2010-01-01

Scrap Reduction Model: By Combination Of Dmaic And Design Of Experiments

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SCRAP REDUCTION MODEL: BY COMBINATION OF DMAIC AND DESIGN OF EXPERIMENTS

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DEDICATION

Dedicated with lots of love to,

My father, mother, brother, sister and my friends for standing by me every step of the way.

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by

ANOOP J. RANDIVE

THESIS

Presented to the Faculty of the Graduate School of

The University of Texas at El Paso

in Partial Fulfillment

of the Requirements

for the Degree of

Master of Science

Department of Industrial Manufacturing and Systems Engineering

THE UNIVERSITY OF TEXAS AT EL PASO

December 2010

ACKNOWLEDGEMENTS

I would like to acknowledge the advice and guidance of Dr. Jianmei Zhang committee chairman. I also thank the members of my graduate committee Dr. Bill Tseng and Dr. Wei Qian for their guidance and suggestions, especially Dr. Jianmei Zhang, for all her advice, encouragement, assistance and support. I would also like to thank the Coleman Cable. Inc., especially Martha Luna. Special thanks go to Martha Luna, without whose knowledge and assistance this study would not have been successful.

I would like to thank my family members, especially my mother for supporting and encouraging me to pursue this degree.

Last but not least, those friends who have stood by me day and night in order to make this project successful. Without their support and encouragement, I would not have been able to complete this project.

ABSTRACT

This project deals with the experimentation which took place at a cable manufacturing company. The thesis describes and summarizes the various strategies and techniques that has been applied and practiced for scrap reduction. DMAIC and Six Sigma Technology has been proven very help full in order to reduce scrap to a major extent. DMAIC help to identify areas in process where extra expense exist, identify the biggest impact factor related production expenses, introduce appropriate measurement system, optimize process and reduce production cost and time. Many issues were detected by the production, such as a lack of a unified procedure for documenting scrap, as well as cable manufacturing concerns suggested by new and experienced operators. Another concern was how best to focus on insulated wire scraps, the reason for scraps and how to correct such things and prevention. The research task of accurately measuring the scrap by improving scrap logistic proved to be very successful in order to measure scrap accurately. A statistical approach has been taken to find the factors affecting the scrap.

The results indicate a precise way for scrap reduction. The results starts from the plant level scrap, in comparison with the scrap in previous months in this year.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

1.1 Background of Company

Coleman Cable, Inc. is a leading manufacturer and innovator of electrical and electronic wire and cable products for the security, sound, telecommunications, electrical construction, for the retail, commercial, industrial, irrigation, HVAC and automotive markets. It provides one of the most extensive and diverse lines of electrical, electronic and assembled wire and cable products in the industry [1]. Examples of the products include flexible cables designed for aircraft boarding bridges, power and control cables for wind turbines, high performance military cables for harsh environments, submersible cables for marinas and fountains, lead wire for panel builders, and power cable for sports lighting systems. Figure 1 describes three major application areas of wire and cables produced by Coleman Cable, Inc.

Figure 1: (a) Application of wires in Automotive Manufacturing Industry
(b) Application of wires in Security and home Technology
(c) Application of wires in construction: industrial, commercial, residential

1.2 Statement of Problem: Scrap and Scrap Reduction

In this case the wire produced which is out of dimensions or has defects and cannot be used for any application is called scrap.

It is that the raw material costs are increasing every day budgets and the production costs are tight. The error in the process produces scrap, which means zero income out of scrap. Unfortunately this drives up production cost and adds time to the production schedule. Scrap can be produced due to many of issues, including mistakes and design inaccuracies in the manufacturing process and sometimes due to the lack of right use of man power and machine and inappropriate planning. The more the scrap, the higher the product cost will be. Moreover the energy used to machine scrapped parts is completely wasted and further drives up the cost.

Figure 2 (a) is an example of the insulated wire scrap produced during the manufacturing of wire. This type of scrap is very common during machine set up and color change. The insulated scrap wire contains approximately of 25% compound and 75% copper.

Figure 2: (b) Is an example of purge scrap also generated during a machine set up and color change. The purge scrap is 100% compound.

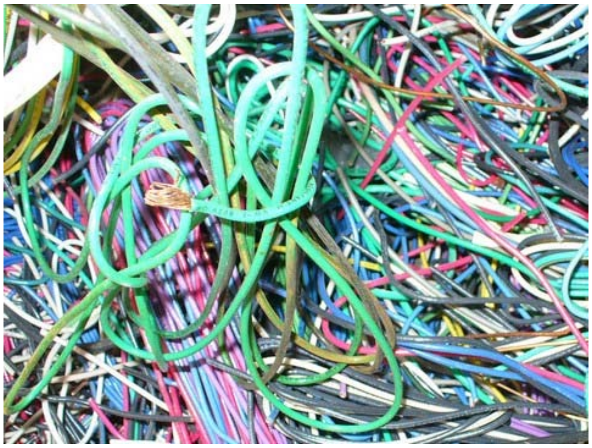

Figure 2: (a) Example of insulated wire scrap

Figure 2: (b) Example of purge scrap

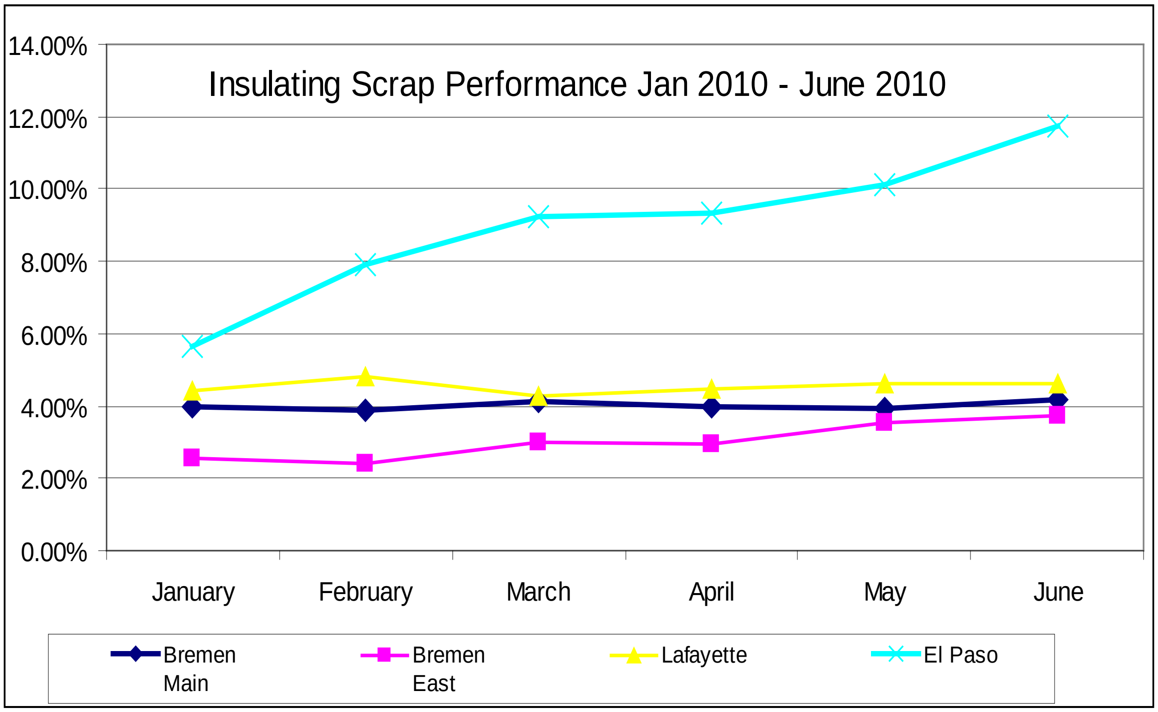

Figure 3: Comparison of insulating scrap performance of all CCI manufacturing units

There is critical need of scrap reduction in El Paso unit. Since the beginning of 2010, the El Paso manufacturing unit has had more scrap than all the other manufacturing units. The scrap numbers from January to May were incorrect as there was no system in place to report and record scrap accurately. And the numbers showed in Figure 3 from the production record. The major objective of the study is two. First, an accuracy reporting system for scrap is needed. And second, strategies to reduce the production time, cost and significant scrap reduction are required.

CHAPTER 2: LITERATURE REVIEW

This chapter describes and summarizes various strategies and the techniques that has been applied and practiced to reduce scrap. Among them, Six Sigma Methodology is one of the major techniques used in the practice to reduce scrap.

2.1 Six Sigma Methodology

Six Sigma is an approach towards quality assurance, quality management and continuous quality improvement and its application can be wide including scrap reduction. The main objective of using Six Sigma Methodology is to reach level of quality and reliability with low scrap that will satisfy and even exceed demands and expectations of today's demanding customer of cable and wire for automotive industry [2].

A term "Sigma Quality Level" is used as an indicator of a process goodness. Lower sigma quality level means greater possibility of defective products, while, higher sigma quality level means smaller possibility of defective products within process [3, 4].

If Sigma quality level can be reduced to six, chances for defective products are 3.4 parts per Million (ppm) [5, 6]. One ppm is 1 part in 1 million or the value is equivalent to the absolute fractional amount multiplied by one million [7]. Tools and methodology within Six Sigma [8, 9] deal with overall costs of quality, both tangible and intangible parts, trying to minimize it, while, in the same time, increasing overall quality level contribute to profit [10].

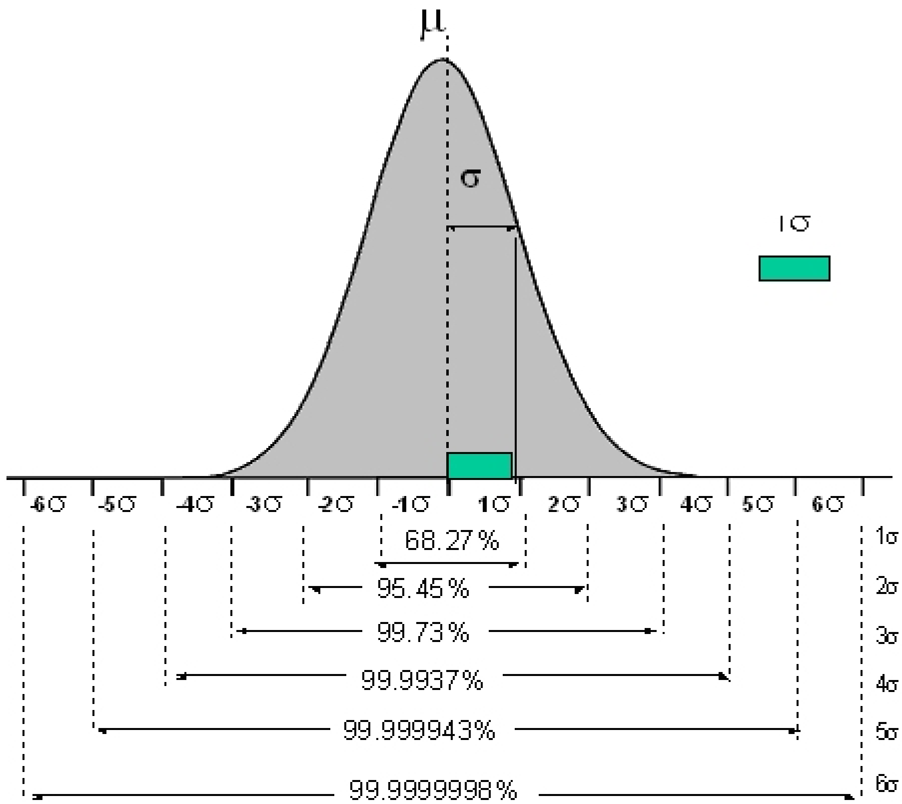

Figure 4: Approximation of what sigma variability looks like [10]

Six Sigma means measure of quality that strives for near perfect product. It is a disciplined, data-driven approach and methodology for eliminating defects (driving toward six standard deviations between the mean and the nearest specification limit) in any process -- from manufacturing to transactional and from product to service.

The statistical representation of Six Sigma describes quantitatively how a process is performing. Application of Six Sigma can be on the process or product for reduction of production cost, scrap reduction etc. The fundamental objective of the Six Sigma methodology is the implementation of a measurement-based strategy that focuses on process improvement and variation reduction through the application of Six Sigma improvement projects. This is accomplished through the use of two Six Sigma sub-methodologies: DMAIC and DMADV. The Six Sigma DMAIC processes (define, measure, analyze, improve and control) is an improvement system for existing processes falling below specification and looking for incremental improvement. The Six Sigma DMADV process (define, measure, analyze, design and verify) is an improvement system used to develop new processes or products at Six Sigma quality levels. It can also be employed if a current process requires more than just incremental improvement [11].

Companies save an average of $100,000 to $200,000 per implemented improvement project, for example, General Electric (GE) increased communication satellites' usage from 63% to 97% realizing a revenue increase of $1.3 million/year. GE changed the original Motorola Six Sigma model to a project based approach that had executive buy-in. GE saved $2 billion during 1999. Companies that have produced good results, have invested adequate resources, provided extensive training and involved many individuals [12].

2.2 Prevention of Water Tree

Water tree has always been an area of concern in making cables and wire. There are XLPE (Cross Link Polymer) insulations that can be designed to inhibit the growth of water trees, allowing for even greater reliability for distribution class cables.

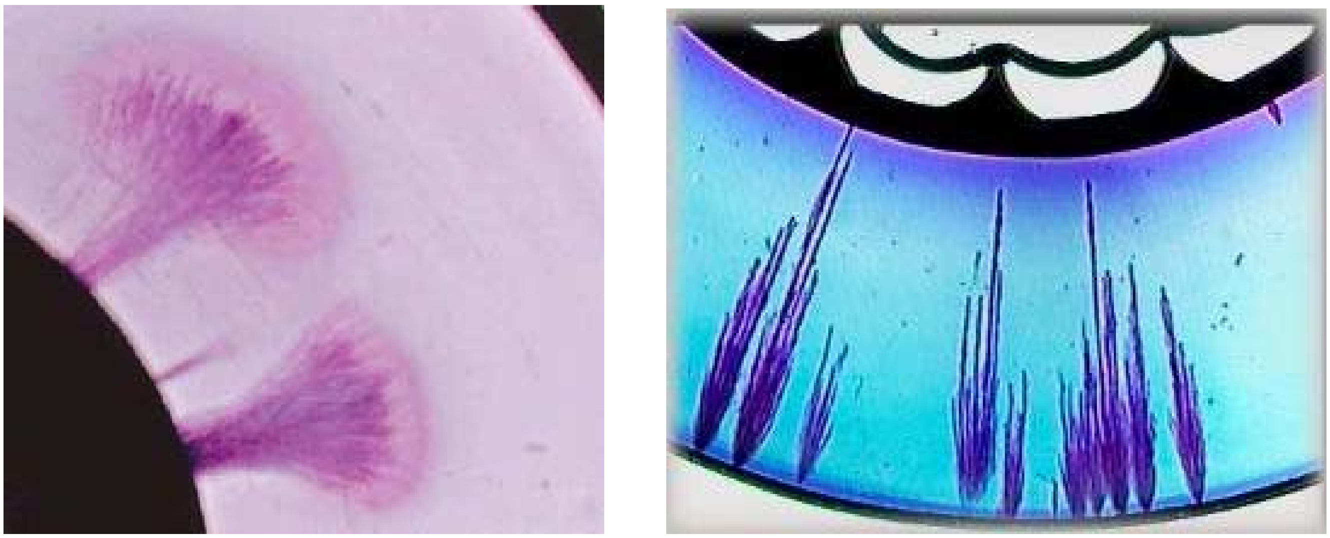

Figure 5: (a) Example of water tree in XLPE wire;   (b) Example of water tree in XLPE wire.

