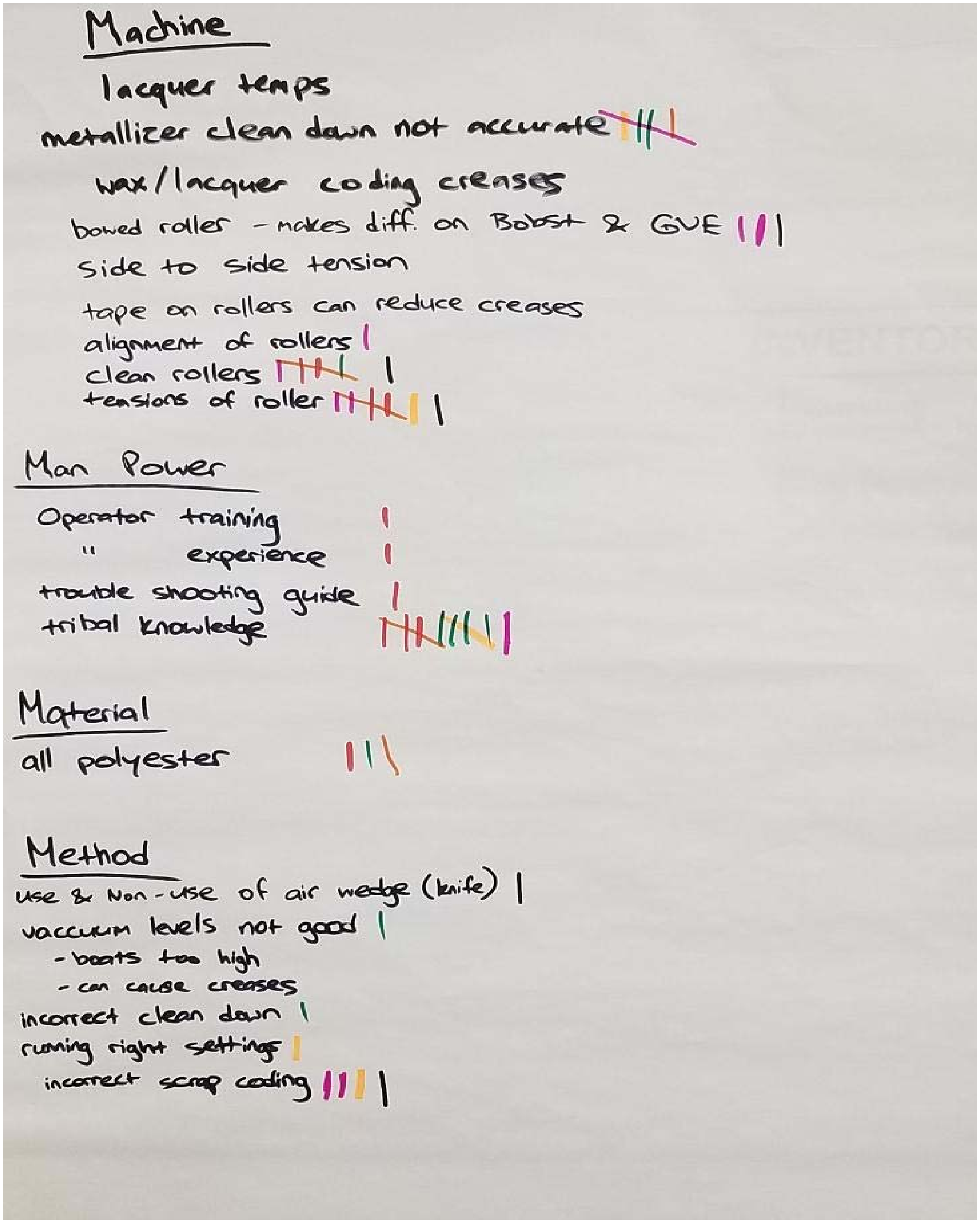


Table for Level One Scrap Pareto Diagram

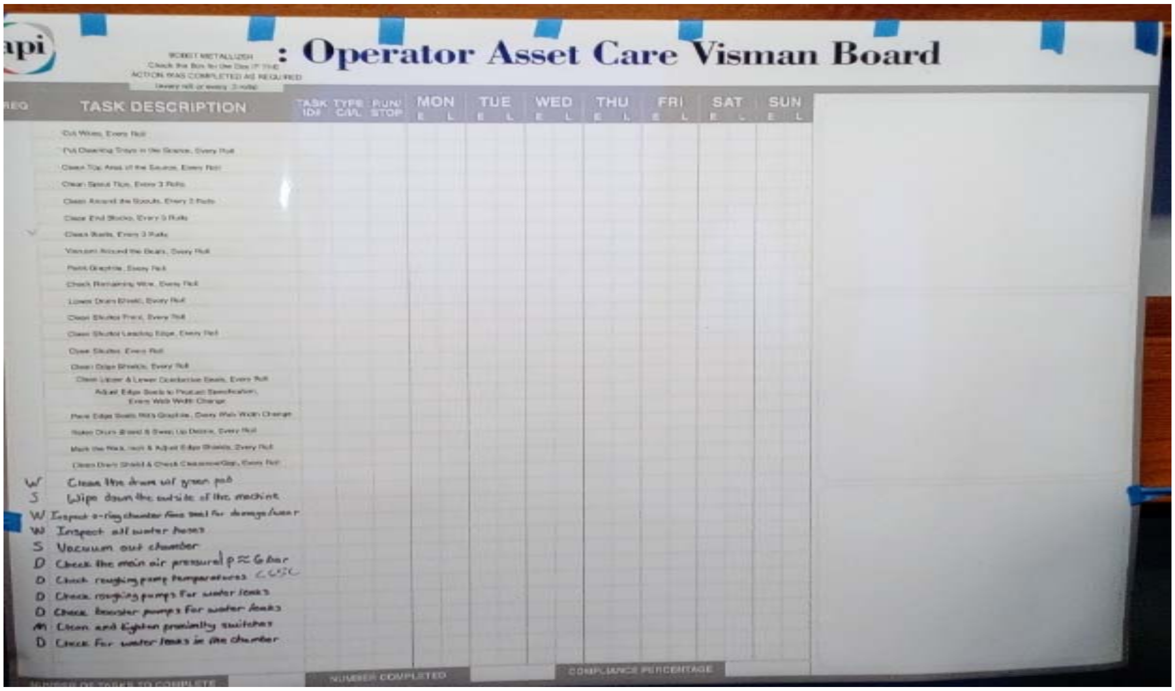
Defect	Scrap Amount (Square Meters)	% Complaint	Cumulative %
Creases	740,000	26%	26%
matl on core	341,688	38%	12%
print performance	330,942	49%	12%
set up - first QC pull	307,217	60%	11%
miss	191,908	67%	7%
coat weight - pig release & size	173,477	73%	6%
off-cut	171,412	79%	6%
lines - pig release laq size coat	160,636	85%	6%
coat weight	142,000	90%	5%
handling damage	48,721	91%	2%
misc stop - start metal	38,338	93%	1%
misc stop - sizing	37,311	94%	1%
finishing machine setup	34,821	95%	1%
pin holding	29,216	96%	1%
