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Using Basic Quality Tools to Improve Production Yields and Product Quality in Manufacturing

Steve E. Black
East Tennessee State University

Using Basic Quality Tools to Improve Production Yields and Product Quality in Manufacturing

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by

Steve Black

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Dr. Mohammad Moin Uddin (Chair)

Dr. Keith Johnson

Dr. Hugh Rogers

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ABSTRACT

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As the U.S. and world economies emerge from years of recession, the hardwood flooring market is currently enjoying strong growth. With this growth come new challenges for hardwood flooring manufacturers. Strong competition from foreign markets and rising log prices are reducing product margins and forcing companies to think lean, while improving product quality.

QEP Wood Flooring division, who struggled through the worst of the U.S. economic down turn is now regaining ground as a strong competitor in the hardwood flooring market. This turnaround is due to internal changes to decrease waste and increase product quality. This is accomplished by using the quality control department as a tool to aid manufacturing.

To accomplish these changes, QEP implemented the use of quality tools and employee awareness training; as a result QEP increased overall product quality and yields while reducing customer claim pay outs.

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LIST OF ACROMNYMS

DMAIC	(Define, Measure, Analyze, Improve, Control)
EGD	Engineer Department
MC	Moisture Content

LIST OF KEY WORDS

Chip-Out - Chipping off of wood fibers in the corners of flooring pieces.

Character - Physical attributes in the wood that are naturally occurring.

Product Off-Color - Product colors that don’t match established color board standards.

Inconsistent grading - Variation in product grading between various graders.

End / Side Match Process - Part of the manufacturing process that mills a tongue & groove on the ends and sides of flooring products.

Pre-Finish - Department responsible for applying stain / top coats to flooring products.

Color Set-ups - Process of matching stain colors to color board standards.

Color Board Standards - Established color board samples used to match stain colors prior to production run starts.

Color Spectrophotometer - Electronic color reading devise used to convert optical inputs to digital outputs in the form of numeric values.

Tongue and Groove - Mating or locking mechanisms on the ends / sides of flooring .

Engineered Panels - 4 foot x 4 foot wood panels, similar to ply-wood construction, with a hardwood face and back.

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CHAPTER 1

INTRODUCTION

Since 2011 sales in the U.S. hardwood flooring markets have steadily increased after several years of decline due to economic conditions. A growing U.S housing market is currently driving strong sales of hardwood flooring according to the National Wood Flooring Association 2014 sponsored Catalina Report (Catalina Report, 2014). The Catalina Report is the leading floor covering analysis of current market conditions in the floor covering industry.

According to the Catalina Report, U.S. hardwood flooring manufacturers who survived declining economic conditions in the U.S. and world markets face new challenges. These challenges are from foreign competitors capitalizing on the upturn in hardwood flooring sales by importing products at costs lower than what U.S. manufacturers can offer. This represents a 34.9% domestic sales increase in dollars of foreign wood flooring product since 2007 (Table 1).

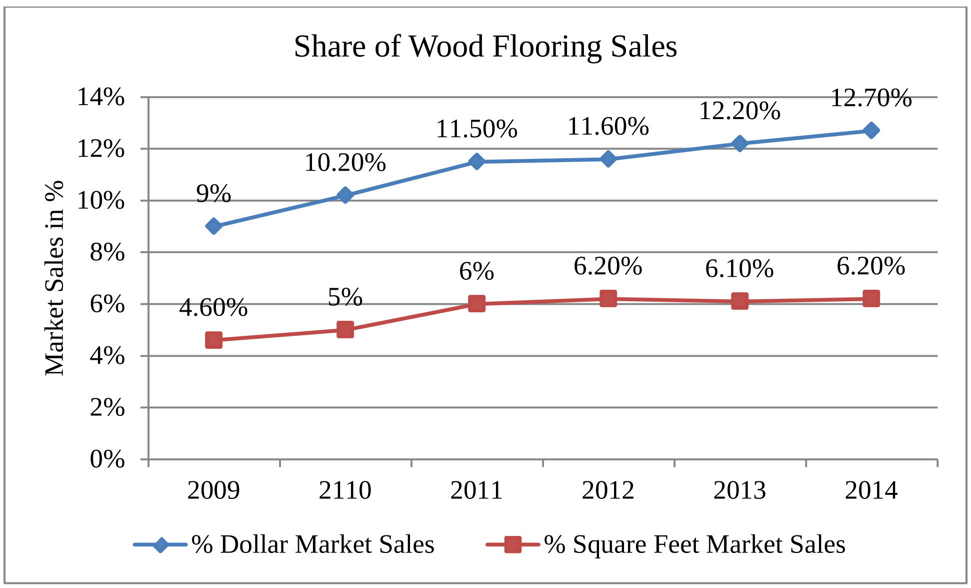
Table 1: U.S. Wood Flooring Imports, 2007-2014

	2007	2012	2013	2014
Dollars (mil.)				
Imports	$313.6	$834.3	$989.1	$1,107.9
Percent Domestic Sales	14.4%	38.2%	40.4%	41.3%
Domestic Sales	$2,184.2	$2,183.5	$2,446.2	$2,684.0
Square feet (mil.)				
Imports	152.2	420.3	507.7	571.5
Percent Domestic Sales	15.4%	38.3%	44.2%	47.6%
Domestic Sales	989	1,097.20	1,148.50	1,203.60
Notes:	Includes hardwood and softwood flooring, solids and engineered, and unfinished and finished. In manufacture's dollars.			

Source: U.S. Department of Commerce.
Compiled, calculated, and estimated by Catalina Research.

Another challenge hardwood flooring manufacturers face is increasing log cost due to high demand for hardwood flooring (Table 2). Foreign competition and rising log costs have decreased U.S. based hardwood floor manufacturers profit margins, forcing them to rethink their operations in terms of efficiency and quality. These actions are a must in order for manufacturers to reduce costs and improve quality as consumer's trend away from wall-to-wall carpeting.

Table 2: Wood Flooring Share of Total U.S. Floor Coverings Market 2009-2014 (Percent of total floor coverings sales)



Source: U.S. Department of Commerce.
Compiled, calculated, and estimated by Catalina Research.

QEP's Wood Flooring manufacturing facility in Johnson City TN is an example of a typical midsize hardwood flooring company who has implemented, basic but effective quality improvement tools in order to remain competitive in terms of efficiency and the quality of their products, in the post-recession U.S. markets. QEP's Johnson City facility has operated under many different owners and names since they opened their doors in 1898 (Harris Wood, 2015); three of them being in the last eight years. Multiple change in owners over the resent years have brought with it new visions and diverse flooring products for the flooring manufacture, however their manufacturing processes remain virtually unchanged until recently. Processes in place for many years have changed very little, and employees that perform these processes continue to carry out the same, cultured, daily routine they were trained to do many years ago.

Routine processes are an inherent part of most all manufacturing; these processes require continued evaluation to ensure the greatest efficiency and product quality possible. When defects or poor quality are present, a closer look at the overall process is needed in order to find and eliminate the root cause contributing to product waste and defects. Allowing quality issues to go unresolved can result in customer claims which in turn increase product costs through waste, material rework, and loss of sales due to negative word-of-mouth publicity.

In 2011 as part of the recovery effort from the U.S. recession, QEP's Johnson City management team implemented an initiative to address the top three leading causes of product defects and waste. The goal of this effort was to reduce product costs and increase yields by eliminating major causes of waste. The top three items selected for this effort were, end chip-out, product off color, and inconsistent grading.

These three areas were selected because of their great potential to increase product quality and yields, while reducing manufacturing costs through waste reduction and minimizing customer claims. This is important to QEP because it allows them to remain competitive in the wood flooring industry by providing their customers quality products at competitive prices. During these improvement processes, clear concise methods known as best practices were established and documented and are key elements in maintaining all improvements.

CHAPTER 2

BACKGROUND

QEP has an operating culture that dates back many years to pre-U.S. recession times when the company operated three shifts seven day a week under a different company name. During this time the company sales volumes were such that any customer complaints that arose were overshadowed by the sheer volume of products sold. Rather than maintaining a balance between production and quality, production remained the main focus. This operation culture continued on for several years.

In the mid to late 2000's the Johnson City facility experienced major decreases in sales volumes due to current economic conditions in the U.S. and world markets. In 2010 when the facility was purchased by QEP Co. Inc. capital was invested in order to remain competitive against other post-recession emerging flooring manufacturers; investment capital went to update some of their antiquated manufacturing equipment still in use.