Water trees grow relatively slowly over a period of months or years. As they grow, the electrical stress can increase to the point that an electrical tree is generated at the tip of the water tree [14-16]. Once initiated, electrical trees grow rapidly until the insulation is weakened to the point that it can no longer withstand the applied voltage and an electrical fault occurs at the water/electrical tree location [13]. Then it becomes extremely difficult to stop water tree and generates more and more scrap for every change. Many actions can be taken to reduce water tree growth, and the approach that has been most widely adopted is the use of specially engineered insulating materials designed to limit water tree growth. These insulation materials are called WTR-XLPE (Water Cross Link Polymer). These insulation materials, combined with the use of “clean” shields and suitable manufacturing processes have dispelled the concerns that many utilities had regarding the use of cables with a polymeric insulation [13]. Two approaches have been in widespread use to retard the growth of water trees and each is a modification of the classic XLPE materials: Modification of the polymer structure, “Polymer” WTRXLPE sometimes termed Copolymer - modified XLPE (Cross Link Polymer); modification of the additive package, “additive” WTRXLPE; sometimes termed TR-XLPE.

In both instances, the compounds maintain the excellent electrical properties of XLPE high dielectric strength and very low dielectric losses. WTR-XPLE insulations were commercialized in the early 1980’s and have now been performing reliably in service for over 20 years [15, 17].

2.3 Improving Cleanliness and Smoothness for less defects

The critical importance of cleanliness (of both the insulation and the semiconducting screens) and smoothness (insulation screen interface) has been a hard learned lesson [14, 16, 18 & 19]. It is also important because it causes contamination and the wire comes with lumps and sparks. Improved cleanliness and interface smoothness increases operating stresses (important for High voltage (HV) & extra high voltage (EHV)) and delivered life which is very important for HV (High voltage cable) and EHV (Extra high voltage). Cleanliness and smoothness of all cable materials has improved significantly over the last 15 years. In the practice, production test has become an important strategy to assure that cables are good quality and made according to required specifications. Cable manufacturers conduct these tests before the cable leaves the factory. Most of the widely used cable standards [13, 14] include production test procedures and requirements. However, it should be recognized that these tests represent the minimum requirements. By improving the cleanliness during the production helped the industry to reduce quality issues and it reflected on the number of customer complaints.

Cleaner raw materials, improved manufacturing technology, and handling techniques have all contributed to enhanced cleanliness. Out of these many initiatives including new generations of XLPE and WTR-XLPE materials have emerged. These are generally supplied with designations that define the cleanliness and voltage use levels.

CHAPTER 3: DMAIC (DEFINE PHASE)

This chapter explains the define phase of DMAIC approach and describes the manufacturing processes of the wire, starting from the raw copper rod leading to the detail of copper thinning and insulation. And also, explains the major and important aspects of making wire and about the core wire manufacturing. The main objective of DMAIC was to identify areas in the process where extra expenses exist, identify the biggest impact factor related with production expenses, introduce appropriate measurement system, optimize process and reduce production cost and time.

3.1. Define Phase

The main goal in define phase was to identify and decrease scrap. There were several major causes for the high production expense variability in manufacturing wire. An adequate metrics for evaluating projects success should be established.

When the project was started, very few useful historical data were available, so the first step was to collect and select these data in the processes. In order to do this, all manufacturing processes have been reviewed and studied in section 3.2 and 3.3.

3.2 Overview of Manufacturing Process

Figure 6 describes the series of manufacturing processes of wires. The starting material is copper rod bought from the vendor, and then it goes to the rod mill. In rod mill, the wire is thinned down into thinner copper wire then comes to the multi wire, where the copper wire is annealed and drawn into the thinner and finer wire and all single strands is then took up into the reels. The reels are then taken to the bunchers, in the bunchers proper lay is given to the thin copper wire, according to the process guide requirement.

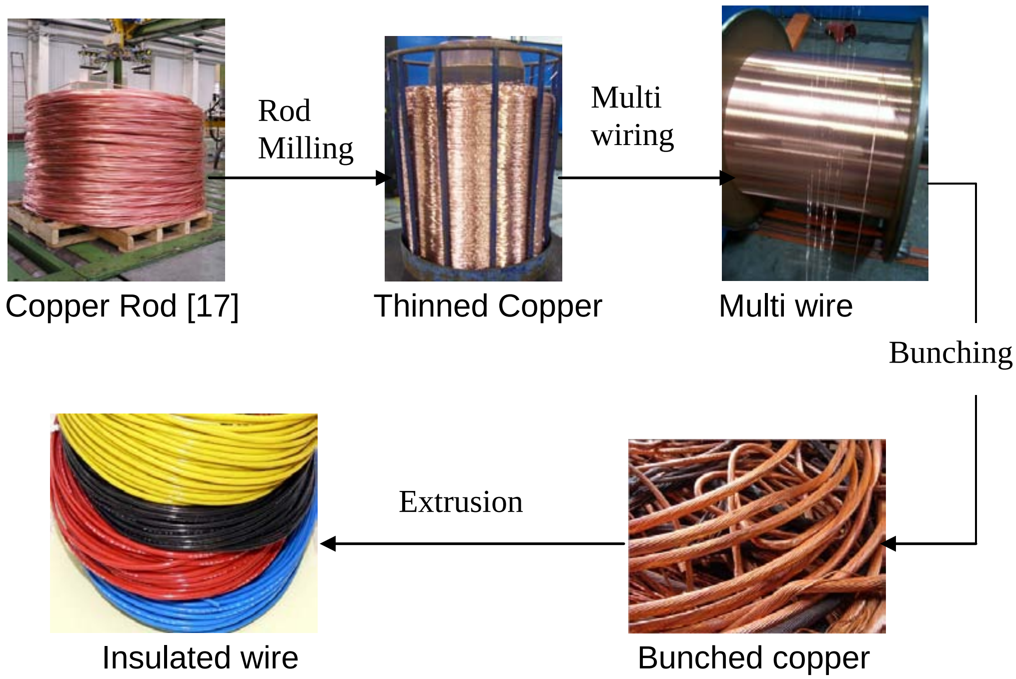

Figure 6: process flow chart of wire from copper to Insulation

After bunching the wire, it goes to the extrusion line for insulation. According to the customer requirements the operators get the required reel. This is the area where my research focused because the goal was to reduce the scrap during insulation. This is considered to be very critical as it requires precession and accuracy to get correct quality of wire as soon as possible.

3.3 Cable Manufacturing

Cable manufacturing is a multistep process. The conductor material (e.g., copper wire) is first drawn to the specified diameter. The bare wire is then transferred to the wire coating line, where electrical insulation material is extruded onto the conductor using a single-screw extruder. The wire coating line typically consists of an unwinding roll for the wire followed by a tension controlled input capstan, possibly a wire straightener, and a wire preheater, which improves the adhesion of the plastic to the conductor. The wire proceeds from the preheater to the extruder's crosshead die, where the melted plastic insulation is applied. Processing temperatures in the die average 400°F (204°C) for HDPE (High Density Polyethylene) and 650 to 700°F (343 – 371°C) for FEP (Fluorinated Ethylene Propylene). The coated wire continues through a water bath and/or air-cooling system, spark tester, gauge controller, tension output capstan, and tension controller, and is then wound onto a bobbin or reel. Output rates for extruding the wire insulation average approximately 550 m/min (1,800 ft/min) for FEP and 1,500 m/min (5,000 ft/min). After the insulation has been applied, two conductors are twisted together (paired) in a process called twinning. The number of twists per foot is precisely controlled during the twinning process, and each of the four pairs is twisted differently (i.e., different number of twists per foot) in order to limit crosstalk between pairs in the final cable. Twinning lines use two motors: one to feed insulated wire to the process and one to take up the twisted conductor pairs. The next step is cabling, in which four of the twisted pairs are bunched or stranded together with a cross-web separating the twisted pairs. A jacket, which protects the conductors from mechanical damage and provides fire retardancy, is then extruded over the core using a process similar to the one used to apply the wire insulation. Any markings are printed onto the cable jacketing during this step. Jacketing proceeds at an average speed of 400 to 500 feet per minute (120-150 m/min); temperatures in the die average 320 to 350°F (160 – 177°C). Both the CMR and CMP cables use compounded PVC for the jacketing. The final cable product is tested for adherence to electrical parameters and then packaged into customer-desired lengths. The primary wastes from the cable manufacturing process (excluding waste from the copper drawing process) are scrap cable, and insulation and jacketing resins. Any insulation or jacketing that is bled from the extruding lines during start-up or shut-down is collected and recycled to the process. Pre-consumer PVC waste is relatively easy for PVC compounders and cable extruders to recycle and reuse as an equivalent for virgin PVC, because the composition is known.

3.3.1 Core Manufacturing

An extruded cable production line is a highly sophisticated manufacturing process that must be run with great care to assure that the end product will perform reliably in service for many years. It consists of many sub processes that must work in concert with each other. If any part of the line fails to function properly, it can create problems that will lead to poorly made cable and will potentially generate many meters of scrap cable [16].

Influence of Extrusion Head Configuration on Cable Aging, as measured by breakdown strength [17], the process begins when pellets of insulating and semiconducting compounds are melted within the extruder. The melt is pressurized and this conveys material to the crosshead where the respective cable layers are formed [19].

Between the end of the screw and the start of the crosshead it is possible to place meshes or screens, which act as filters. The purpose of these screens was, in the earliest days of cable extrusion, to remove particles, or contaminants that might be present within the melt. While still used today, the clean characteristics of today's materials minimize the need for this type of filter. In fact, if these screens are too tight, they themselves can generate contaminants in the form of scorch or pre cross-linking. Nevertheless, appropriately sized (100 to 200-micron hole size) filters are helpful to stabilize the melt and protect the cable from large foreign particles that most often enter from the materials handling system. The most current technology uses a method called a true triple extrusion process where the conductor shield, insulation and insulation shield are coextruded simultaneously. The cables produced in this way have been shown to have better longevity [17]. After the structure of the core is formed the cable is cross-linked to impart the high temperature performance. When a CV tube is used fine control of the temperature and residence time (lines peed) is required to ensure that the core is cross-linked to the correct level [15].

3.3.2 XLPE Insulation

XLPE is a thermoset material produced by the compounding of LDPE with a crosslinking agent such as dicumyl peroxide In this process, the long-chain PE molecules "crosslink" during a curing (vulcanization) process to form a material that has electrical characteristics that are similar to thermoplastic PE, but with better mechanical properties, particularly at high temperatures. XLPE-insulated cables have a rated maximum conductor temperature of 90°C and n emergency rating of up to 140°C.

- Insulation Curing Processes

The crosslinking process begins with a carefully manufactured base polymer. A stabilizing package and crosslinking package are then added to the polymer in a controlled manner to form the compound. Crosslinking adds tie points into the structure. Once cross-linked the polymer chains retain flexibility but, cannot be completely separated. For example, they can be transformed into a free-flowing melt. There are essentially two types of crosslinking processes that can be used for XLPE-insulated power cables:

Peroxide cure – thermal decomposition of organic peroxide after extrusion initiates the formation of crosslinks between the molten polymer chains in the curing tube. This process can be used for XLPE or EPR insulations. The peroxide cure method is the most widely used crosslinking technology globally and is used to manufacture MV (Medium voltage), HV (High Voltage) and EHV (Extra High Voltage) insulated cables. The moisture-cure approach is almost universally used for making LV cables and is sometimes used to manufacture MV cables.

Moisture cure – chemical (silane) species are inserted onto the polymer chain; these species form crosslinks when exposed to water. The curing process occurs in the solid phase, after extrusion. Moisture curing is most often preferred for the manufacture of MV cables when many different cable designs are made on the same extrusion line and/or when manufacturing lengths are relatively short. In these situations, the separation of the extrusion and curing processes is attractive from a production standpoint.

CHAPTER 4: DMAIC (MEASURMENT PHASE)

This chapter describes my first research task: scrap logistic which has been used to measure scrap accurately from June 2010. The old scrap logistic and new scrap logistic will be compared and discussed. The measurement by using the new scrap logistic will be described. It has been approved that the new scrap logistic can measure the scrap accurately and reduces material handling.

4.1 Scrap Logistic

One of the major issues was that the scrap generated from the lines never matched with the scrapped shipped for recycling. For example, in the month of May 2010 the scrap amount was incorrect. The total amount of scrap not reported was 42,331 pounds. In other words there was 42,331 pounds of scrap produced but not reported. Table 1 describes the comparison between scrap produced and scrap reported in May 2010.

Scrap generated during the month of May per Department.

Table 1: Scrap produced Vs. scrap reported

Total of scrap shipment shipped (6 shipments)						
	PVC ins	**Battery Ln**	**Bonder**	QA	Towers	**Silicone**
1st load (Lbs)	0	0	0	0	0	0
2nd load (Lbs)	35,001	6,095		1,175		
3rd load (Lbs)	28,997	7,605		2,076		
4th load (Lbs)	27,179	8,040	704		675	753
5th load (Lbs)	28,948	6,970	722		774	
6th load (Lbs)	33,080	2,555	2,393			719
Total shipped (Lbs)	153,205	31,265	3,819	3,251	1,449	1,472
Total reported (Lbs)	120,844	28,024	1,462	0	0	1,800
Total not reported (Lbs)	**-32,361**	**-3,241**	**-2,357**	**-3,251**	**-1,449**	**328**

The first target was to bring the scrap generated numbers equal to scrap shipped. A summary of the daily scrap was recorded in a form. The daily scrap form was used by the supervisor to verify the pounds of scrap generated, reported and shipped.