scratch	22,577	97%	1%
customer overage	22,000	98%	1%
metal transfer	21,500	98%	1%
delamination	19,043	99%	1%
misc stop - release laq	12,700	100%	0%
mill join splice	12,328	100%	0%
Total	**2,857,835**		100%

Table for Level Two Scrap Pareto Chart

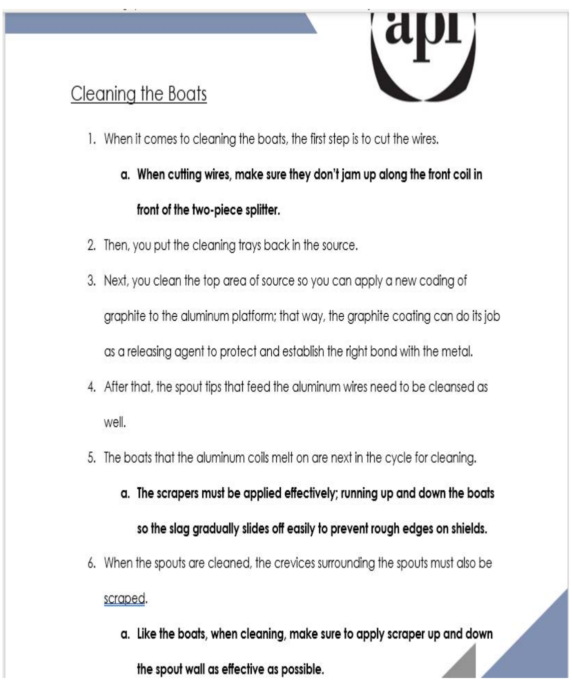
Defect	Scrap Amount (Square Meters)	% Complaints	Cumulative %
Crease - Metal	348,654.91	0.471	0.471
Crease - Size Coat	269,424.61	0.835	0.364
Crease - Release Lacquer	47,880.13	0.900	0.065
Crease - Finishing	34,088.34	0.946	0.046
Crease - Pigment	29,447.42	0.986	0.040
Crease - Embossing	10,502.13	1.000	0.014
Total	**739,997.55**		