In addition to updating equipment, and turning to trending flooring products saturating the market, QEP focused on establishing an effective quality department which up to this point they were lacking. Management's goal in the Johnson City facility was to build a streamlined quality department that works on a daily basis with production to identify and resolve quality issues. This includes keeping minimal but effective quality staff, and using simple but effective quality tools to immediately address any concerns as they arise.

Objective

The objective of this thesis is to demonstrate how, using basic quality tools, and focusing on key areas of production waste and poor quality, can improve QEP's overall production yields, while improving their customer satisfaction. To achieve this, the three areas of focus in production are end chips, product off-color, and inconsistent grading. These three areas are determined to be three largest areas of waste, while believed to be easily resolved.

Projects for these three areas include observing key processes and identifying deficiencies in the process, then implementing recommended improvements. Sufficient data are be gathered both prior to and after each project in order to demonstrate the effectiveness of each project. In addition, the three projects selected set the foundation for future improvement projects, while using basic quality tools and methods.

Scope

The scope of this thesis is to take a look at three production areas at QEP's Johnson City facility that are top sources of waste, and poor quality, identify their root causes, and then implement solutions using appropriate quality tools. Data are provided before and after each improvement project to validate the effectiveness of each project.

Typical quality improvement projects use assembled teams, conduct meetings to formulate in-depth plans to identify and resolve quality issues. The three projects in this thesis are carried out using minimal time and resources due to the nature of the problem areas needing addressed, and how well the existing problems are currently understood.

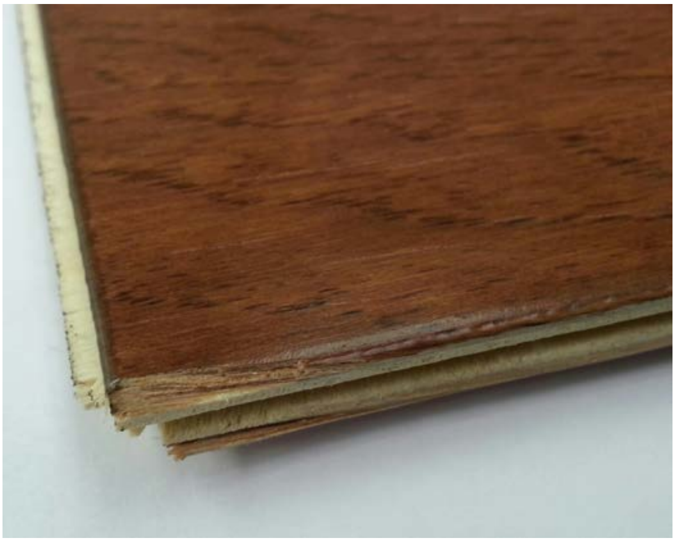
The first improvement project addresses chip-out on the ends of flooring caused during the end match process. The quality tool known as the DMAIC (Define, Measure, Analyze, Improve, and Control) process provides a step-by-step guide in identifying, resolving, and maintaining improvements. Included in the DMAIC process is the cause and effect diagram, this tool will assists in identifying the cause or causes of chip-out.

The second improvement project addresses inconsistent color-sets during the floor staining process in the pre-finish department. After using the “5-why method” to identify why color set-ups are inconsistent, a process improvement plan is implemented to standardize color set-ups. This is accomplished using statistical process control charts, color standards, and a color spectrophotometer to digitally measure color rather than judging color using the human element. Before and after data is provided to measure the overall effectiveness of this project.

The third improvement project, inconsistent grading, was selected as one of the three improvement projects due to its potential to generate large amounts of waste due to mis-identifying natural character in wood as defects. Another waste generator while grading flooring is to mis-judge defect sizes. By incorrectly identifying defects or mis-judging their sizes, flooring that is technically acceptable by product grading specifications, and industry grading standards is pulled from the production line and defected out, causing a loss of production yield.

Chip-Out

End chip-out occurs on the end corners of flooring after it is end-matched with a tongue & groove or click locking profile. Chipping out of the corners creates a void noticeable when installing flooring (Figure 1).



(a)

(b)

Source: Photo Courtesy of QEP

Figure 1: Chip-out on the Corners of Flooring

Product Off-Color

Depending on product color and extent to which color is mis-matched, product off-color creates color differences between different lot numbers produced, and can result in noticeable color variations when installing flooring from multiple lot numbers as seen in Figure 2.


(a)
(b)

Source: Photo Courtesy of QEP

Figure 2: Product Off-Color

Inconsistent Grading

Inconsistent grading creates waste by removing natural character and minor defects allowed by local and industry product standards, while allowing true defects to remain in the product that should be removed. Figure 3 illustrates differences in the amount of natural color variation (character) between a select, and number 1 common grade of lumber (NWFA, 2015).

(a)

(b)

Source: www.nwfa.org/nofma-grade-photos

Figure 3:(a) Select (clear) Grade Red Oak, with Minor to no Natural Color Variation;(b) #1Common Grade Red Oak with Darker Color Variation

CHAPTER 3

THREE QUALITY IMPROVEMENT PROJECTS

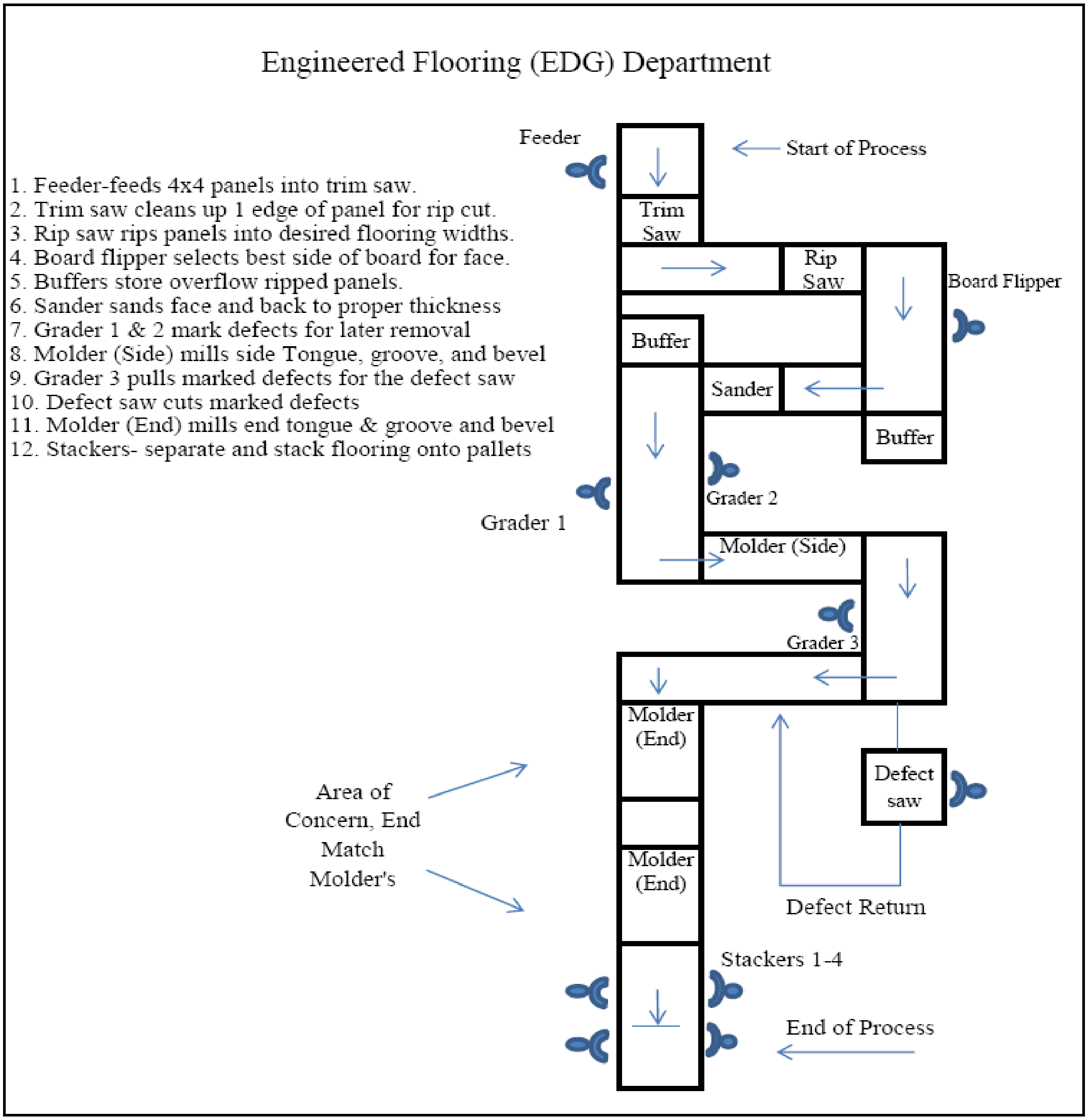
End Chipout Project

Problem Description

Flooring milled from engineered panels both 3/8” and ½” thick require milling a side and end bevel, and tongue & groove as part of the product manufacturing process. During this process, chip-out on the leading and trailing corners of the flooring are created, this causes a void on the corners of the product that stands out as an unstained area (Figure 1).