Table 2: Example of Supervisor Scrap Report

	Shift	______		Date:	______________		Super visor	____________
Box 1	Partial Box	Full Box	Differ ence	Box 2	Scrap (Lbs)	Total Box	Total Shift	Difference
Extrud er Cu				Extrude r Cu				
Extrud er TC				Extrude r TC				
Bare Cu				Bare Cu				
Tin Cu				Tin Cu				
Purge				Purge				

Line #	Operator	Gauge Description	Extruder (Lbs) Coppe r	Extruder (Lbs) Tin	Bare (Lbs) Coppe r	Bare (Lbs) Tin	Purge scrap (Lbs)
SCV 1							
	Total						
SCV 2							
	Total						
SCV 3							
	Total						
Total By Shift							

The supervisor at the end of the shift collects the scrap summary form from all the production lines and measures it. The supervisor is responsible if the scrap produced does not match the scrap shipped. But there was still a difference between the shipped and the reported scrap. The logistic of scrap travel was changed and different scrap boxes for night and day shift were allotted. Even this didn't help. Therefore, the time a supervisor spends in collecting scrap from the lines which was approximately 2 hours every shift was noted. The scrap collection time was presented before management. The time supervisor spends in scrap collection and entry can be saved for better things. The operator should be responsible for the scrap generated on the machine. This gave the supervisors the opportunity to assist operators on the line, especially newly trained operators. After the change in scrap logistics, the total scrap produced matched the scrap shipped and the production scrap was in control.

Old Scrap Logistic:-

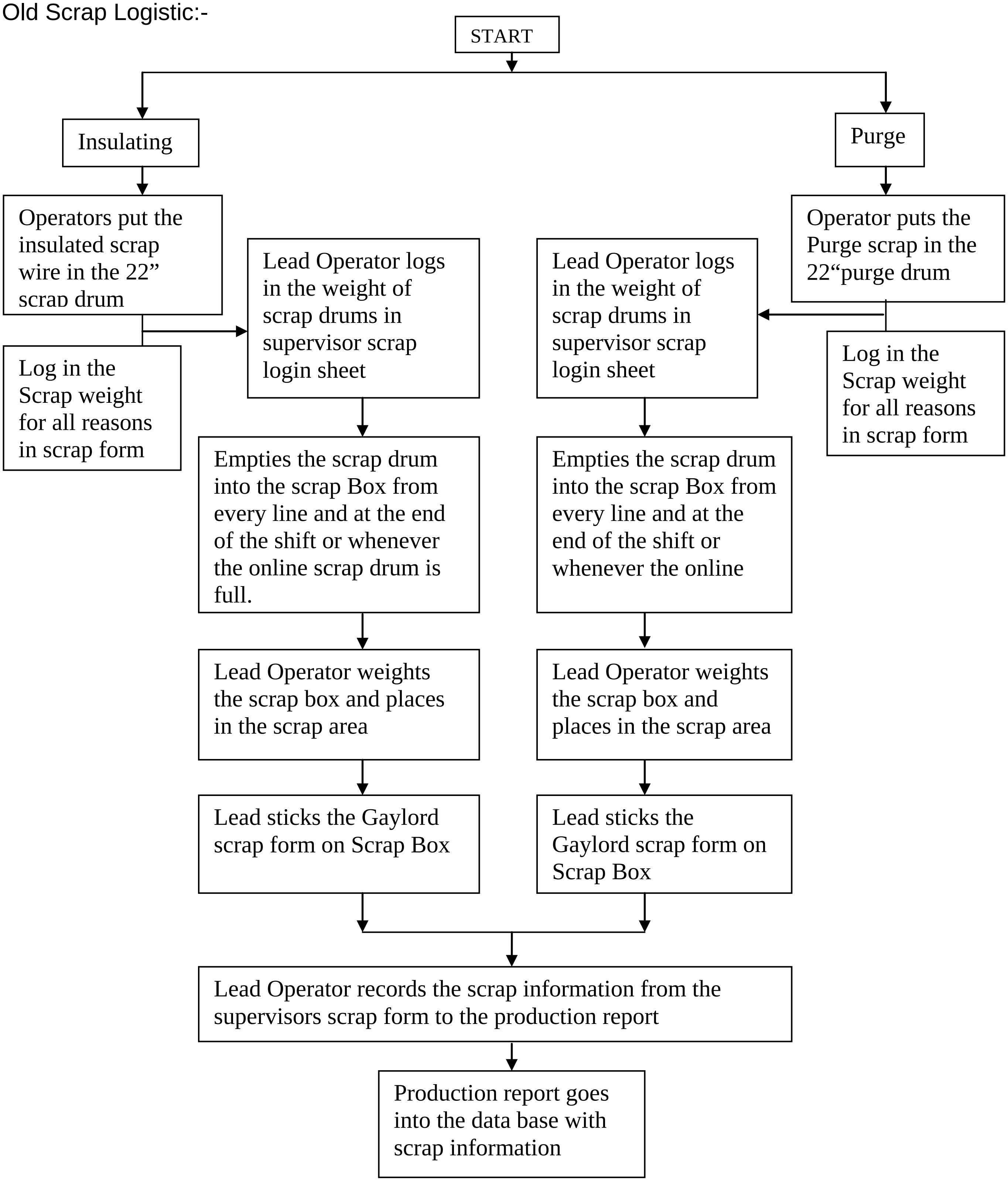

Figure 7: Old Scrap Logistic

New Changed Scrap Logistic:-

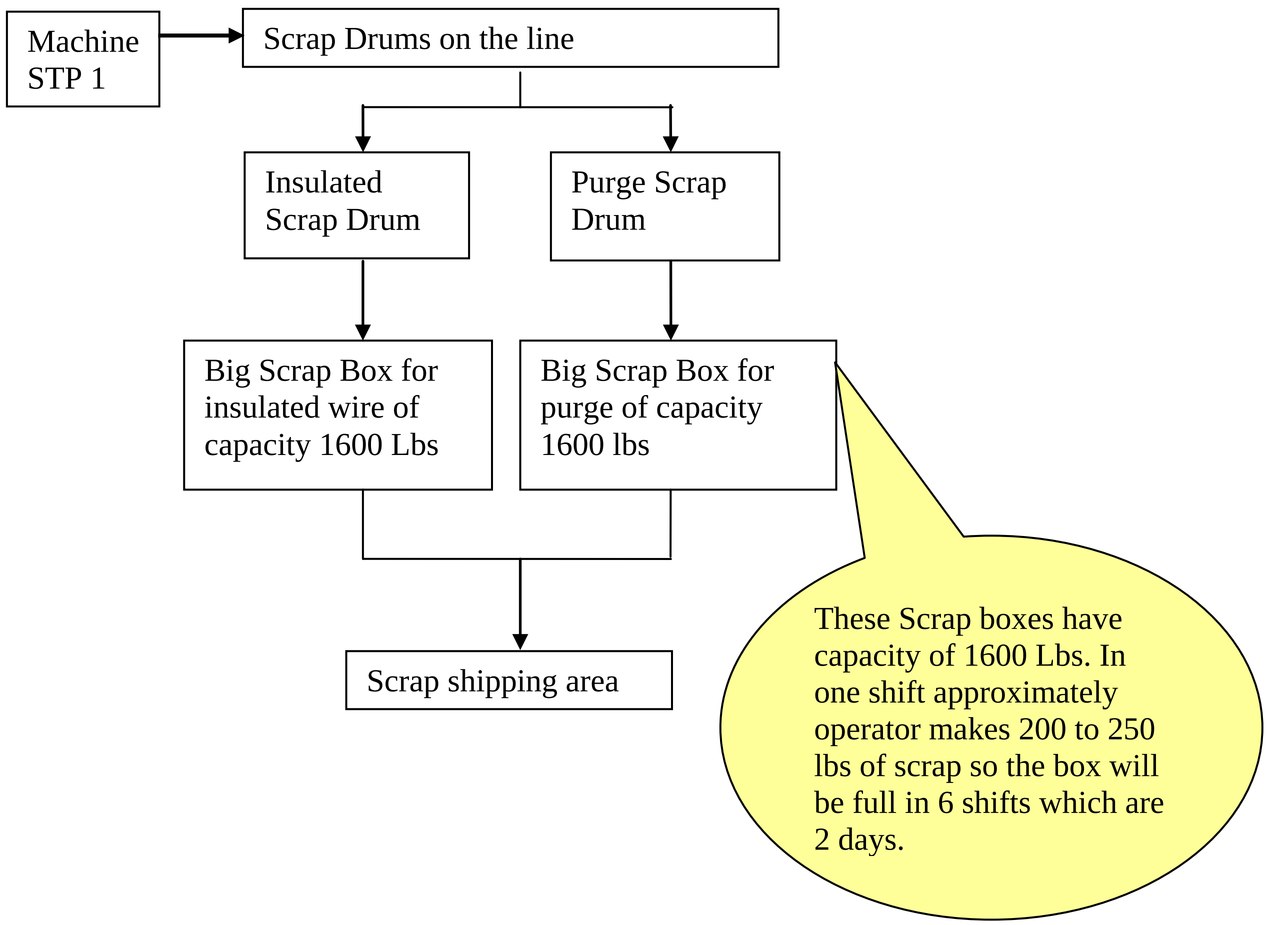

Figure 8: New Scrap Logistic

Table above shows that in the month of June the scrap reported was accurate as the scrap shipped. This means that the improved scrap logistic worked.

Table 3: Scrap shipped Vs. Scrap reported

Total of scrap shipment shipped (5 shpments)										
Loads / ship date	**PVC ins**	**Battery Ln**	**Bonder**	QA	Towers	**Silicone**	Purge	BC Fab	BC Ext	TC UnIn
1st load (Lbs)	2,132	0	0	0	0	0	34369			
2nd load (Lbs)	34,125	5,578	0	0	782	575				
3rd load (Lbs)	21,540	4,656	0	0	499	0				
4th load (Lbs)	25,269	2,940	1506	0	640	1173		6611	2426	1388
5th load (Lbs)	0	0	0	0	0	0				
6th load (Lbs)	13,372									
7th load (Lbs)	17,737	3,360						2996	4733	
Total shipped (Lbs)	114,175	16,534	1,506	0	1,921	1,748	34,369	9,607	7,159	1,388
Total reported (Lbs)	114,170	19,726	590	0	877	1,197	29,139			476
Total not reported (Lbs)	**0**	**3,192**	**-916**	**0**	**-1,044**	**-551**	**-5,230**	**-9,607**	**-7,159**	**-912**

4.2 Percentage of Scrap before June 2010

The scrap and production numbers for 2010 were provided along with the goal of 5% by the end of December 2010. In order to determine the best targeted area to reduce the amount of scrap. The Pareto was done for all insulating areas. The result of the Pareto determined the best area of concentration.

- Total insulation scrap

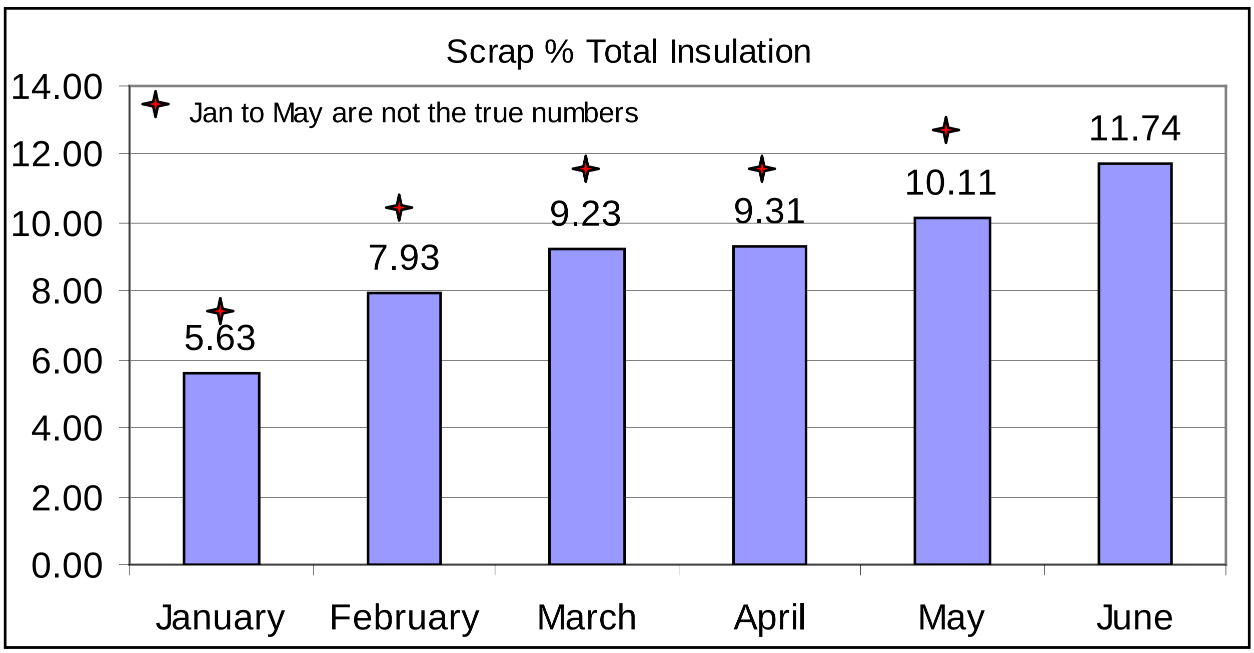

Figure 9: Insulation Scrap Percentages

In the graph it is clear that at the beginning of the year the company started well with approximately 5% and from there it began to rise, reaching 11.74% in June. Since the production was increasing it was not something unexpected but with the increase in production no one concentrated on the scrap and this result in an increase of the scrap to 11.74% in June. This factor alone clarifies the importance of this project.