APPENDIX D

Operator Asset Care Chart

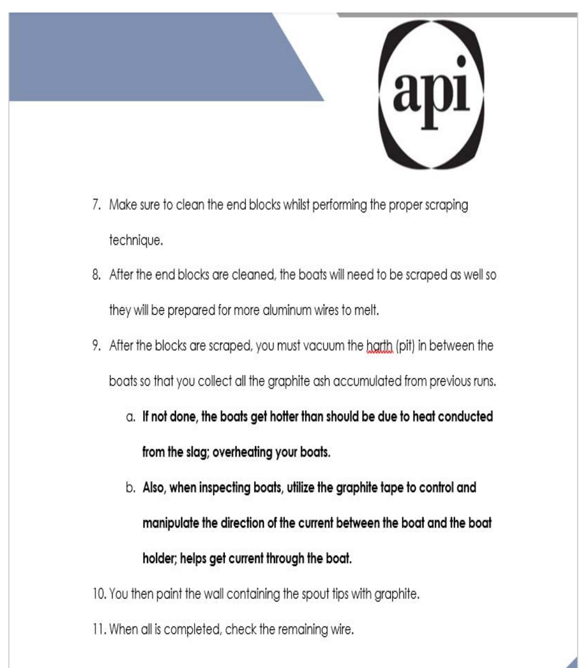


Revised SSOP for Production



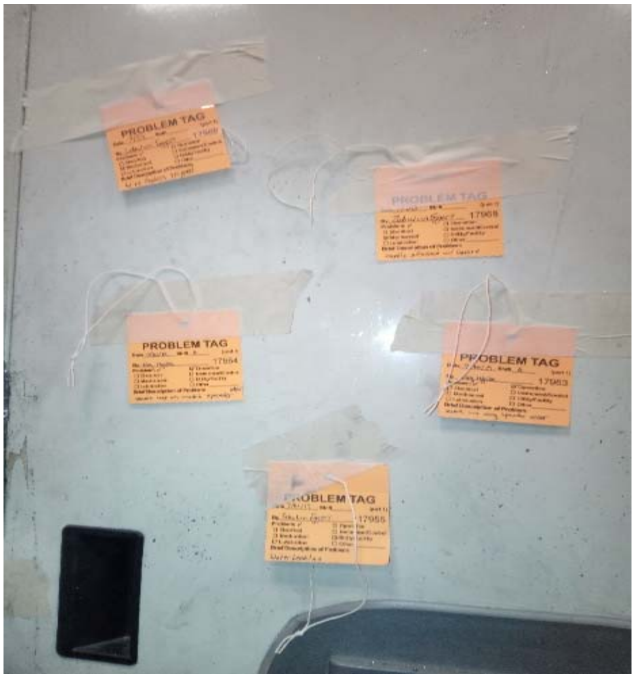
Cleaning the Boats

1. When it comes to cleaning the boats, the first step is to cut the wires.
   a. **When cutting wires, make sure they don't jam up along the front coil in front of the two-piece splitter.**
2. Then, you put the cleaning trays back in the source.
3. Next, you clean the top area of source so you can apply a new coding of graphite to the aluminum platform; that way, the graphite coating can do its job as a releasing agent to protect and establish the right bond with the metal.
4. After that, the spout tips that feed the aluminum wires need to be cleansed as well.
5. The boats that the aluminum coils melt on are next in the cycle for cleaning.
   a. **The scrapers must be applied effectively; running up and down the boats so the slag gradually slides off easily to prevent rough edges on shields.**
6. When the spouts are cleaned, the crevices surrounding the spouts must also be scraped.
   a. **Like the boats, when cleaning, make sure to apply scraper up and down the spout wall as effective as possible.**



7. Make sure to clean the end blocks whilst performing the proper scraping technique.
8. After the end blocks are cleaned, the boats will need to be scraped as well so they will be prepared for more aluminum wires to melt.
9. After the blocks are scraped, you must vacuum the harth (pit) in between the boats so that you collect all the graphite ash accumulated from previous runs.
   a. **If not done, the boats get hotter than should be due to heat conducted from the slag; overheating your boats.**
   b. **Also, when inspecting boats, utilize the graphite tape to control and manipulate the direction of the current between the boat and the boat holder; helps get current through the boat.**
10. You then paint the wall containing the spout tips with graphite.
11. When all is completed, check the remaining wire.

Problem Tag System



Example of Clean Boats for Aluminum Wire to Melt On

APPENDIX E

Glossary

Acrylic Resin – Resins widely used in the wood coating sector being suitable for the preparation of several coatings type involving different technologies (solvent, water, Radcure and powder).

Athlone Press Industries (API) – Pigmentation Industry founded in Germany in the early 1900s.