Background

At one time chip-out was not an ongoing problem in the Engineered Department (EGD), however after interviewing several short and long term employees, it could not be concluded exactly when the problem manifested into an ongoing quality concern. Figure 4 gives a process lay-out view of the EGD department, and shows the area in the process where chip-out occurs. Some EGD employees feel chip-out has always been present in all species of wood and across all products run on a daily basis, while other employees stated they hardly ever notice end-chips in the products. Lacking any specific requirements to inspect for end chips, there is no historical data to help identify how long or how often end-chips have been an issue.



Source: Photo Courtesy of QEP

Figure 4: Diagram, EGD Department Layout

EGD operators who are responsible for setting up milling equipment, and maintaining proper product tolerances have no specific adjustment requirements to follow in order to eliminate chip-out when noticed. When the operators were asked where they felt the end chips were coming from, most of the time the answers given we're either the moisture content in the material was too low (dry), or it was just the nature of the particular wood specie due to the fact that chip-out was more prevalent in some species than others.

Downstream from the EGD department, pre-finish graders initially identified the end-chip problem due to how noticeable it is after the product is stained and top coated. Areas that are chipped out are usually below the stain roller coverage area thus leaving this area void of stain. As with employees in the EGD department, pre-finish employees could not agree on when or for how long end chips in the product have been present on a regular basis.

End Chipout Project Details, DMAIC Process

Steps taken to resolve the EGD chip-out problem starts with using a structured data driven Six Sigma Methodology known as DMAIC. The acronym stands for Define, Measure, Analyze, Improve, and Control (DMAIC). Used effectively, this quality tool will help identify, eliminate, and control issues with product quality that may arise.

The DMAIC methodology uses statistic and process improvement tools to improve current processes or, as in the case of the EGD department, to help locate and solve existing problems. The goal of the DMAIC process is to implement long term solutions to current problems. Each step in the DEMAIC process builds on the previous step, and according to Carl F. Berardinelli's on-line Quality Progress (QP) article (Berardinelli, 2015), the process should be used to solve complex problems, or when risks are high. The following DMAIC process steps will describe how the EGD chip-out problem was identified and resolved.

Define (D)

The process starts with clearly defining the problem; define the problem in terms of not only physical attributes such as the physical chipping of wood on the corners of flooring but also why chip-out is a problem, and who is the customer that is affected by the chip-out. The rest of the steps in the DMAIC process will build on properly defining the problem.

Defining the problem should also include relevant performance metrics, as well as customer complaints, if any. If a problem is too widely or vaguely defined, one runs the risk of implementing ineffective solutions in resolving the problem, thus having a high probability of the problem persisting and/or returning. In the EGD department, the defined problem is obviously the chipping out on the corners of the flooring during the end matching process.

Measure (M)

The measure step of the DMAIC process involves data gathering; this is achieved by random sampling of EGD production runs throughout a two week period. Four species of wood are included during the sampling process (hickory, red oak, walnut, and maple). At each random sampling interval, each end of 100 consecutive pieces of flooring was inspected for chip-out; the number of chips found during the sampling process was then documented.

Data collected during the two week sampling process was documented on a tally sheet, Table 3, and then an overall percentage of chips found during the two week period were displayed on a bar chart as seen in Table 4. In order to determine if one end of the flooring is more susceptible to chip-out than the other, each end of the flooring was identified separately and labeled as to its function, either insert end, or non-insert end.

Table 3: Tally Sheet, Chip-Out Count

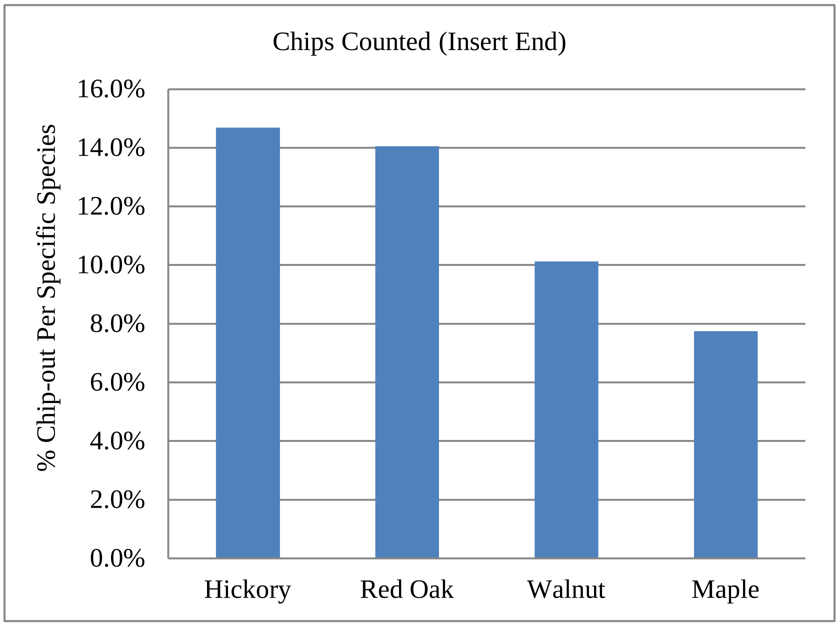
Insert End				
	Hickory	Red Oak	Walnut	Maple
	Number of Defects Counted			
Mon	16	11		
	17	10		
	14	14		
	15	12		
Tues		15		7
		14		10
		16		6
		16		6
Wed		12		8
		16		10
		15		6
		14		7
Thurs		14	12	
		15	8	
		15	12	
		12	12	
Mon	16			10
	15			11
	12			6
	15			6
Tues	15	14		
	10	12		
	12	16		
	17	18		
Wed			8	
			7	
			12	
			10	
Thurs	18			6
	13			8
	14			10
	16			7
Total chips	**235**	**281**	**81**	**124**
Total boards	**1600**	**2000**	**800**	**1600**

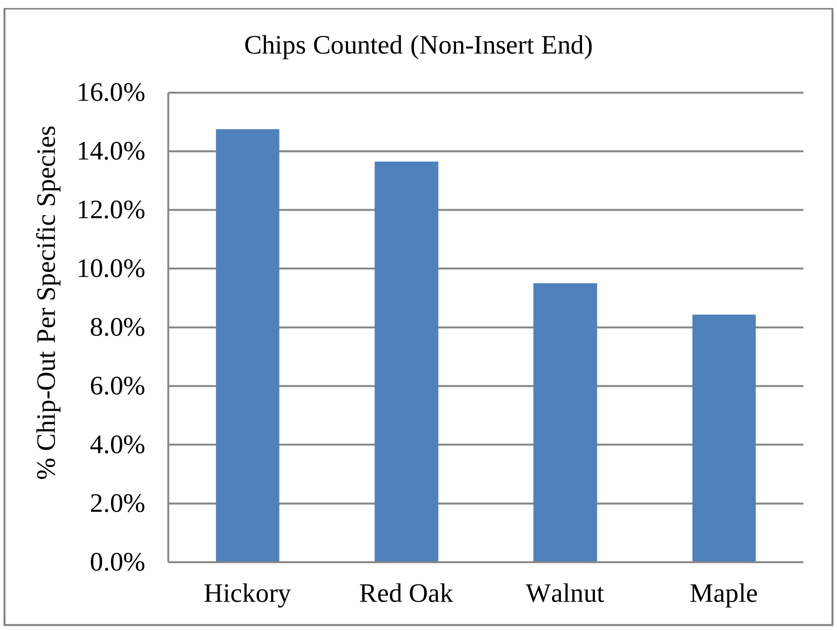
Non-Insert End				
	Hickory	Red Oak	Walnut	Maple
	Number of Defects Counted			
Mon	15	12		
	15	16		
	16	12		
	17	10		
Tues		15		9
		16		11
		17		10
		14		7
Wed		13		8
		16		10
		12		7
		14		7
Thurs		10	14	
		16	10	
		12	9	
		10	8	
Mon	15			11
	9			7
	13			9
	17			8
Tues	16	18		
	12	14		
	10	10		
	18	16		
Wed			6	
			10	
			7	
			12	
Thurs	12			5
	18			9
	17			9
	16			8
Total chips	**236**	**273**	**76**	**135**
Total boards	**1600**	**2000**	**800**	**1600**