- Silicone scrap

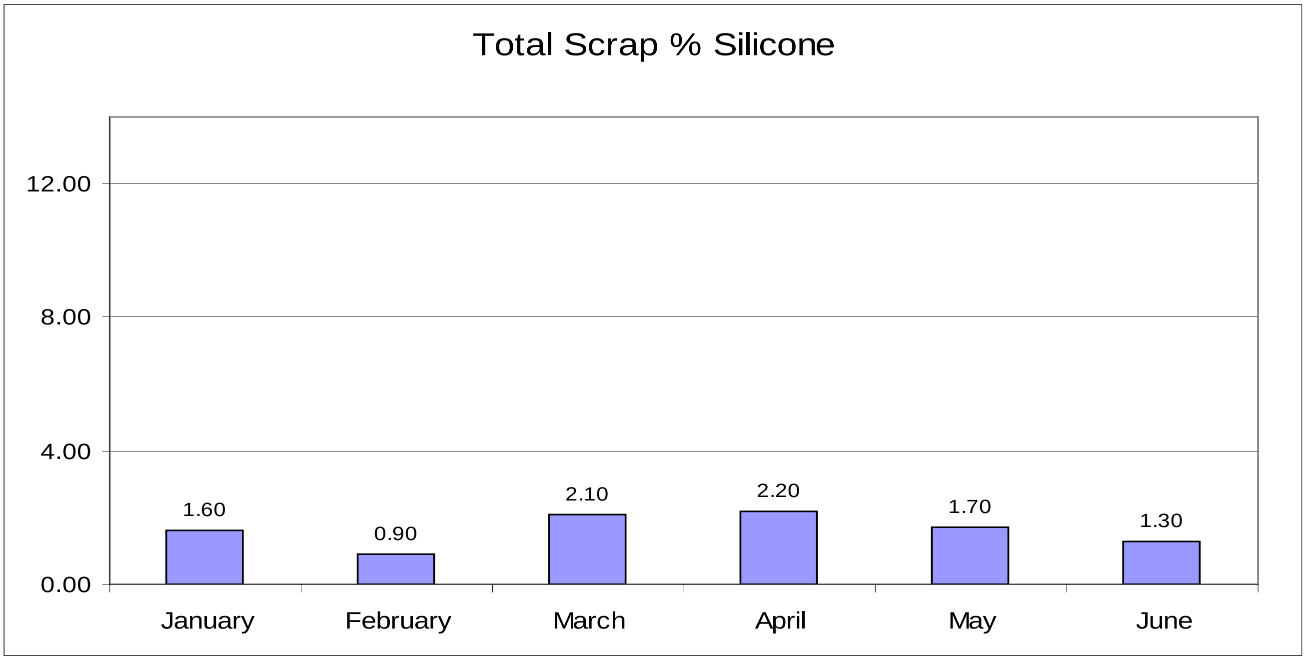

Figure 10: Silicone Scrap percentages

It is clear (figure 10) that the silicone area was not the area of concern as the scrap from this area was quite low. Silicone did not really have a major contribution to scrap, it was usually below 2%.

- PVC scrap

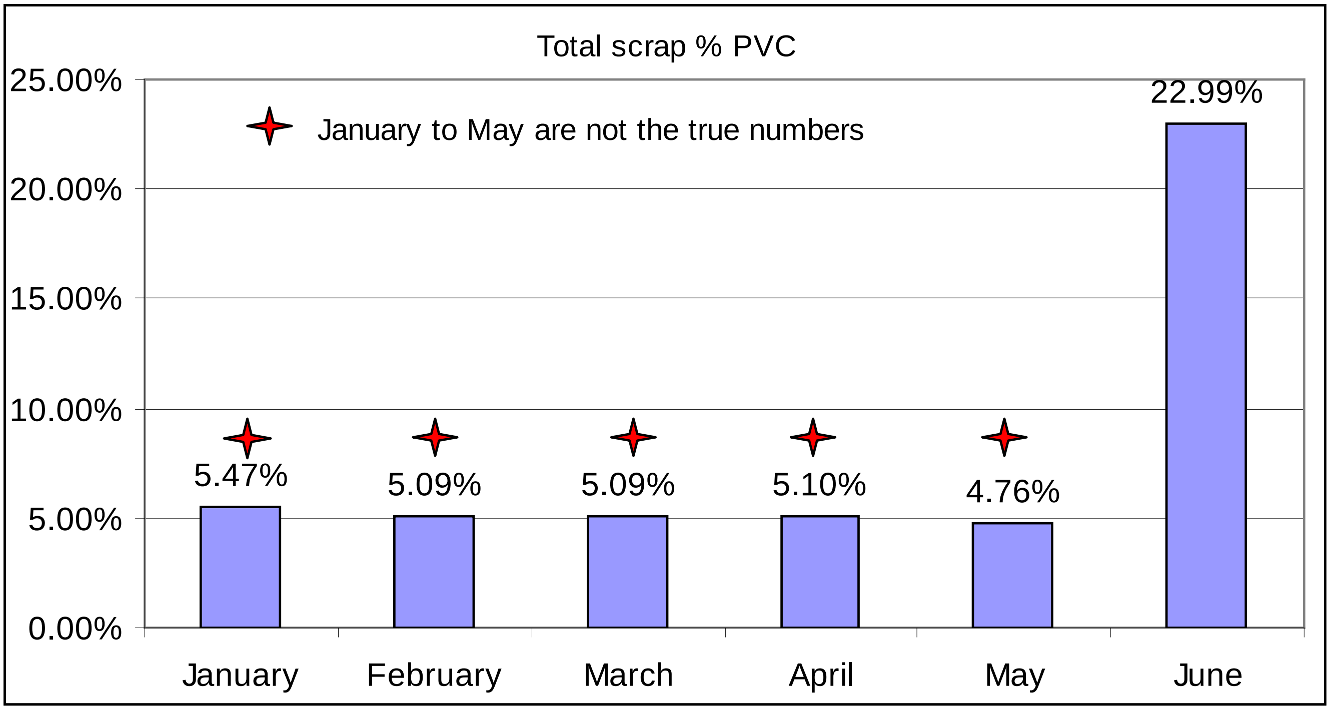

Figure 11: PCV scrap percentages

There was a drastic change in the PVC scrap in the month of June. But before June as explained in the previous chapter, the scrap reported was incorrect so even though the graph says 5% it does not necessarily mean it was 5%. At this point it is impossible to determine the correct percentage of scrap for the months prior to June. Since the supervisor scrap report form has been adopted, the real numbers show the correct amount of scrap was 22.99%. The correct reporting of scrap began in June. After this point the scrap has been calculated accurately.

- XLPE Scrap

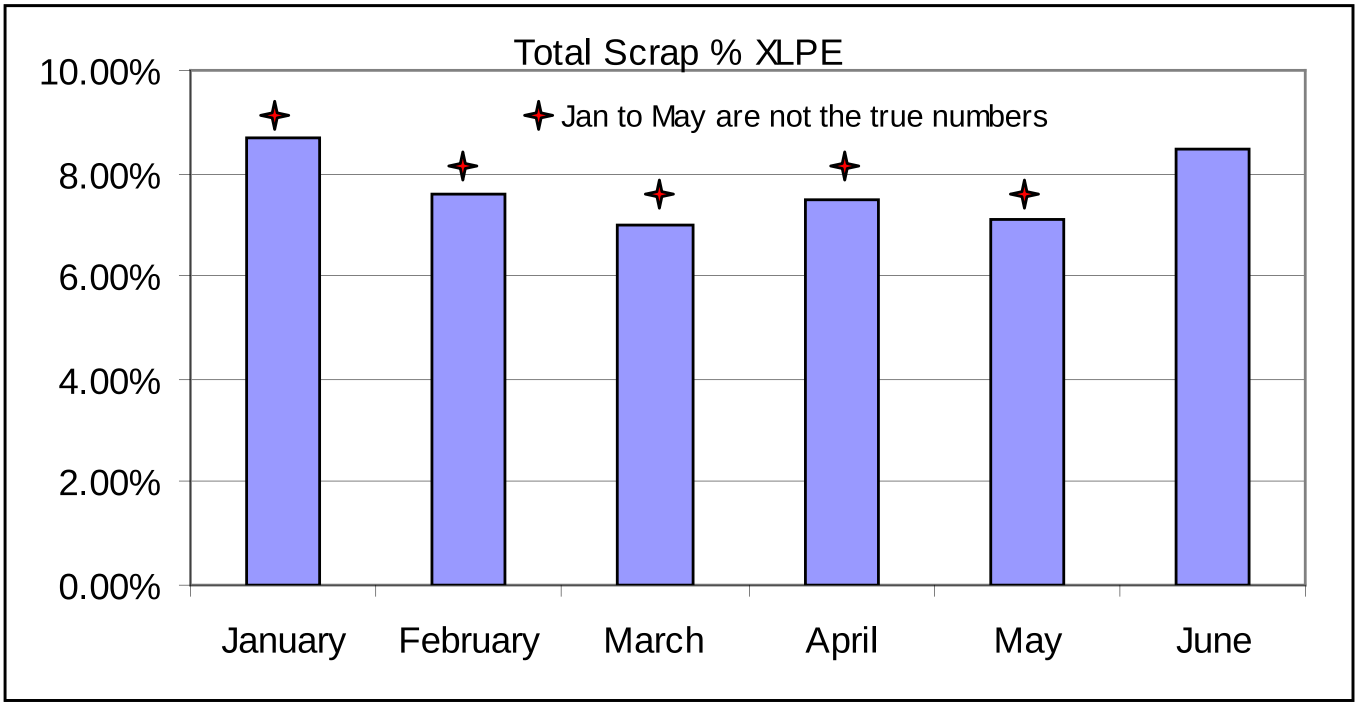

Figure 12: XLPE scrap percentages

The scrap for XLPE before June was definitely high than what is shown in Figure 12.

4.3 Concentrated Area

The Pareto analysis was done to determine which area produces a larger amount of scrap when compared to other areas. It was determined that the larger percentage of scrap comes from PVC as compared to other areas. The reason being that, the production pounds for PVC are much higher than other areas.

Table 4: Production and scrap by each area

June 2010 Report on Production and Scrap						
	Production (Lbs)	Insulated Scrap (Lbs)	Purge Scrap (Lbs)	Total Scrap (Lbs)	% of scrap from total scrap	% of scrap STP lines
PVC	1705973.40	364151.00	28117.00	392268.00	87.58%	22.99%
XLPE	475013.10	35182.00	5096.00	40278.00	8.99%	8.48%
Silicone	158439.10	1642.00	16.00	1658.00	0.37%	1.05%
Battery	230739.40	10863.00	2817.00	13680.00	3.05%	5.93%
Total	2570165	411838	36046	447884		17.43%

PVC production was much higher than the XLPE, silicone and battery. Therefore, even the scrap percentage was higher than other areas. The percentage of scrap it had from total insulated scrap was also quite high of 87.58%.

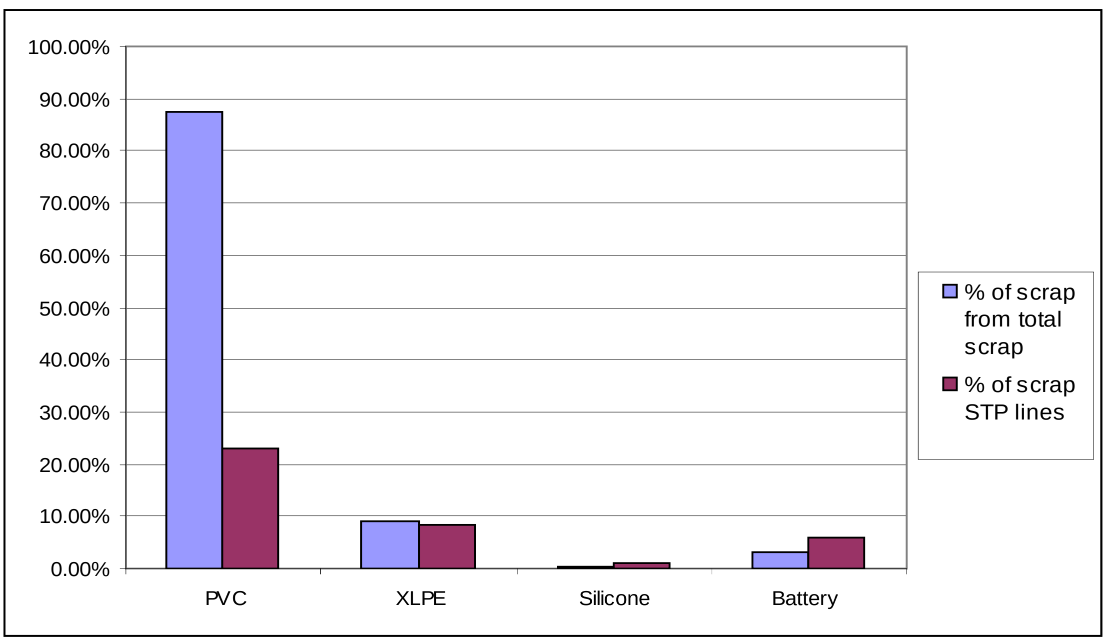

Figure 13: Percentage of Scrap From total Scrap all areas

The blue color bar represents the scrap percentages of the total insulated wire scrap. On the other hand the maroon bar represents the area scrap percentages. The graph above (figure 13), shows that 87.58% of the scrap was produced from PVC, so it was clear that PVC area needed to be the area of highest concentration.

- PVC Pareto

There are a total of five PVC lines. The Pareto analysis was done on all the PVC line to determine the highest percentage contributor to scrap.

Table 5: Production and Scrap by each STP Lines

June 2010 STP Lines Production and scrap						
Production Lines	Production (Lbs)	Insulated Scrap (Lbs)	Purge Scrap (Lbs)	total scrap	% of scrap from total Scrap	% of scrap STP lines
STP 1	292414.60	74289.00	6501.00	80790.00	20.60%	27.63%
STP 2	575641.80	72490.00	6081.00	78571.00	20.03%	13.65%
STP 4	201794.80	72494.00	4501.00	76995.00	19.63%	38.16%
STP 5	261963.40	102300.00	5610.00	107910.00	27.51%	41.19%
STP 6	374158.80	42578.00	5424.00	48002.00	12.24%	12.83%
Total	1705973.4	364151	28117	392268		22.99%

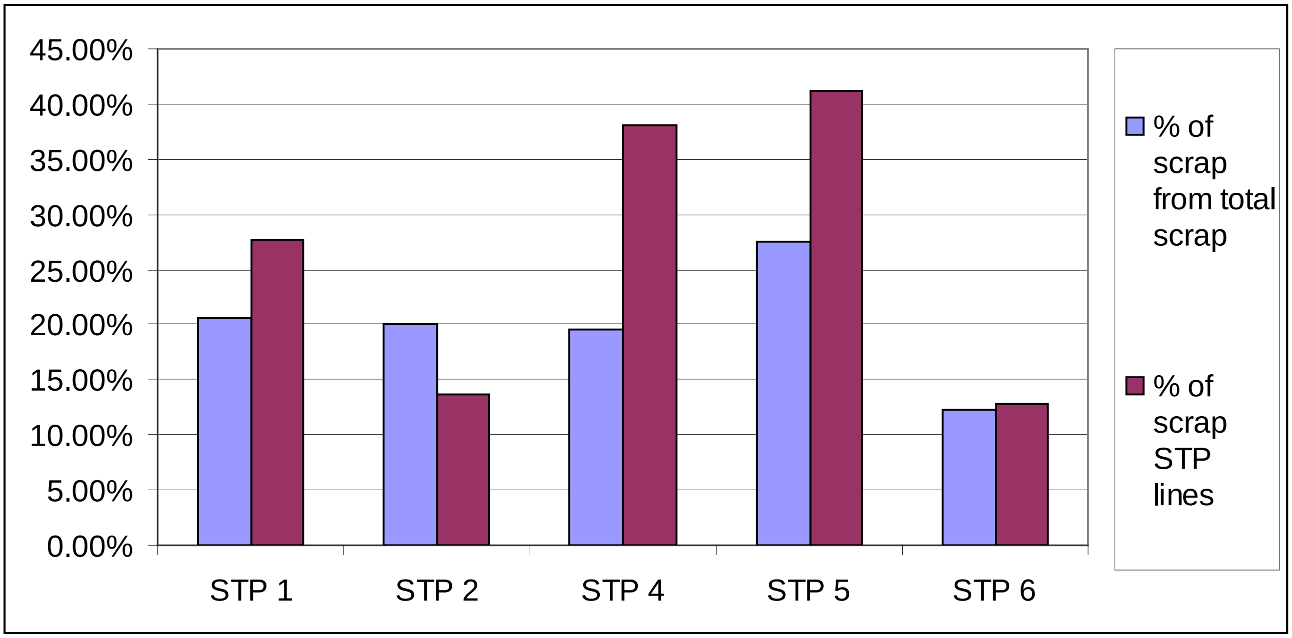

Figure 14: Percentage of Scrap from total Scrap by all STP lines

The above chart (figure 14), clearly indicates that all lines almost equally contribute to total scrap except STP 6. The scrap percentage for all lines was quite high. After reaching the results of scrap production for each line, the goal was to begin the reduction line by line. Since STP 5 produced the greatest amount of scrap the goal was to reduce its scrap first, as it makes heaviest wire than other lines.