Booking Code List – List that finance department utilizes to categorize commodity SKU's based on profit and sales.

Bottleneck – Analogy in relation to capacity constraint that comes from the area at the top of the bottle that limits the flow coming out. No matter how big the rest of the bottle is, liquid will only flow out as fast as the size of the neck will allow.

Current Best Approach (CBA) – Method or technique that has been generally accepted as superior to any alternatives because it produces results that are superior to those achieved by other means, or because it has become a standard way of doing things.

Cellulose Acetate – A synthetic compound derived from the acetylation of the plant substance cellulose; resin spun into textile fibers known variously as acetate rayon or triacetate.

Chalking Silicon Dioxide – A silicon oxide made up of linear triatomic molecules in which a silicon atom is covalently bonded to two oxygens.

Chamber – Heating platform necessary to apply aluminum to the polyester running through the rollers.

Chloroprene Rubber – Synthetic rubber has a good balance of properties, including good chemical stability and usefulness over a wide temperature range.

Cold Stamp Foil – Modern method of printing metallic foil on a substrate in order to enhance the aesthetic of the final product.

Creases – Costly defect on material that appears as streaks along the foil, damaging the lacquer.

Delpro – Coating laminator at API that applies wax and lacquer to the polyester running through the rollers.

Digital Raised Foil – Foil placed over raised UV coating during the offline (post-print) process. The specialty coating gives the effect of embossing without compromising the stock and is valued in the industry for its vogue factor.

Epicore – Manufacturer of Tropos.

Ethenoid Resin – Made from monomer or linear polymers to yield cross-linked structures as a result of double bond polymerization.

Gauges – Meters on tanks or compression systems that ensure both quality and safety remain constant.

Hazard Analysis Critical Control Point (HACCP) – Management system in which food safety is addressed through the analysis and control of biological, chemical, and physical hazards from raw material production, procurement and handling, to manufacturing, distribution, and consumption of the finished product.

Hot Stamp Foil – Printing method of relief printing in which pre-dried ink or foils are transferred to a surface at high temperatures.

Just in Time (JIT) – Workflow methodology aimed at reducing flow times within production systems, as well as response times from suppliers and to customers.

Kaizen – Strategy where employees at all levels of a company work together proactively to achieve regular, incremental improvements to the manufacturing process.

Metallizer – Equipment essential to the foil manufacturing process that provides outstanding performance at high speed when applying aluminum to the polyester.

Mica Powder – Superb resin dye colorant and will give a shimmering and pearlescent look to your handmade products.

Operator Asset Care (OAC) – Essential part of the 'world class' approach to maximize the effectiveness of operational assets and processes within companies.

Pareto Diagram – Principle that serves as a general reminder that the relationship between inputs and outputs is not balanced; also known as the Pareto Rule or the 80/20 Rule.

Peaslee – Warehouse where potential reusable foil is stored for API, as well as facility where scrap can be split into smaller dimensions to serve certain customer requests.

Polyethylene Terephthalate (PET) – An optimized coating process used to ensure that the pores of the membrane are not occluded.

Polyethylene Wax – An ultra-low molecular weight polyethylene consisting of ethylene monomer chains on-purpose production used as a byproduct of polyethylene production.

Polytype – Laminating coater used for API production.

Polyvinyl Butyral – Acetal that is formed from the reaction of an aldehyde and alcohol.

Problem Tag – Tool used to identify problems at their exact locations for faster reprimanding of the issue.

Pumps – Air compressors needed to maintain accurate atmosphere for polyester to run through and provide more output in production, such as booster and diffusion pumps.

Standard Operational Procedures (SOP) – Document providing explicit directions for completing a certain task.

Soy lecithin – Food additive extracted from raw soybeans.

Splice – Attaching the beginning of a new polyester roll at the laminator coaters (or foil roll at the Metallizer or size coater) to the core (or the remaining material on the core) of the old roll to ensure the continuation of production.

Sanitation Standard Operational Procedure (SSOP) – Document providing explicit directions for completing a certain task regarding sanitation.

Steel Partners – Parent company for API Americas.

Total Quality Control (TQC) – Methodology in terms of putting **quality** into place, both within the product and within the system to bring forth, sustain, and retire the product.

Tribal Knowledge – Knowledge that fails to be passed down in relation to anything that assists with the benefit of something; tidbits considered as either lost or forgotten.

Tropos – Database that collected all data with respect to this study.

Vinyl Cellulose – Key ingredient in its polymer dispersions from cellulosic materials.

Weigh Dump – Area in manufacturing plant where scrap bins are taken, weighed on the scale for data extraction, then shipped off to either recycle dump or stored at Warehouse.