Insert End				
	Hickory	Red Oak	Walnut	Maple
Average	14.7%	14.1%	10.1%	7.8%

Non-Insert End				
	Hickory	Red Oak	Walnut	Maple
Average	14.8%	13.7%	9.5%	8.4%

Table 4: Percent of Chip-out With-in Specific Species





On click locking floor systems, the insert end describes the end of the flooring that receives a locking insert and the non-insert side does not receive an insert. On Tongue & Groove locking systems the Tongue is considered the insert end, and the groove is considered the non-insert end (Figure 5). Once sample data was collected, tallied, and charted during the measuring phase of the DMAIC process, the data was then analyzed for key attributes in order to help determine where in the process the chips are coming from.


(a)

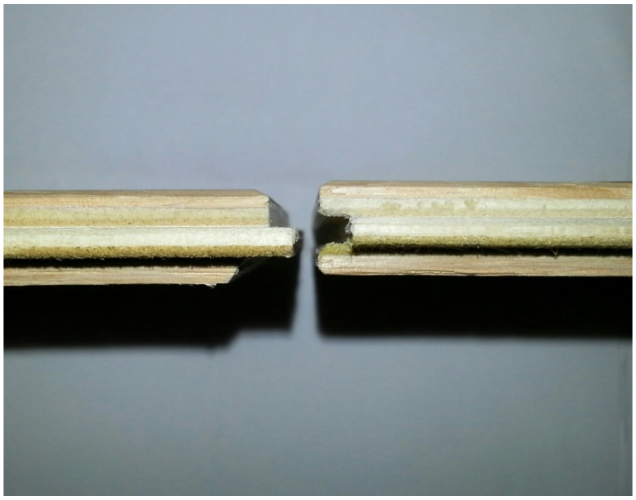

(b)

Figure 5: a (Click Lock Profile), Left (Insert End), Right (Non-Insert End): b (Tongue & Groove Profile), Left (Tongue End), Right (Groove End)

Analyze (A)

During the analyze phase of the DMAIC process, data collected was analyzed by first determining the overall percent of chips found for each species of wood sampled. The results of the data clearly shows that across all four wood species, chips exceeding total allowable defects of 5% or less were present; in addition chip-out was more prevalent in the hickory and red oak species, than in the walnut and maple species. This is consistent with what is expected of each species given their structural fiber make-up.

After determining the amount of chip-out present in all four species of wood exceeded established specification limits of 5%, the next step is to determine what part of the milling process is causing the problem. This is accomplished using a cause-and-effect diagram. The purpose of the cause-and-effect diagram is to determine the most probable cause of a defect by first listing all possible causes in the process and then eliminating non-relevant ones.

According to the American Society for Quality (ASQ), an on-line quality publication, the cause-and-effect diagram, otherwise known as the Fishbone (Ishikawa) Diagram, is one of seven basic quality tools, and is used to list many possible causes or problems (Tague, 2005). The diagram in Figure 6 lists four categories that the most probable cause of chip-out will fall under (people, machine, material, and methods). Each main category was subdivided into sub categories in order to list more specific causes of chip-out under the four main causes.

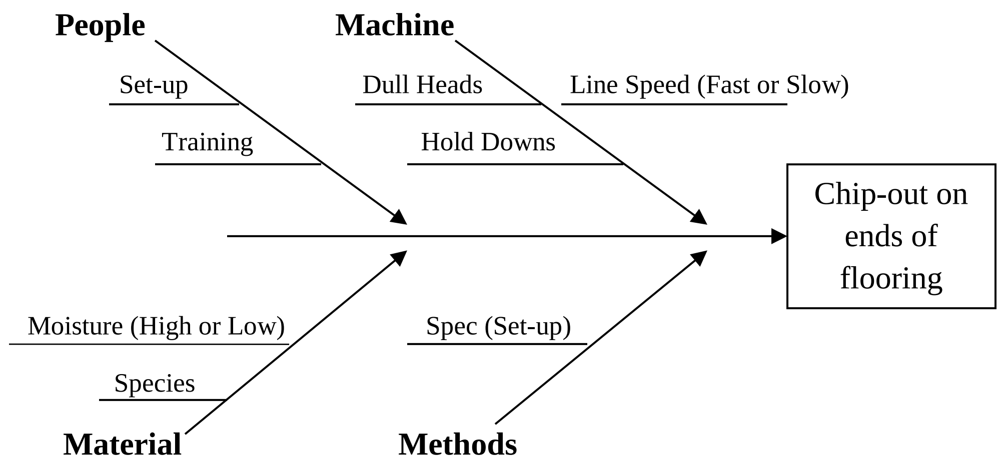


Figure 6: Cause and Effect Diagram Listing Most Probable Causes of Chip-Out

Results of the four possible contributing factors evaluated:

- **Methods**: Manufacturers Specifications for machine set-up are acceptable and ruled out as a contributing factor to chip-out.

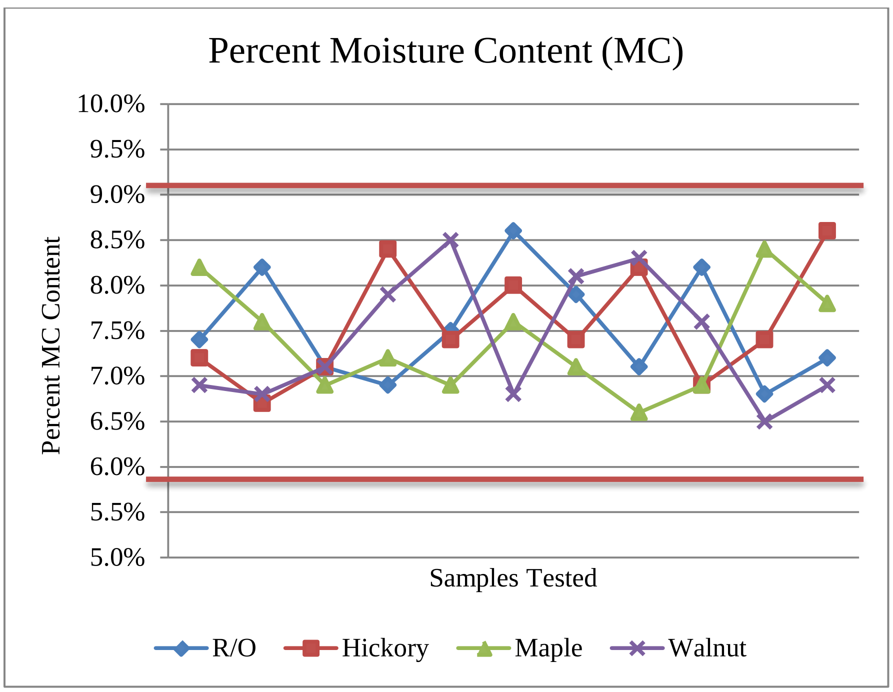
- **Material**: Moisture (High or Low); Figure 11 shows that moisture samples taken from the same run as the chipped material samples were taken concludes high or low moisture was not a contributing factor to chip-out. See "Wood Moisture Content" section for details.

- **Machine**: Line speeds were adjusted at different rates during a test run and determined to not be a contributing factor to chip-out. Hold downs that maintain constant positioning of the flooring as it goes through the milling process we properly adjusted and also determined not to be a contributing factor to chip-out.

  NOTE: It was discovered that no scheduled processes were in place to ensure regular cleaning and sharpening of cutter heads. In a trial test, it was observed that during the milling process when chip-out was present, changing cutter heads did slightly decrease the number of chip-out occurrences, but not below the 5% acceptable target.