CHAPTER 5: DMAIC (ANALYSIS)

This chapter describes the types of defects that occur on the wire during manufacturing processes. And also, it explains how the scrap report form helps determine which type of defect produces the most scrap, via the Pareto analysis.

5.1 Reason for Scrap

The percentage of scrap was increasing, and it was necessary to determine the reason behind this. In order to measure scrap on a daily basis, samples were collected for inspection in the laboratory under specialized equipment. Every defect indicates a problem with the machinery, an operational problem or a processing issue. The major defects were analyzed using the 5 why analysis followed by knowledge obtained from the six sigma theory. It was difficult to determine the major defects, as every machine operator has their own way of doing things. Therefore, generated a table in which they would record the amount of scrap and the reason for its existence. Generating this table was very helpful when it came time to inform the engineers of the problems and issues found at hand. Prior to the use of this table operators did not inform maintenance of any such issues until the production line had stopped completely therefore the downtime was longer.

Table 6: Scrap report form to find out the reason for scrap.

Scrap report form PVC and CV						
Operator:						
Date:						
Line:						
Gauge No.	**Down time**		Color change	Purge scrap (Lbs)	Wire Scrap (Lbs)	Reason for scrap
	Stop time	Start time				
Number of color changes =						
Note: Write down the down time. Every time the machine stops due to any reason wire break, purge, gauge set up, maintenance etc. write down the time it stopped and then the time when again started manufacturing wire. Give reason for the scrap generated eg. lumps, OD defect, wire breaks, spark outs, color change etc. Be accurate in measuring the scrap. Do not forget to subtract the weight of drum from the measured purge and wire scrap.						
Comments:-						

Reference Only

There can be many types of defects that can occur during the cable manufacturing process, such as color change, lump, weld, air bubble, cold compound, outer diameter variation, center, bleed over, spark outs etc.

- Color Change

This is the most common type of defect and cannot be avoided. But nothing was ever tried or experimented to reduce color change scrap. This definitely needed to be reduced. The numbers indicate that the scrap percentage would be lower if there were only a few color changes. As the number of color changes increases the scrap percentage also increases. The target was to reduce the pounds of scrap for every color change. There are two methods in which color can be changed.

- Color change on the run

During this there should not be any change in the gauge. The machine continues running and on the run the next color is added. But the downside of this process is that the color does not change instantly. For example if it is changing from white to black. The wire will first change to light grey then dark grey and then finally black. The change is gradual. This process produces approximately of 30 pounds of insulated scrap. The good thing about this type of color change is that is reduces downtime.

- Color change by purging the color compound

In this the entire compounds in the extruder has to be purged out. What exactly they do is take out the tip and dye from the head and purge the entire compound present in the extruder. A typical extruder can hold 43 pounds of compound. After purging entire compound from the extruder the machine is started again. The wire produced after this kind of color change has many defects and it takes a while to get good quality wire. But this process produces less scrap than the scrap produced by doing a color change on the run.

Figure 15: Example of color change scrap by purging of compound through extruder

- Lump and neck

Lump and necks are created when the compound is not mixed well in the extruder and the compound is still not heated properly. There are screen packs fitted just before the head to catch all the unwanted particles and for the very small micro granules of compound. If the screen packs are not changed in a timely manner the chances of getting lump and necks are increased. There is a lump and neck detector on the line to detect if the wire has any lump or neck. A typical lump defect on the wire is shown below (figure 16).

Figure 16: Example of Lump defect observed on the wire [20]

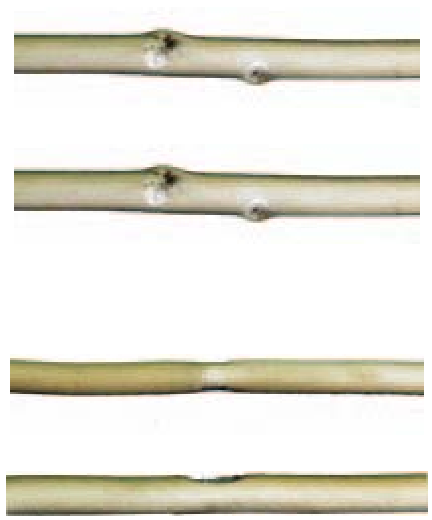

Figure 17: Example of spark out observed, mostly on small gauge wire

- Spark Outs

This happen when there is insulation missing on the wire. It could happen if the screen packs are not changed in a timely manner. The screen packs gets clogged by the compound and the small unwanted particles. Sooner or later come these particles come out with the wire and sparks. Sparker are installed on the line to catch spark outs [21].

For both the above defects it was found that screen packs should be in good condition all the times. Most of the extrusion processes pass melt through wire mesh screens on the way to the dye to provide filtering and improved mixing. But screens also introduce process variables, raising backpressure and melt temperature and sometimes reducing output. Screens are held by a breaker plate with holes or slots, which form the seals between the extruder and dye. Clean screens add only a small amount of pressure, maybe 50 to 100 psi, to the resistance of the head. The greatest pressure variable is the amount of contamination they trap [21].

When clogged screens are changed, pressure suddenly drops, melt temperature may do the same, and either screw rpm or line speed must be adjusted to maintain the same product dimensions. When extruding a circular product, these process changes may not cause serious problems, but in a flat or irregular profile shape, the melt temperature change may affect the product shape. For instance, in a flat die, cooler melt will give sheet a thinner center and thicker edges. This may be compensated for by automatically or manually adjustments to the dye, but it shouldn’t be ignored. Placing a gear pump after the screen changer can prevent this problem by maintaining constant output through the die. But the change in melt temperature after a screen change may still require dye adjustments. Also, gear pumps have a very small clearance that can be damaged by hard contaminants, so fine screens are needed to shield the pump. Extruders of rigid PVC, for example, know that screens make the melt hotter, which therefore needs more stabilization, which adds to material costs. Some suppliers offer special screen changers for plasticized PVC. But for rigid PVC most processors either avoid screens altogether, or use a relatively coarse pack without a changer to keep out only large contaminant particles.

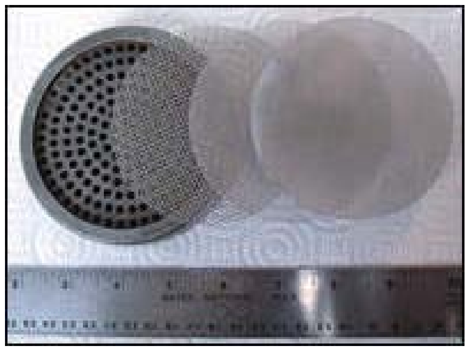

Figure 18: Example of screen filter [21]

Screens filter contamination and improved mixing, may raise pressure and temperature, which can affect output and product dimensions [21].

- Weld

The copper wires for insulation are in reels. So in order to continue running without breaks we have pay offs where we can weld the two wires. But the welded wire is not acceptable to the customer so we have to scrap this wire as well. On the positive side the scrap produced by weld is not very much and therefore not really given much focus.

- Air bubble

This type of defect is very common but can be very easily fixed. There needs to be a vacuum given to the head from behind in order to suck all the air gaps. If the vacuum pump is not in proper working condition we can have air bubble.

- Cold compound

This was a major issue with all the lines. They used to get cold compound wires during the start ups. The reason being that when the operators purge the extruder for a color change the temperature drops down as they slow down the line speed. So the temperature was not sufficient to keep the compound heated enough. When they started producing the wire the wire did not have a smooth surface. This was due to cold compound.

- Outer diameter variation

After purging the wire does not come out right according to the settings on the machine. It needs to be adjusted slowly so that the correct OD (Outer Diameter) is obtained. So here it is kept as low as possible. By the time correct OD is obtained the wire produced is all scrap. This is the most important problem the company is dealing with.

- Center

Often when the operator purges the extruder, the center is lost which means the copper is not at the center of the insulation. One of the reasons this may occur is due to the usage of worn out tools. Even the pulleys located at the back of the head causes this problem. The pulley needs to be adjusted every time there is a change in the gauge.

5.2 Reason for Scrap Pareto

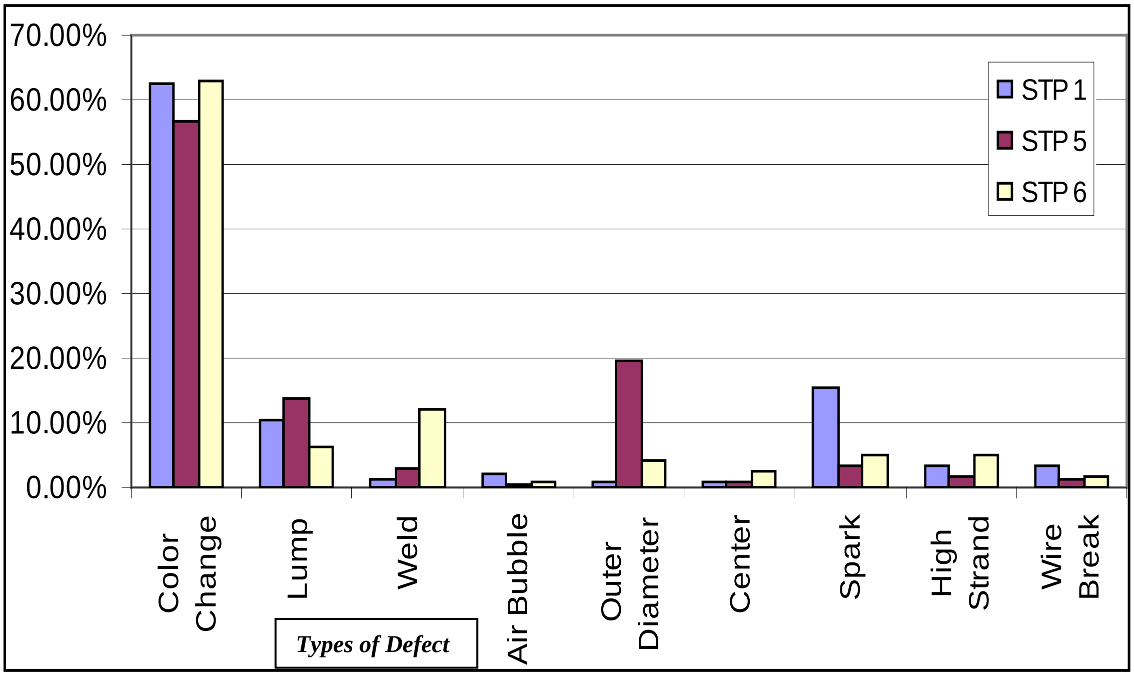

Figure 19: Reason for scrap pareto

The graph above shows that for STP 1, 5 & 6 color change has been the major concern. Even though the color change scrap cannot be eliminated, it can definitely be reduced significantly.

CHAPTER 6: DMAIC (IMPROVE)

This chapter briefly explains the flow of the color change process, and the critical operations and factors involved in this process. Furthermore, the different scrap approaches of reducing scrap have been discussed and compared.

6.1 Background of Color Change Process Flow

One of the objectives of project was to identify major process variables impacting the high expenses. The Pareto chart for total expenses, in the measurement phase in Chapter 5 is displays that PVC would give a major impact for scrap reduction. Based on Pareto chart, the decision was made to analyze and make improvements within the working style of operator. The change in some method and fixing of some machine issues would bring it to direct half of what it was in June 2010. There was also acquiesced that quality improvement and reduction of quality costs within process are achievable. The significant improvement in scrap could be accomplished by: 1) reduction of cycle time, 2) reduction of control time, 3) reduction of down time.

From the PVC scrap by color change was chosen because Pareto diagram showed that it is major contributor to scrap. The chosen color change process involves the following steps.

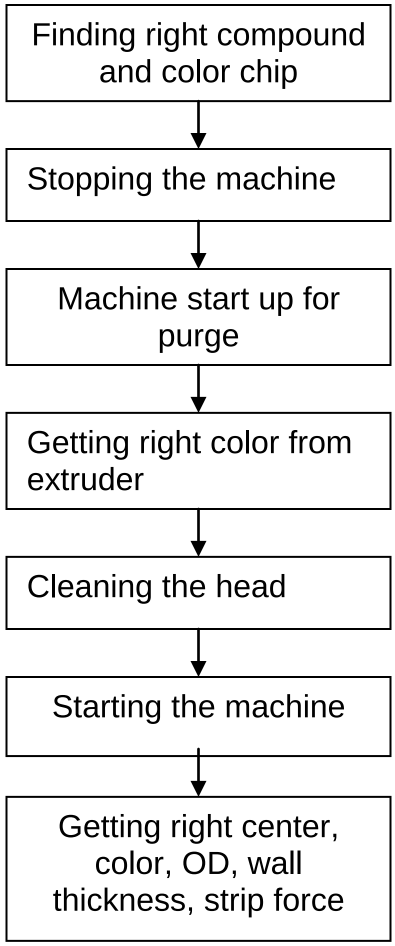

Figure 20: Color change process flow diagram

The process map was drawn for all operations in the color change and a list of the input and output variables were completed. The input variables were ranked as, *Critical, Noise, Controllable* and *Standard operating procedures variable* and, furthermore, non-value added operations are defined and marked. Scrap from color change was always going to be there but can be reduced for sure. Only lowering down number of color changes was not going to help. Every time color change is done approximately 50 pounds of scrap is produced.