- **People**: When evaluating the operator set-up process, it was discovered that this process was not consistently followed; in addition, each operator's set-up was slightly different based on their experience level. Operator training is another factor to consider as no standard training processes are in place. Both Operator set-up and the lack of operator set-up training were identified as contributing factors to chip-out.

Table 5: Moisture Content (MC) Results from Test Samples



Green Weight – Dry Weight / Dry Weight = Percent Moisture Content (MC)

Desired MC = 6-9 Percent.

Wood Moisture Content Testing

In National Wood Flooring Association's Technical Publication No. A100, drying lumber to a moisture content between 6-9 percent before milling is a commonly accepted practice in the wood flooring industry (National Wood Flooring Association, 1996), QEP uses this standard to gauge moisture content in their raw materials prior to milling. During the test sampling process for chip-out, several samples from each wood species, some with chip-out, and some without, were tested for moisture content.

QEP uses ASTM4442-07, Standard Test Method for Direct Moisture Content Measurement of Wood and Wood-Based Materials (method B) as an industry guide to determine moisture content in their wood panels prior to milling them into flooring (ASTM4442-92, 2003). One inch-by-one inch samples are cut from wood flooring panels and weighed (green weight), then placed in a drying oven using an electric heating element set to 103 degrees Fahrenheit. The samples are dried for 24 hours, during which time periodic weight checks are made to determine when the samples stops loosing moisture weight. At this time the samples are considered void of all moisture and their weight (dry weight) is measured.

The formula used to determine moisture content (MC) as a percentage of overall sample weight is as follows: MC% = (A-B) / B x 100 where A = original mass (green weight), and B = over dried mass (dry weight). In Table 5 the results of the samples tested for moisture as being a contributing factor to chip-out are listed. Results of the data show that moisture content being too high or too low is not a contributing factor to chip-out and thus, material as a cause of chip-out is eliminated.

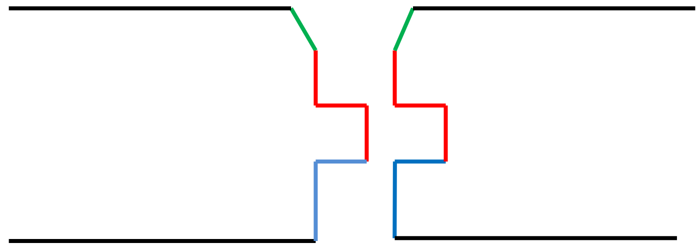
Corrective Actions for Chip-Out

Once results of the cause-and-effect diagram were analyzed it was determined that corrective action procedures for chip-out were focused in the following areas.

- People – Operator Set-up, and Training
- Machine – Dull Cutter Heads (Although not a main cause, but still a contributing factor)

When considering operator set-up as a contributing factor to chip-out, it was determined that operators use different methods for setting-up and adjusting machinery for the milling process. The main contributing factor discovered during operator set-up was placement of the three cutting heads, used to mill different parts of the tongue and groove profile, in relation to the material being milled. Operators incorrectly setting up the second and third cutting head directly contributed to excessive chip-out during the milling process as follows.

Three cutting heads as shown in Figure 7 are used to mill the various parts of the tongue and groove profile on the ends of the flooring. It was determined by watching the set-up process that operators were using head number 3 to cut a larger portion of the final profile than the head was designed to cut, this left less material for cutting head number two to cut.

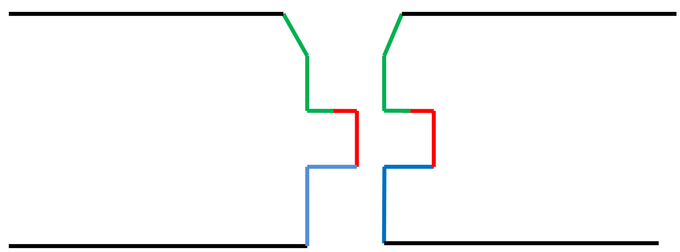


A: Proper Cutting Head Set-up

Blue – Milled by head #1

Red – Milled by head #2

Green – (Bevel) Milled by head #3



B: Cutting Head Set-up before Improvement Project

Blue – Milled by head #1

Red – Milled by head #2

Green – Milled by head #3

Figure 7: Cutting Heads 1-3 Milling Profile

For privacy reasons, this diagram is intended to give a simplified visual indication of how various parts of the tongue and groove profile are milled by each cutting head and is not an exact representation of the actual profile drawing. Various colors indicate specific areas of the tongue and groove profile that are cut by cutting heads 1-3. Notice the difference in the amount of material cutting heads 2 and 3 mill between diagram A and B.

In diagram A, cutting head #3 is required to only mill the bevel part of the overall profile. In diagram B you can see that in addition to the bevel, cutting head 3 is also cutting part of the tongue & groove profile as well.

A properly designed and follow-up training plan to show and remind operator's specifics about machine set-up would eliminate variances in the set-up process between operators, and ensure all operators set the machinery up the same, using a set standard. In addition, implementing a sharpening and cleaning schedule for cutter heads would eliminate cutter heads from remaining in use beyond a reasonable duration with-out being cleaned and sharpened.

<u>Improve (I)</u>

The improve part of the DMAIC process uses data analyzed in the previous step to come up with viable long term tested solutions to improve the part of the process that is causing the issue or issues. The set-up process mentioned above was considered to be common practice as it decreased the changeover time between products of different thicknesses. Once each of the three cutting heads was properly set-up during a test run, chip-out immediately decreased. A written set-up process was incorporated in the operator's daily set-up tasks; the procedure requires each operator to sign off on each set-up task prior to starting a production run. Department supervisors are responsible for ensuring operators properly set-up and sign off on the set-up process prior to each run, and quality control auditors verify set-up procedures are signed off on.

A training plan was also included in the improvement part of the process to bring focus on the importance of proper machine set-up as well as a cleaning and sharpening schedule to ensure cutter heads are not in use for extended periods of time without being removed for cleaning and sharpening. Incorporating these improvements in the EGD department contributed to an immediate improvement on the overall milling process, thus reducing the number of chips the graders defect out of a typical production run. The reduction in chip-out also allows graders more time to look for other defects.

Control (C)

The final step in the DMAIC process requires controlling changes and improvements made to the process. This requires continuous monitoring of newly implemented processes to ensure gains made are sustained over time. To sustain the improvements made in the EGD department, three follow-up actions are implemented.

1. Operator set-up check lists, and cutter head cleaning and sharpening scheduled check sheets.
2. Daily Supervisor checks – Supervisors are required to make frequent checks to ensure operators are performing proper set-up procedures.
3. Quality control auditors make frequent checks of the process to ensure proper set-up and documentation procedures are followed.

Chip-Out Improvement Project Results

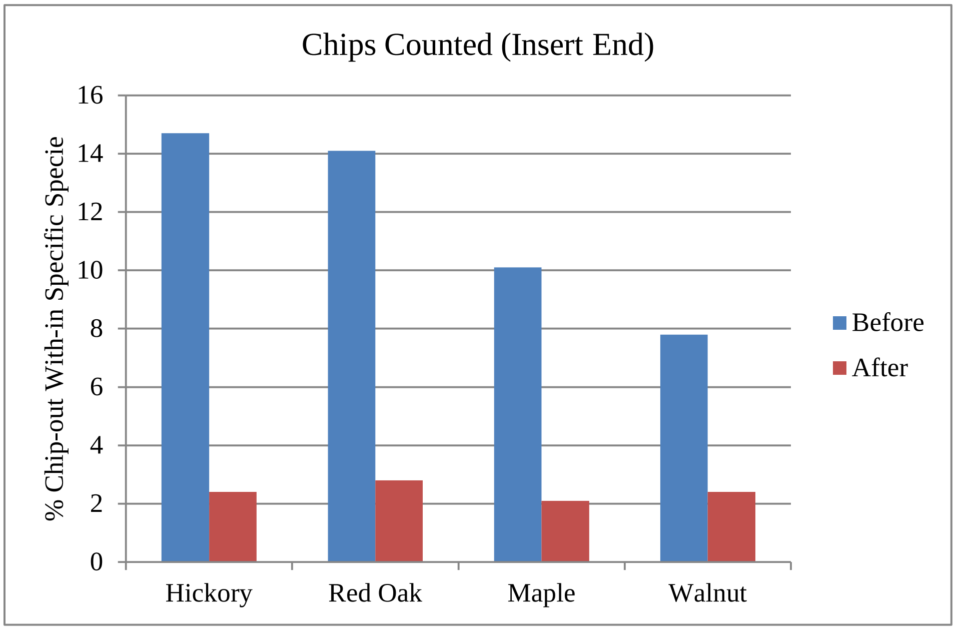
As seen in Table 6 and 7 below, at the beginning of the chip-out project, the average amount of chip-out during a given production run was 11.7% on the insert end of the line and 11.6% for the non-insert end. Results after the chip-out improvement project show the average amount of chip-out dropped to 2.4% on the insert end of the line and 1.9% on the non-insert end of the line. This is an overall 20.5% reduction in chip-out on the insert end and 16.4% reduction on the non-insert end. Percent’s for specific species are listed below.

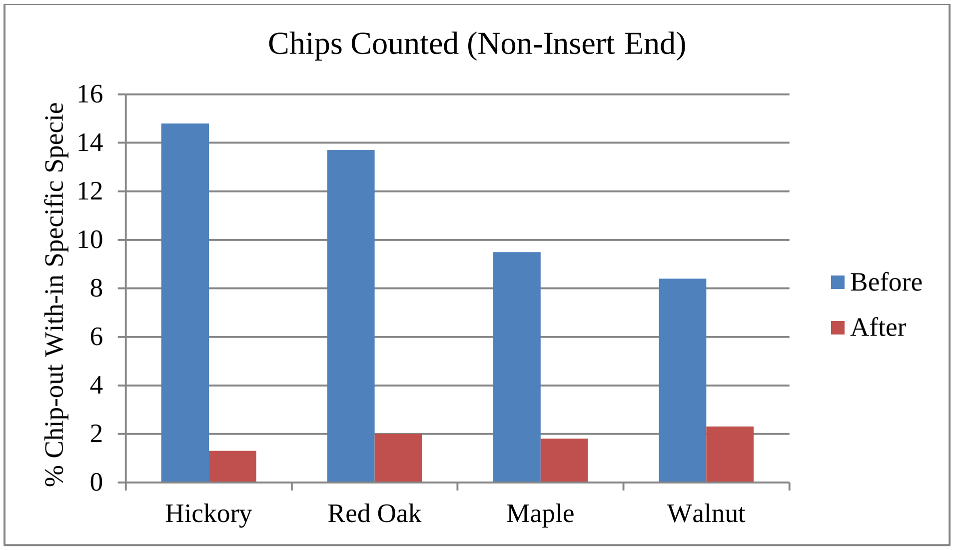
Table 6: Results Before and After Data Collected During the Chip-Out Project

Insert End					
	Hickory	Red Oak	Maple	Walnut	Average
Before	14.7%	14.1%	10.1%	7.8%	11.7%
After	2.4%	2.8%	2.1%	2.4%	2.4%
				Overall Reduction in Chip-Out	**20.5%**

Non-Insert End					
	Hickory	Red Oak	Maple	Walnut	Average
Before	14.8%	13.7%	9.5%	8.4%	11.6%
After	1.3%	2.0%	1.8%	2.3%	1.9%
				Overall Reduction in Chip-Out	**16.4%**

Table 7: Reduction in Chip-Out on Insert and Non-Insert End of Flooring





PRODUCT OFF-COLOR IMPROVEMENT PROJECT

Problem Description

Due to the difference in how line operators view color, as well as operators not having a standard process to follow when setting up productions runs for staining products, off-color runs are the leading cause of product defects from the pre-finish department. The second of three improvement projects QEP focused on to eliminate waste and improve the quality of their products was to eliminate the human element, to the extent possible, when comparing proper color match to established color standards during production runs.

Background

Pre-finish department line operators use experience, and trial and error to match flooring stain colors to established color board standards (Figure 8). Color board standards are built once product development teams approve new stain colors for customer products; material used for color board standards are pulled from the actual approved test runs. During the initial color set-up of a new product, detailed notes are kept as to what dyes are added to a base stain in order to achieve a specific color. Once a specific color is finalized, the detailed notes are filed in an electronic data base, as the stain recipe, for use in all future productions runs for that particular product.

Pre-finish production runs are started when line operators feel the stain color they set-up correctly matches the given color board standard. Due to natural color variation in wood products, it is standard practice to make small color adjustments to the original stain recipe, by the pre-finish operator, using dyes and solvents. The color is then compared to color board standards previously approved by the product manager specialist. These color adjustments are made using experience and many times trial and error on the part of the line operator.

(a)

(b)

Source: Photo Courtesy of QEP

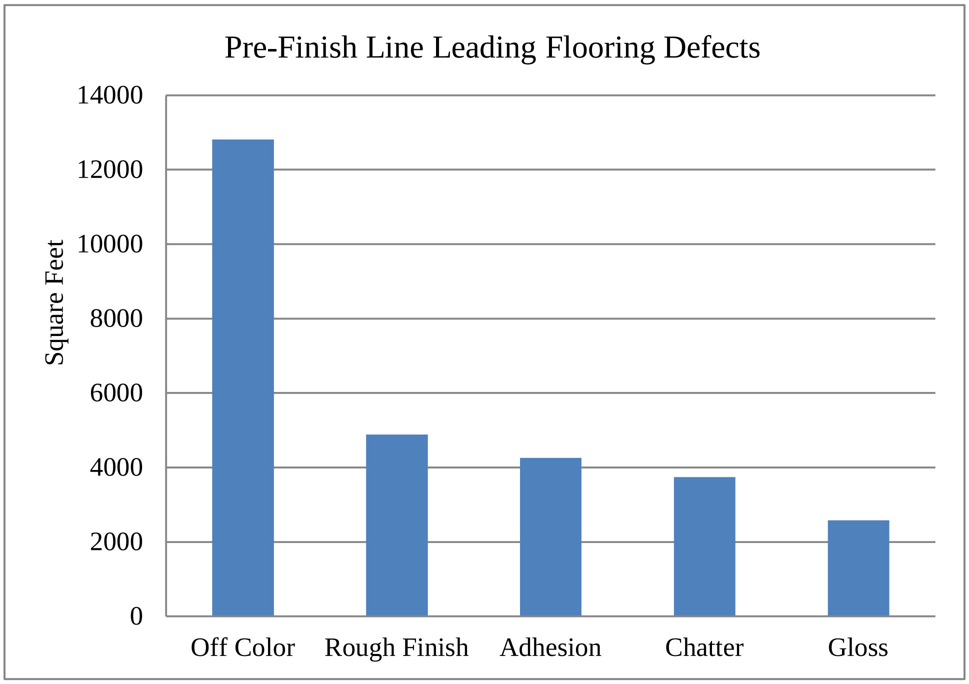
Figure 8: (a) Color Standard Storage Rack, (b) Typical Color Standard

Variances in how operators perceive color such as, viewing angle, their position in reference to the color standard, and own personal opinion, all play a role in whether or not an operator feels they have correctly matched stain color to the established color board standard. Complicating this process, each color standard has a light to dark color flow from left to right across the standard. This light to dark range establishes the color range operators must set each color with-in, in order to start a production run.

Product Off-Color Project Details

Maintaining a consistent color match between production runs (lot numbers) reduces customer claims by ensuring a consistent flowing color throughout different flooring lot numbers. For this project, in order to determine if product off-color is a top quality concern as it is suspected of being, the top five defects in the pre-finish department were selected using a pareto analysis. A pareto analysis consist of listing causes of occurrences in order of frequency from most to least creating a pareto distribution, then plotting the results on a graph called a pareto diagram (Table 8).

Table 8:Pre-Finish Line Top Five Defects Found During Quality Audits



Data gathered from months of quality audits is used for pareto analysis; and displayed in a pareto diagram. A pareto diagram is one of the seven basic quality tools used for process improvement projects. After plotting data, it is clearly visible that product off-color is an issue needing addressed (Table 8). Addressing this issue requires determining why product off-color is such an issue.

The 5-Why Technique

By using another of the seven basic quality tools, the 5-Why technique, it was determined that ultimately it is the operator's decision regarding color match that prompts the pre-finish line to start a production run. If stain color during the production run does not match the color standard then the finished product is considered defective; this contributes to lost production time, lost product, and if not caught before being boxed, pay-out in the form of customer claims.