The most critical operations were the amount of compound and color chip added to the extruder and the time when to stop the machine. Conducted analysis showed that there was no data or value for when to change the color in other words when to stop pouring more compound. The extruders keeps filling all the time through the vacuum and sensor control as soon as it senses that there is no compound the vacuum starts and extracts compound.

6.2 Approach to Reduce Scrap

As the main goal was to identify and decrease scrap in process by 5% [22]. The objective was to determine a specific value at which the pouring of the compound into the extruder should cease at the end of the work order. During the analysis few detail things were fined like capacity of the extruder, time taken for the extruder to purge out the compound at a certain speed and what the operator does during the purging of compound. The extruder was completely filled. After the extruder was completely filled the no more compound was given to the extruder for that particular order. To stop pouring compound the operator has climb the ladder all the way to the hopper to switch off the machine. At a temperature of 355°F all zones had the same speed of 300 fpm. At this speed it took 15 minutes for the extruder to purge its contents completely.

The extruder can hold up to 62 pounds of compound. So every time they change the color of the wire they have approximately 62 pounds of purge scrap. At this point calculated the amount of compound needed to produce insulated wires of different gauges. In this case of approximately 42 pound of compound was needed to make certain feet for wire. Therefore operator was given 62 pounds of compound and 2 pounds of colored chips in order to produce the work order.

The production line started, but until the operator could produce a high quality wire, 20 pounds of insulated wire was already scraped. However, the contents of the extruder, was still enough to produce required wire to full fill the work order.

Even though the calculations were correctly determined and only 42 pounds of compound was required, the outer diameter decreased at the end of the work order due to a lack of pressure in the extruder, produced by the compound. The decrease in pressure resulted in a smaller amount of compound being excreted from the head of the extruder. As a result increasing the outer diameter setting on the extruder did not help. Therefore the work order was not competed, and resulted in the work order being short.

In this approach, 62 pounds of compound was poured into the extruder. But at the same time even after filling up the extruder the vacuum pump for supplying the compound to the extruder was not stopped. During this experiment the color change was from white to black. Started producing white wire and towards the end of the work order the color was changed to black using black chips. This would allow for continuous production of wire without ceasing production. But the downside would be that the color does not change immediately, it would fade into black.

So either stop running the extruder and purge the contents or continue running the extruder but in this case the amount of scrap would increase and would contain copper. Being that copper is quite expensive, the decision to stop the extruder and obtain the quality of black desired was made. In doing so, scrap was reduced and 10 pounds of copper and compound were saved.

The next step was to determine the appropriate time to change the color. In order to do so, experiment was designed to determine the value and length when the color needs to be changed to get least amount of scrap.

According to the capacity of the extruder for every gauge the amount of compound required to manufacture the length of wire needed was calculated. For a 2.0 gauge wire the extruder required 37.26 pounds of compound to produce 40,000 feet or wire. Once the extruder has produced 35,000 feet of wire it still has enough compounds to produce another 5,000 feet or wire. Therefore, color can be changed at this point and by doing so we 4,000 feet of wire and 20 pounds of compound can be saved.

CHAPTER 7: STATISTICAL ANALYSIS: DESIGN OF EXPERIMENTS AND RESULTS

This chapter describes the two step statistical analysis. First a full factorial design is implemented with a few factors, such as length, speed and temperature. Results from main effects, two factor interaction and three way interaction are discussed and significant factors are identified. Finally this continues with the optimum level of factors obtained to produce the least amount of scrap.

7.1 Statistical Analysis

The design of experiments involves three controllable variables (settings) length, speed and temperature. Table 7 shows the variables with their low and high levels.

A 2^3 (three factors and two levels) was used. It is a full factorial design. Matrix and data for scrap is shown in Table 7. The software used for the analysis is Minitab 16.

Step 1

Control Variable and their levels:

Control variable is that factor which is controlled by the experimenter to cancel out or neutralize any effect they might otherwise have on the observed phenomenon (dependent variable). The control Variables used in this experimentation were, Length, Speed and Temperature as shown in Table 7.

Table 7: Control variables and levels

Control Variable	Low Level	High Level
Length (ft)	35000	40000
Speed (ft/min)	1000	1500
Temperature (ºF)	325	350

Table 8: Experiment results

Run Number	Length (ft)	Speed (ft/min)	Temperature (ºF)	**Scrap (lbs)**
Run 1	35,000	1,500	350	**21**
Run 2	40,000	1,500	350	**45**
Run 3	35,000	1,000	325	**25**
Run 4	40,000	1,000	350	**55**
Run 5	35,000	1,000	325	**28**
Run 6	35,000	1,500	350	**22**
Run 7	40,000	1,500	350	**56**
Run 8	35,000	1,500	325	**25**
Run 9	40,000	1,500	325	**46**
Run 10	35,000	1,500	325	**23**
Run 11	40,000	1,000	325	**58**
Run 12	35,000	1,000	350	**26**
Run 13	40,000	1,000	325	**56**
Run 14	40,000	1,000	350	**57**
Run 15	35,000	1,000	350	**24**
Run 16	40,000	1,500	325	**59**

Table 9: ANOVA for Scrap

Estimated Effects and Coefficients for Scrap (Lbs) (coded units)

Term	Effect	Coef	SE Coef	T	P
Constant		39.125	1.111	35.22	0.000
Length	29.750	14.875	1.111	13.39	0.000
Speed	-4.000	-2.000	1.111	-1.80	0.110
Temperature	-1.750	-0.875	1.111	-0.79	0.454
Length*Speed	-1.000	-0.500	1.111	-0.45	0.665
Length*Temperature	0.250	0.125	1.111	0.11	0.913
Speed*Temperature	-0.500	-0.250	1.111	-0.23	0.828
Length*Speed*Temperature	-0.000	-0.000	1.111	-0.00	1.000

S = 4.44410   PRESS = 632

R-Sq = 95.82%   R-Sq(pred) = 83.28%   R-Sq(adj) = 92.16%

- Main Effects

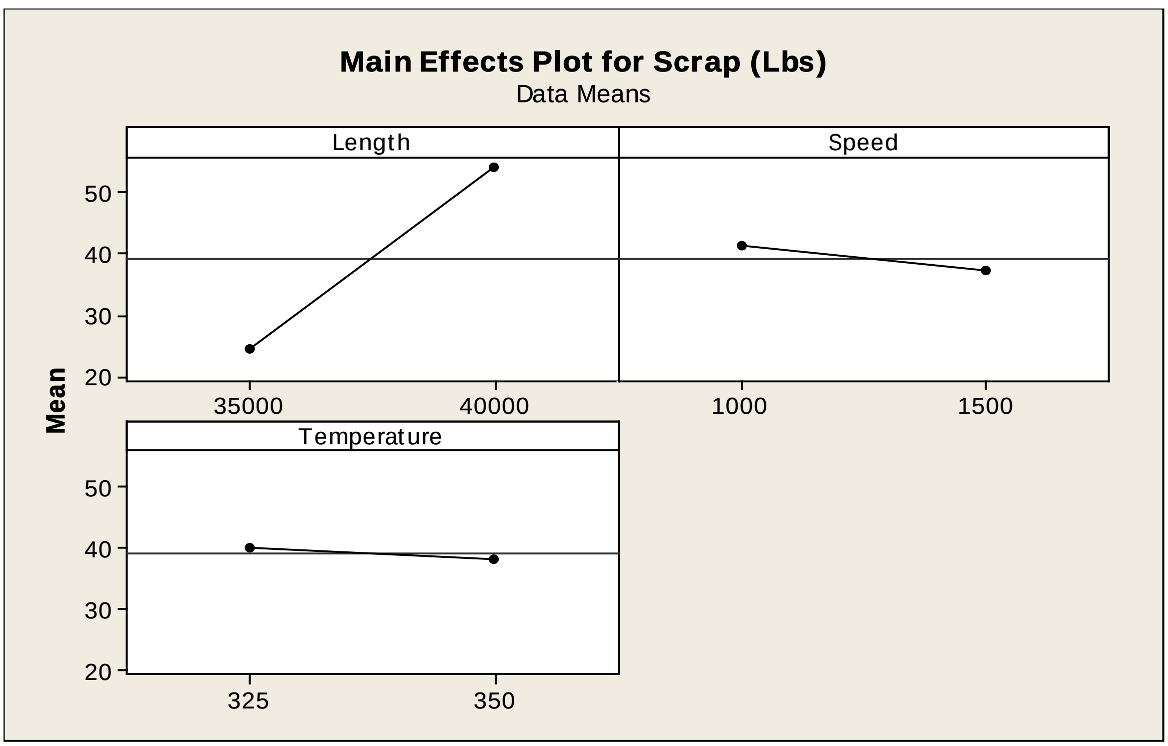

Figure 21: Main Effects Plot

A main effect is an outcome that is a consistent difference between levels of a factor. The main effects plot is used to examine the main effects of factors. The main effects of three setting length, speed and temperature are shown in main effect plot (figure 21). It can be observed that length has a significant effect on the scrap. Speed and temperature has no significant effect on scrap. Also at 35,000 feet scrap is less than what it was at 40,000 feet.

- Two-factor Interactions

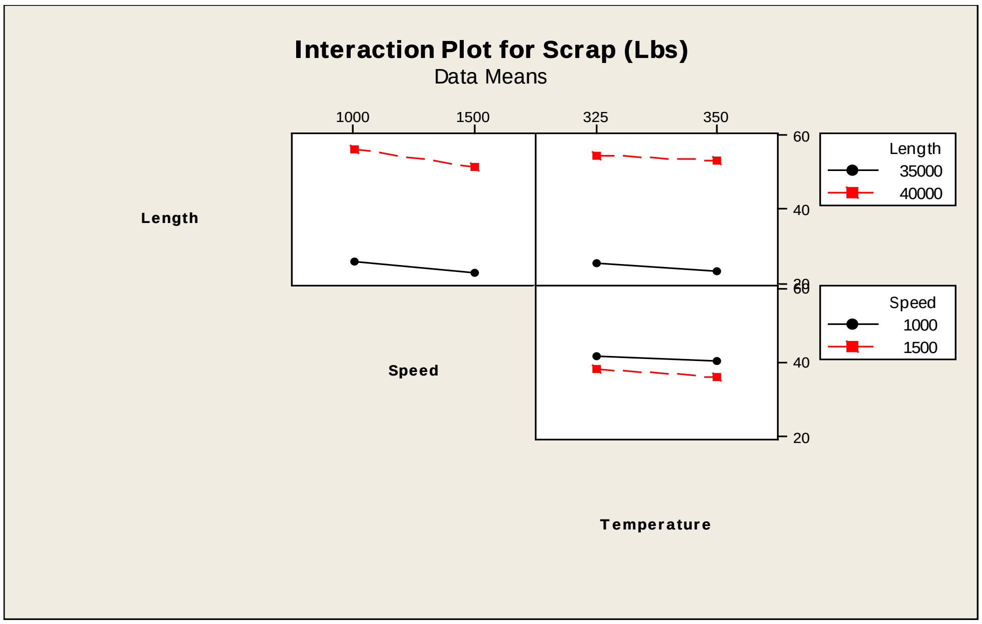

Figure 22: Interactions Plot for Scrap

Figure 22, shows the two factor interaction plot, information for all possible two factor interactions that should be examined [23]. And was found that length speed interaction is not significant and length temperature is not significant either. The same conclusion can be drawn from (ANOVA Table 9).

- Three Factor interactions

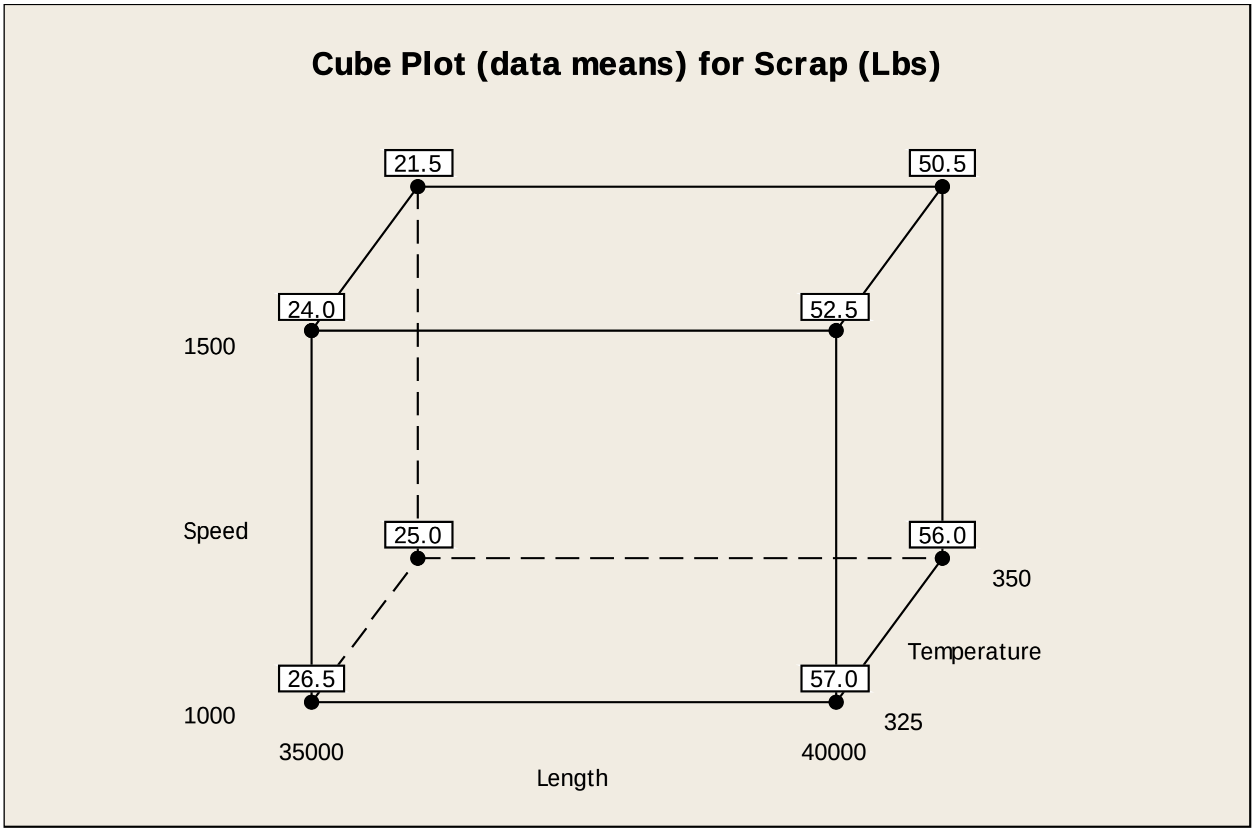

Figure 23: Cube plot

From the cube plot (Figure 23), it is found that the least scrap can be achieved at low length (35000 ft), high speed (1500 ft/min) and high temperature (350 ºF).