The 5-Why technique uses a series of five questions, each starting with “why”, in reference to the current issue. This technique helps redefine the problem statement as a series or causes and effects, and helps identify the source of the problem. The following in Figure 8 are results from using the 5-Why technique to attempt to discover the root cause of why off-color in the pre-finish department has such a high frequency of occurrences.

QEP

Pre-Finish Department

5-Why Process to determine why production runs are started off-color

- Why is the product defective? Because the stain color formulated by the line operators does not match the color standard
- Why does the stain color not match the color standard? Line operators, in their opinion, feel the stain color matches the color standard.
- Why do operators think the stain color matches the color standard? Line operators stand in different locations in the color room until the lighting is correct to make the color look correct.
- Why do operators move to different locations in the color room until the color looks correct? Operators see color slightly different when standing in a single location vs. viewing color from multiple locations and angles.
- Why do operators see color differently? This question could not be directly answered due to various opinions; however some input from the operators were that height of the operator, reflection from the color room lights on the color standard, and personal opinion all contributed to various reasons why line operators feel the color match was correct to the color standard to where they are comfortable starting a production run.

Figure 9: The 5 Why Process used to determine Root Cause for Starting Production Runs with Product Off-Color

Although results from the 5-Why process did not point to a single specific root cause, the process did reveal some facts that were not known prior to the process. It was determined that operator opinions, coupled with pressure to get production lines running as fast as possible causes variation between operator color-sets. It was decided the best way to eliminate variation between line operators was to take the operator out of the decision making process by using an electronic color spectrometer to read each stain color setup.

Removing the human element from the final decision making process when establishing color-sets matching a given color board standard, a Color Spectrophotometer (Spectro-Guide 45/0) was introduced into the color-set process (Figure 10a). By removing the operator from the decision making process, variations in perceived color between various operators are minimized to the point that color-sets remain very consistent across lot numbers of the same product.

Color Spectrophotometer & Hunter Color Scale

Although this thesis will not go into the inner workings of the Color Spectrophotometer, some basic information on it and the Hunter Color Scale is needed as these two items are used together to determine correctness of color match as well as determining needed color adjustments. The Spectro-Guide 45/0 measures the amount of light, in wavelengths, as it passes through a medium and displays the results in the form of numeric outputs.

(a)

(b)

Source: Photo Courtesy of QEP

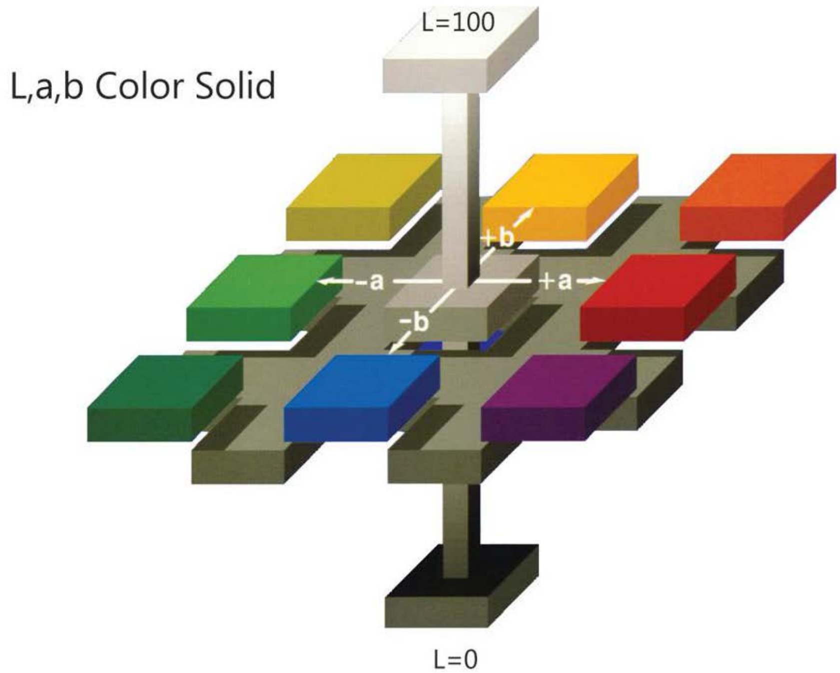
Figure 10: (a) Color Spectrophotometer (Spectro-Guide 45/0, (b) L,a,b readings

The Hunter L, a, b Color Scale (Figure 11) is a diagram used in conjunction with the Color Spectrophotometer to assist operators in determining the correct direction to adjust stain color in order to match a given color standard. The three color axis's used by operators on the color spectrophotometer are L, a, and b (Figure 10b), these readings correspond to the three axis's used on the Hunter Color Scale.

On the Hunter Color Scale, "L" corresponds to the light-to-dark range; a "L" reading equal to 100 represents a perfect reflecting diffuser, and a "L" reading equal to 0 represents black. No numeric value range is assigned to "a" or "b", however, positive "a" represents red, negative "a" represents green, and positive "b" represents yellow, negative "b" represents blue.

Depending on the numeric values of L, a, and b from a sample color reading when compared to the numeric values of L, a, and b established on the color standard, (see establishing color baseline section, and Table 2), the operator will know which color/s to add to the stain mixture to bring the current color reading from the test sample into acceptable range of the color board standard.

As an example, if a sample reading is, 35.6, for "a", and the mean color standard reading for "a" is 42.1(refer to Figure 18: Hunter Color Scale), this tell the operator that the sample reading is on the negative (green) side of the color standard reading of 42.1 for "a". The operator would then add red to the stain mixture in order to increase the sample color reading of 35.6 to a reading of 42.1. Although there is no set correlation between the distance the numeric value of a sample reading is from the desired numeric value per the color board standard, common practice is to approach the desired mean color value by adding dyes in 1 oz. increments.



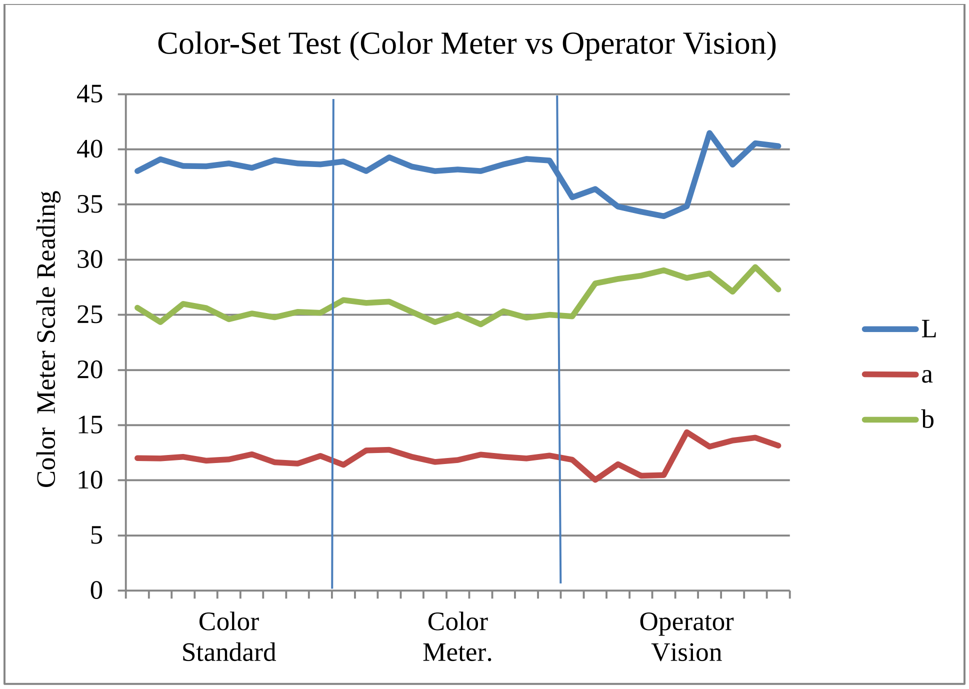
Source: WWW.Hunterlab.com

Figure 11: Hunter L, a, b Color Scale

Prior to incorporating the use of a Color Spectrophotometer in the color-set process, an analysis was performed to measure the results of color-sets using the Color Spectrophotometer and operator vision only, compared to the color standard. Table 9 shows results between four production runs (different lot numbers) of the same product; in color-sets one and two, color match was set using the Color Spectrometer, color-sets three and four were set using operator vision only. Color readings for the "operator vision" color-set test were taken electronically, using the Color Spectrometer, for display data purposes only, and were not used by the operator when making the final color match decision.