Step 2

Set of Experiments:

Table 10: Lengths used for the experimentation

Set of Experiments	Length (ft)
1	35,000
2	35,000
3	35,000
4	35,000
1	37,500
2	37,500
3	37,500
4	37,500
1	40,000
2	40,000
3	40,000
4	40,000

Using the temperature, speed, outer diameter, and other settings mentioned in the process guide, the finds were consistent for the three lengths and the 4th trial was done for every length.

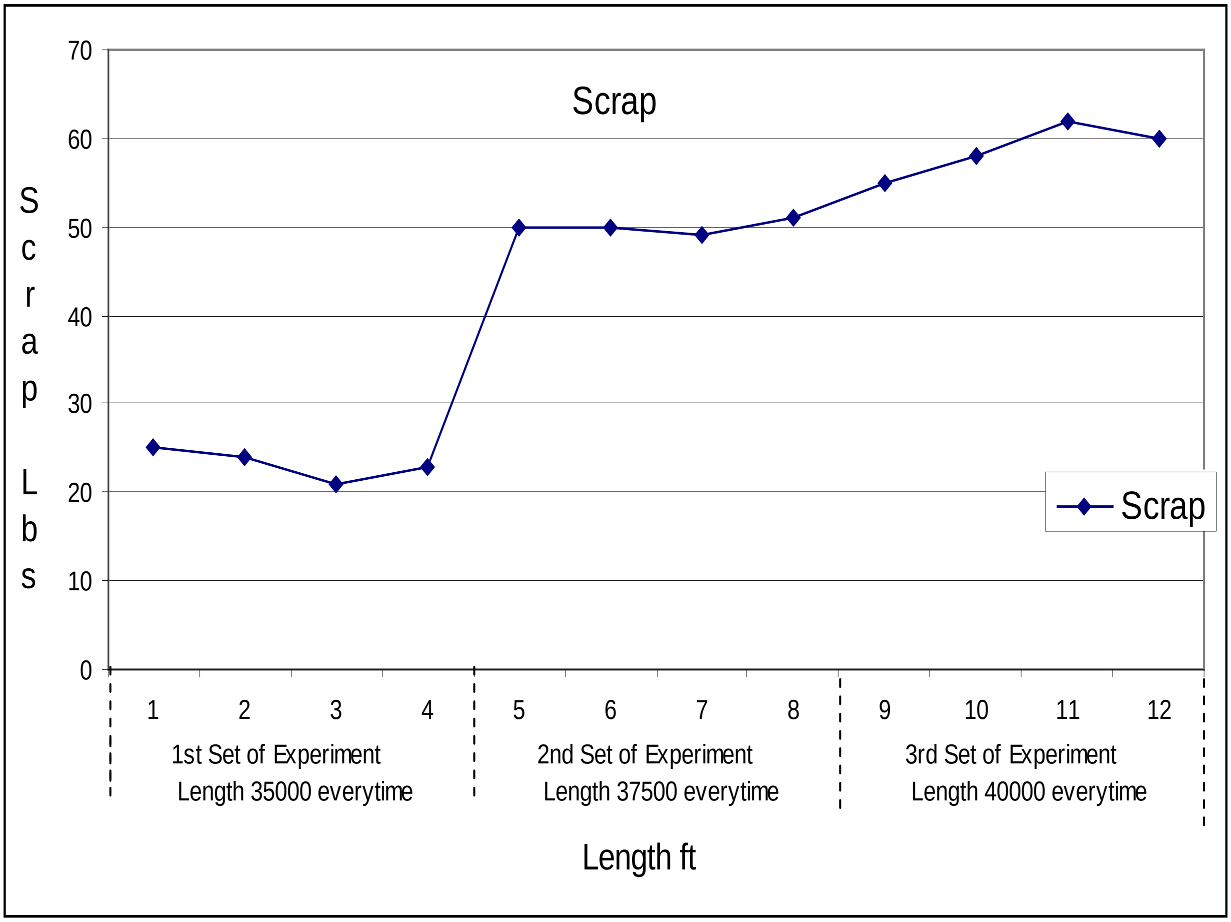

Figure 24: Scrap results when color changed at 35,000, 37,500 and 40,000 feet

The above graph shows that with one length, 4 trials were performed and scrap readings were taken. The result is shown in the graph above (figure 24). For the length of 35,000 feet the scrap was close to 20 pounds. For 37,500 feet the scrap was approximately 50 pounds and for 40,000 feet was as expected, 60 pounds.

The graph proves that the length 35,000 feet will produce the lowest amount of scrap, from 20 pounds to 25 pounds. By using this length almost 40 pounds of compound was saved at every color change for 2.0 gauges. Like this for 3.0, 5.0, 1.25 and 0.85 lengths were found when the color should be changed to get the least amount of scrap.

7.2 Results and Discussions

- Year To Date Total PVC Scrap percentage

With the scrap reduction the production cost also was successfully reduced with process organization [24]. The scrap percentage of PVC for the month of June 2010 was 22.99% and for November was 7.6% which means there was a reduction of 15.39%. Every month saw a consistent decrease in scrap percentage.

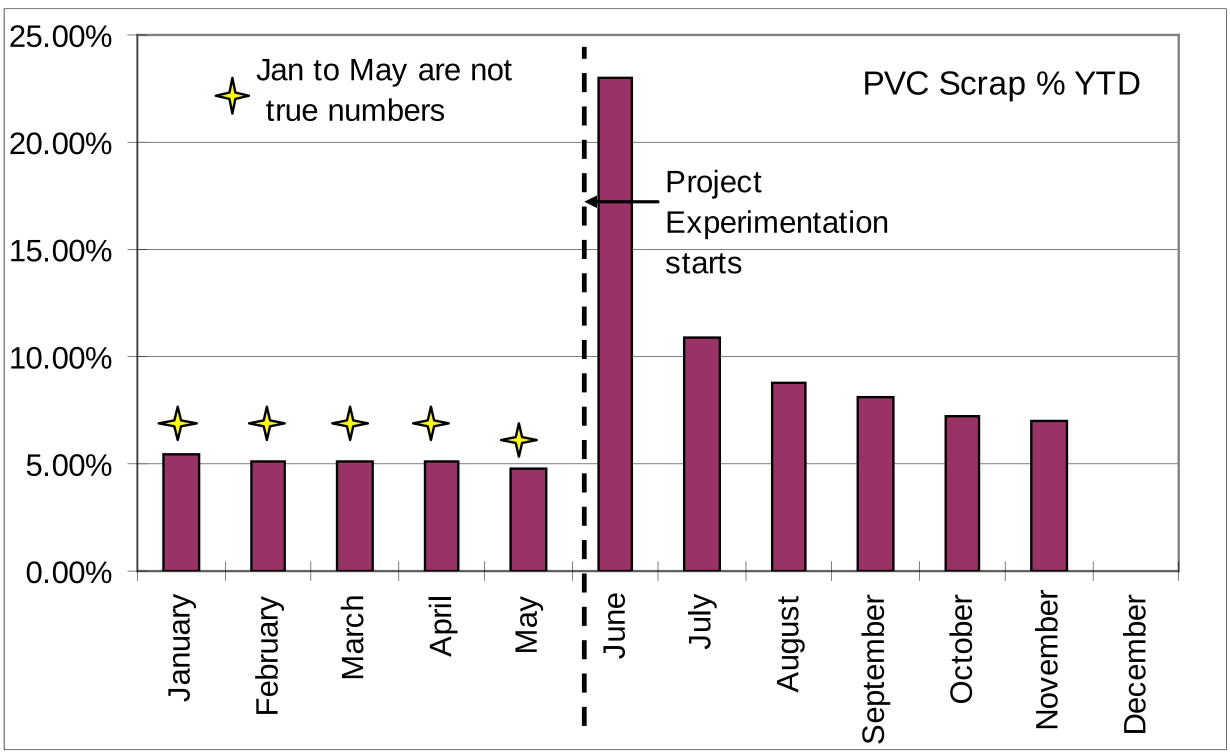

Figure 25: PVC Scrap Percent YTD

June 2010 saw major jump in scrap in PVC lines which contributed to the total insulation scrap. Reporting of right scrap started in the month of June 2010 and that's when company came to know the correct percentage of scrap. Before June the percentage shown in the graphs are the one on the production reports but the amount of scrap shipped and amount of scrap reported were not even close. Another reason why June was high is because the company concentration in June was more on Quality.

The scrap for October and November could not go down because of high number of color changes. As explained before the scrap from color change cannot be avoided. And is one of the major reasons why the scrap percentage did not decrease that much. The numbers of color changes for May on PVC lines and for the October were compared. For example STP 1 did 86 color changes in 10 days in comparison to 181 color changes in October 2010.

- Year To Date Total XLPE Scrap 2010

Scrap project on XLPE started in August 2010. In August 2010 the scrap percentage was 15.14% and in November 2010 it was 7.2% which means there was decrease of 7.94%

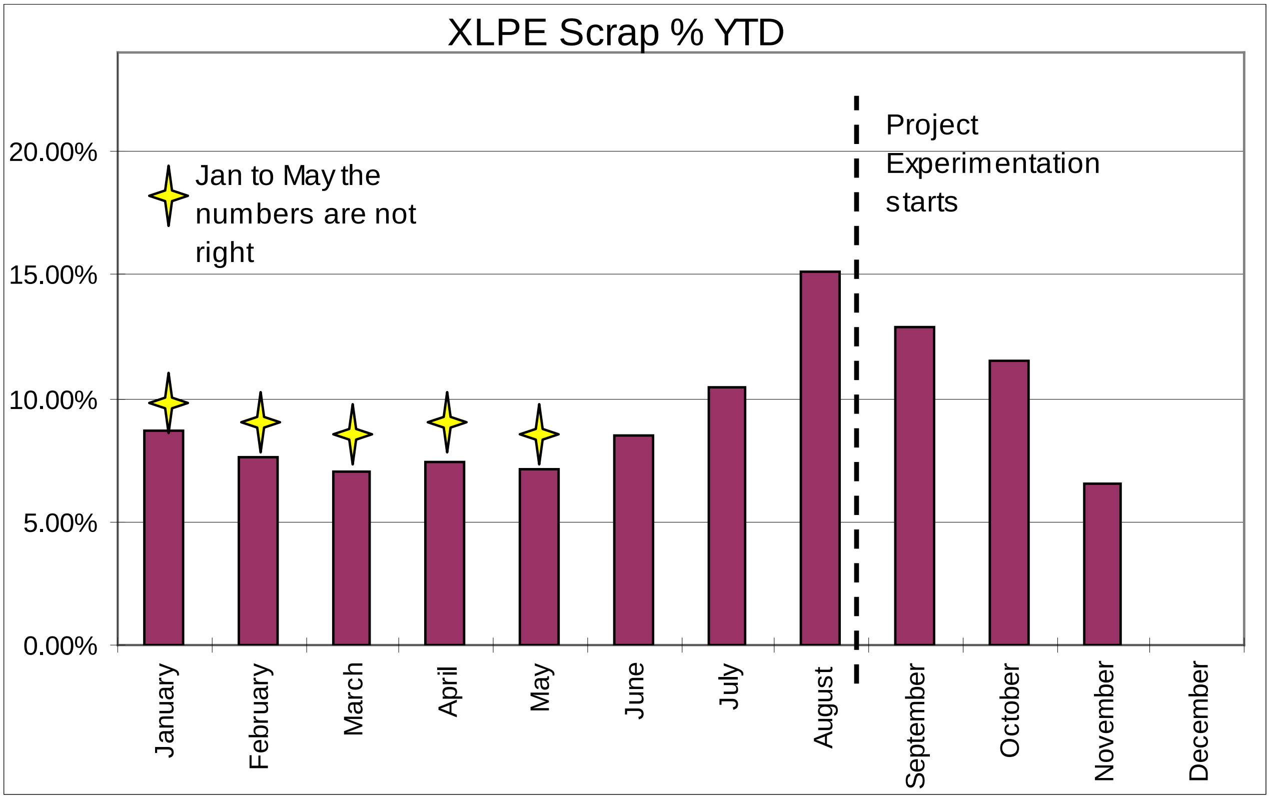

Figure 26: XLPE Scrap Percent YTD

The scrap numbers from January to May are not the right numbers. But after the project started on XLPE the scrap decreased.

- Total Insulation Result

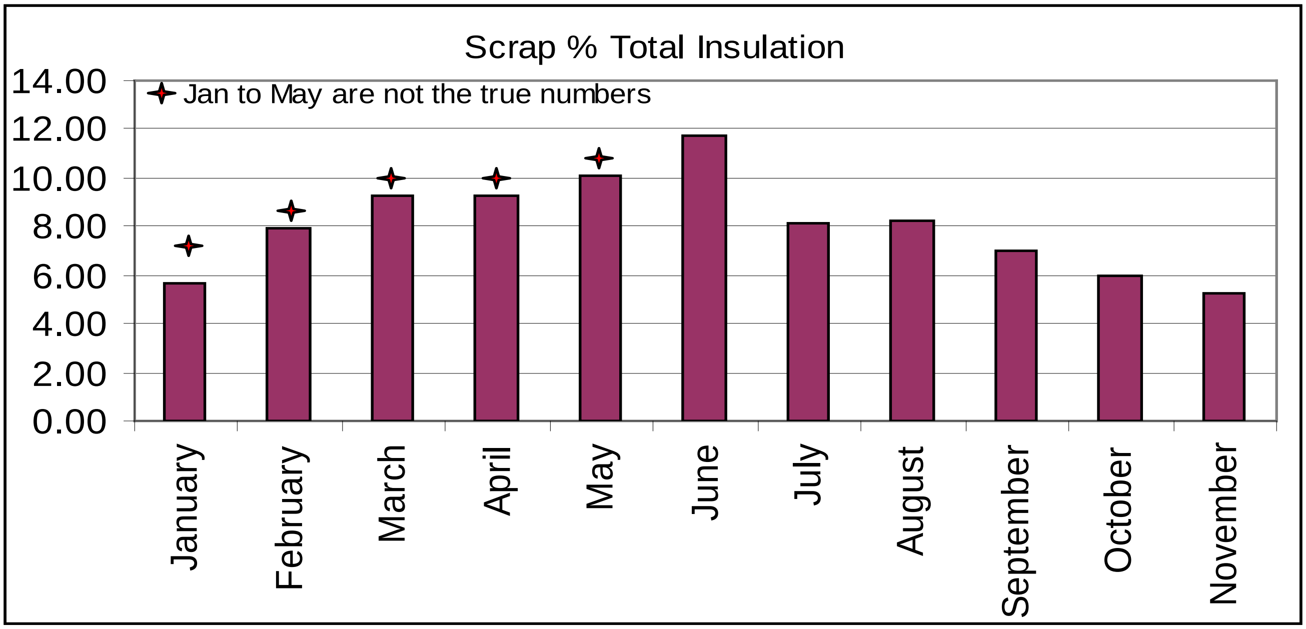

Figure 27: El Paso Insulation scrap percentage 2010

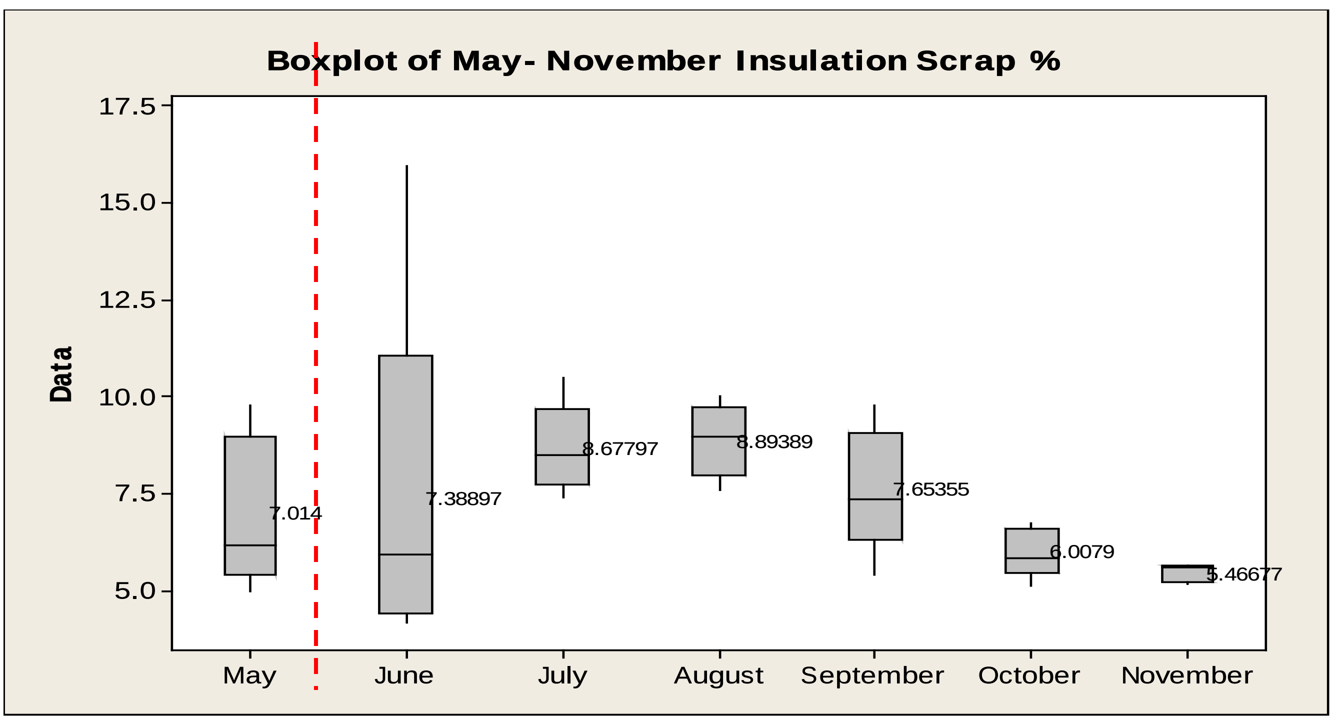

Figure 28: Box Plot Insulation Scrap percentage May 2010 to November 2010

The box plot (figure 28), shows a box encased by two outer lines known as whiskers. The box represents the middle 50% of the data sample - half of all cases are contained within it. The remaining 50% of the sample is contained within the areas between the box and the whiskers. The single line in the box represents the median, which is middle value of entire sample. In this case for November it is 5.4 %. You can see the scrap tendency and variation per month. It can be observed that in November there was less variation.

- DMAIC (Control Phase)

This is the last phase of DMAIC methodology. In this control phase of DMAIC methodology, a control plan will be developed to ensure that processes and product consistently meets company and customer requirements, and to check how length still impacts on quality production level [26, 27, and 28]. In this phase, large emphasis will be given on proper implementation of solutions. For this, regular checking of check charts will be carried out. Monitoring of scrap will be done shift wise, day wise and month-wise. The improvements will be adhered to by providing training to the staff, implementing various incentives schemes and adhering to the modified systems [25].

CHAPTER 8: CONCLUSIONS AND FUTURE DIRECTION

Conclusion:

Six Sigma methodology and Design of Experiments were used to reduce scrap. The introduction of six sigma technologies to reduce scrap provided the company with new tool of cost reduction. For this particular cost reduction project scrap improvement became the most important source. The results suggested that the scrap came almost to half from where it was in the beginning. **Scrap percentage for total insulation area was 11.74% in May 2010 and in November 2010 it was 5.38%.** So Six Sigma with the help of DOE does help to determine the correct setting for all the process and in that case for reduction of scrap too. Three factor two level full factorial designs helped determine the significant factor to reduce scrap. The analyses results showed that the scrap process was in control as compared to that before November.

Future direction**:**

Defects generally result from a process problem or material contamination, which result in lumps, breaks and neck-downs. The system Alarms and Reports Surface Quality Defects (SQD) as they happen, using advanced 3-Axis Visible LED Detection technology to cover the circumference of the product 3 times more effectively than 2-axis gauges. The one used in the company is 2 axis gauges which mean if the defect is very small it might escape. 3 axis gauges cover more area of the wire and will catch even smaller defects [29].

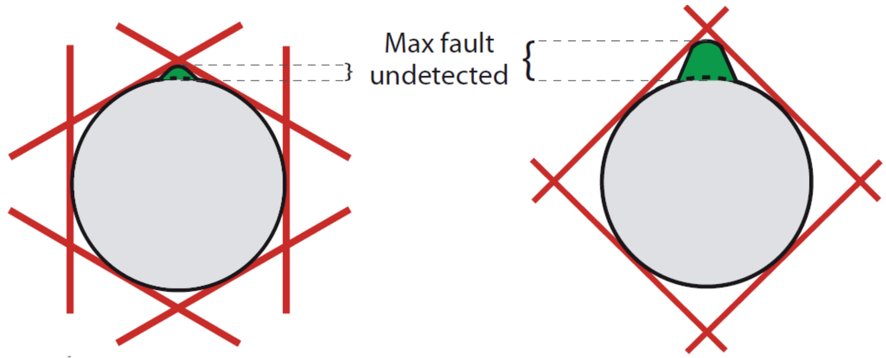

Figure 29: a) Three axis gauge b) Two axis gauge

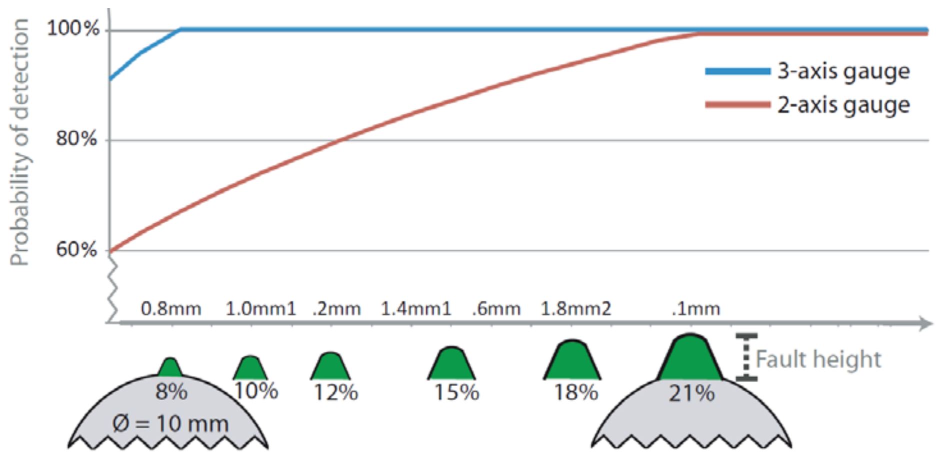

Figure 30: Probability detection [29]

This approach shown in the figure 29 a) and b) is being considered by the company. In the near future this process will be used to detect the defects more easily. The figure shows that the probability of detection of defects is greater on 3 axis gauges than that of the 2 axis gauges [29].

REFERENCES

[1] www.colemancable.com.

[2] T. Pyzdek, The Six Sigma Revolution, Quality America Inc. 1999.

[3] M. Harry and R. Schroeder, Six Sigma: The Breakthrough Management Strategy Revolutionizing the World's Top Corporations, Currency, New York, 2000.

[4] F.W. Breyfogle III, Implementing Six Sigma: Smarter Solutions Using Statistical Methods, John Wiley & Sons, Inc., New York, 1999.

[5] F. Cus, Produktionsmanagement in kleinen und mittleren Unternehmen. E I, Elektrotech. Inf. Tech., 114 No. 4 (1997) 176-181.

[6] M. Sokovic, D. Pavletic, PDCA cycle vs. DMAIC and DFSS, Proceedings of the 1st International Conference ICQME 2006, 13th-15th September, 2006, Budva, Montenegro.

[7] Z. Satterfield, What does ppm or ppb means? On tap fall, West Virginia, 2004

[8] T. Pyzdek, Six Sigma Implementation, John Wiley & Sons, Inc.,New York, 1999.

[9] R. Basu, Implementing Quality – A Practical Guide to Tools and Techniques, Thomson Learning, London, 2004.

[10] www.operational-excellence.net.

[11] www.isixsigma.com.

[12] N. Dedhia, Six Sigma Basics, San Jose, 2005.

[13] N. Hampton, R. Hartlein, H. Lennartsson, H. Orton, R, Ramchandran, Long-Life XLPE Insulated Power Cable, Jicable, 2007.

[14] H, Orton and R. Hartlein, “Long Life XLPE Insulated Power Cables”, October 2006.

[15] A. Campus and M. Ulrich, 20 Years Experience with Copolymer Power Cable Insulation. Jicable03, Paper B1.6, 2003.

[16] L Dissado and J Fothergill, Electrical Degradation and Breakdown in Polymers; IEE Materials and Devices, 1992.

[17] H Sarma, E Cometa and J Densley, Accelerated Aging Tests on Polymeric Cables Using Water-filled Tanks - a Critical Review. Electrical Ins Magazine, IEEE, Vol 18, No 2, pp 15-26. 2002.

[18] U Nilsson, The use of model cables for the evaluation of the electrical performance of polymeric power cable materials; Nord-IS05 Trondheim pp 101-106

[19] B Holmgrenand S. Hyidsten, Status of Condition Assessment of Water Treed 12 & 24 kV XLPE Cables in Norway & Sweden,NORDIS05, pp 71-75.

[20] www.audiokarma.com

[21] A. Griff, Extrusion Trouble shooter, Plastic Technology, Gardner Publication, Inc 2004.

[22]] E. Krulcic, EKOFIN - Black Belt project, PS Cimos, PPC Buzet, 2001.

[23] http://support.sas.com/documentation/cd/en/adxgs/60376/HTML/default/fullfac_sect11.htm

[24] F. Vizintin, M. Sokovic, Implementation of the 6 Sigma infrastructure in CIMOS company, Diploma thesis, (not published), Faculty of Mech. Eng., University of Ljubljana, 2001.

[25] http://www.kayoprojectmanagement.com/Sample%20Project%20Charter.pdf

[26] D. Pavletic, S. Fakin and M. Sokovic, Six sigma in process design. Stroj. Vestn., Vol. 50 No. 3 (2004) 157-167.

[27] M. Sokovic, D. Pavletic and S. Fakin, Application of Six Sigma methodology for process design, Journal of Materials Processing Technology, Vol. 162-163 (2005) 777-783.

[28] M. Sokovic, D. Pavletic and S. Fakin, Application of six sigma methodology for process design quality improvement, Proceedings of the 13th International Scientific Conference AMME '05, Gliwice-Wisla, Poland, May 2005, 611-614.

[29] www.protonproducts.com.

December 16, 2010

Re: Verification of Mr. Anoop J Randive's Original Work and Contribution

Dear Thesis Committee:

This letter is written on behalf of Mr. Anoop Randive to support his thesis defense "Scrap Reduction Model: by Combination of DMAIC and Design of Experiments" guided by Dr. Jianmei (Jenny) Zhang in Department of Industrial, Manufacturing, and Systems Engineering at The University of Texas at El Paso.

I am a Plant Manager in El Paso manufacturing unit at Coleman Cable Inc., and have been with company for many years now.

Mr. Anoop Randive joined our company in May 2010, and started to work on scrap reduction. The strategies and approaches proposed in his thesis work – combination of DMAIC and design of experiments was originally from him. The company started to implement his proposed approach from June 2010. We are especially delighted that his approach is working successfully and producing a lot of savings on scrap, including raw material, manufacturing cost, and related energy saving. Compared with scrap percentage of 11.74% in May 2010, the current scrap percentage is about 5.38% (in November 2010). I am confident to say that the work from Mr. Anoop Randive has significant impact on our company.

Please feel free to contact me if any questions related with this issue,

Sincerely,

Salvador Perez
Plant Manager
Coleman Cable Inc.,
7811 Hoover Ave.
El Paso, TX 79912
Tel: (915) 858 2104

VITA

Anoop Janglu Randive a Masters student of Manufacturing Engineering at The University of Texas at El Paso, Texas, USA. I have completed my Bachelor of Engineering in Mechanical Engineering, G. H. Raisoni College of Engineering, Nagpur, India.

I have been working as a process engineer at Coleman Cable, INC, El Paso, TX for the last 8 months. I have previously worked as a teaching assistant at The University of Texas at El Paso (Aug 2009 – May 2010), also as a research assistant at The University of Texas at El Paso, TX (Aug 2008-Jun 2009) and also as an engineer in research and development, PIX Transmissions Ltd, Nagpur, India (Aug 2007- Jul 2008)

I have successfully carried out few academic projects and researches, “Scrap reduction model: by combination of DMAIC and design of experiments” at the University of Texas at El Paso, TX, USA. “Implementation of supply chain management” at Superior Drinks Pvt. Ltd, MIDC, Nagpur, India (Jan 2007-Jun-2007) and an intensive voluntary training from Vurshali offsets Nagpur, India.

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This thesis/dissertation was typed by Anoop Janglu Randive.