As you can see from Table 9, color-sets made with the Color Spectrometer have a smaller standard deviation in color variation when compared to the color board standard, than the operator's color-set using vision only when compared to the color board standard. To eliminate possible skewed readings due to natural variation in the test substrate, flooring pieces of similar color and species, and void of natural color variation were selected for the test.

Table 9: Color Meter vs. Operator Vision ColorSet Test



Establishing Color Standard Baseline

In order to compare readings from the Color Spectrophotometer, during production runs, to established color board standards, base line readings are taken on each color board standard used; this data is then used to establish an upper and lower control limit (color range) that color-sets must stay with-in in order for a production run to be considered serviceable. Sixty color readings were taken on each color board standard in a left to right pattern starting in the upper left had corner of the color standard, and finishing with the last color reading being taken from the lower right hand corner of the color standard.

The 60 readings (table 10) were averaged, and the standard deviation of the 60 readings used to establish upper and lower control limits of positive and negative 1.5 and 3 standard deviations from the mean. Based on these results, L,a,b control charts (Figure 20, 21, 22) were developed for operators to plot each L,a,b color reading on, both for production start-up and during production run color checks. The green band, 1.5 standard deviations above or below the mean, represents the color range that initial color-sets have to fall with-in, in order for operators to start a production run. The yellow band, > -3.0 <-1.5 below, and >1.5 < 3.0 above the mean represents the range where operators can continue production runs, but must actively adjust color back into the green range. If a color reading is found to be in the red range </= -3.0 or >/= 3.0 the operator must stop the production run and re-establish stain color back into the green range.

Table 10: Color Standard L, a, b Data Used to Construct Color Standard Control Charts

Color Chart L,a,b Data

Product SKU

Product Color

L	a	b	L	a	b		L	a	b
30.05	23.35	18.32	29.93	22.75	18.30	+3SL	21.34	25.40	22.44
30.08	23.47	18.83	31.14	24.28	20.34	+1.5SL	19.20	23.94	20.20
30.14	23.77	19.38	30.53	23.81	19.50	X (Mean)	17.05	22.48	17.96
31.17	23.40	18.86	32.30	24.25	20.82	-1.5SL	14.91	21.03	15.72
28.67	22.65	17.22	30.15	22.94	17.98	-3SL	12.76	19.57	13.48
27.03	22.17	16.25	29.93	22.95	17.96				
28.31	21.88	15.90	30.08	23.18	18.08	STDEV	1.43	0.97	1.49
26.37	22.47	16.70	28.22	22.57	17.48				
27.51	22.46	16.80	29.22	22.31	17.54				
32.10	19.33	13.83	28.34	21.71	16.75				
27.12	22.43	16.48	26.97	21.09	15.37				
26.72	22.41	16.33	27.20	20.93	15.79				
26.96	22.43	16.64	26.12	19.96	13.89				
26.48	21.92	16.29	28.82	22.93	17.15				
25.70	21.20	14.60	28.87	21.39	16.50				
27.40	22.29	16.60	28.76	22.41	17.85				
28.54	22.65	17.50	30.11	22.16	18.05				
28.96	22.72	17.82	30.26	23.06	19.18				
28.14	22.80	17.59	28.43	21.38	17.01				
30.37	22.56	17.97	29.59	22.28	17.98				
28.65	21.97	16.81	30.16	22.82	18.92				
27.91	22.77	16.91	28.91	21.96	17.61				
26.48	22.47	16.64	31.88	23.19	19.04				
26.53	21.50	15.52	31.54	23.44	19.95				
27.79	21.88	16.27	32.06	22.83	18.92				
27.07	22.55	16.98	30.70	22.48	17.90				
31.54	23.55	19.35	29.68	22.04	17.48				
30.60	21.96	18.52	31.71	21.42	16.87				
31.00	23.73	19.84	32.83	22.90	20.08				
28.56	20.13	14.80	30.66	23.09	18.55				

QEP Pre-Finish Control Chart

Date	Operator	Product SKU	Green Range: Start / Continue Run
Time	Run #	Product Color	Yellow Range: Continue Run & adjust color back into green range
(L) Light to Dark			Red Range: Immediately stop run & reset color back into green range

Pre Control Chart

		1	2	3	4	5	6	7	8	9	10	11	12
Red Zone: 21.34													
Yellow Range													
	19.20												
Green Range													
	17.05												
Yellow Range	14.91												
Red Zone: 12.76													

Figure 12: Color Standard Control Chart (L)

QEP Pre-Finish Control Chart

Date	Operator	Product SKU	Green Range: Start / Continue Run
Time	Run #	Product Color	Yellow Range: Continue Run & adjust color back into green range
			Red Range: Immediately stop run & reset color back into green range

(a) Red to Green

Pre Control Chart

Range	Value	1	2	3	4	5	6	7	8	9	10	11	12
Red Zone: 25.40													
Yellow Range													
	23.94												
Green Range													
	22.48												
Yellow Range	21.03												
Red Zone: 19.57													

Figure 13: Color Standard Control Chart (a)

QEP Pre-Finish Control Chart

Date	Operator	Product SKU	Green Range: Start / Continue Run
Time	Run #	Product Color	Yellow Range: Continue Run & adjust color back into green range
(b) Yellow to Blue			Red Range: Immediately stop run & reset color back into green range

Pre Control Chart	Range	Value	1	2	3	4	5	6	7	8	9	10	11	12
	Red Zone: 22.44													
	Yellow Range													
		20.20												
	Green Range													
		17.96												
	Yellow Range	15.72												
	Red Zone: 13.48													

Figure 14: Color Standard Control Chart (b)

Corrective Actions for Off-Color Project

Prior to starting a production run, operators must follow the steps in (Figure 15) when setting color. These steps were developed to guide operators through a standardized systematic process that reduces guessing when setting color. Due to natural color variation and unique characteristic's with-in and between various wood species, deviations to the color-set steps are sometimes required. When it is necessary to deviate from these steps, the Quality Manager, Line Supervisor, and Line Operator are all required to work together and agree upon the final color match, while using the Color Spectrophotometer to the extent possible.

QEP

Pre-Finish Department

Line Operator Color-set Procedures

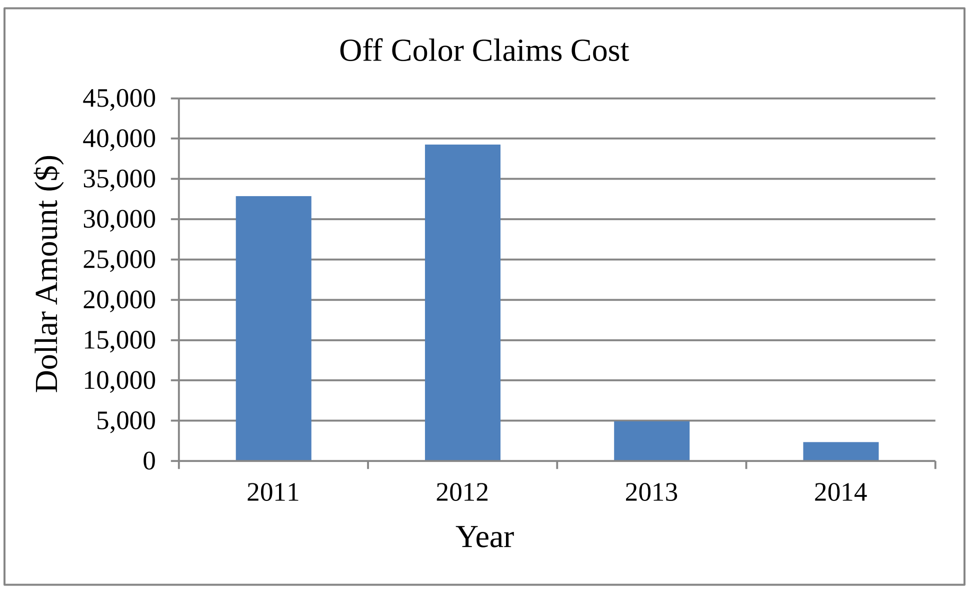
1. Mix initial stain color from color recipe.
2. Run 5 character neutral sample boards down the line for staining.
3. Check color with Color Spectrophotometer.
4. Compare sample color numeric values (L, a, b) to color standard L, a, b charts.
5. If sample color numeric values fall with-in the green range of the color standard L,a,b charts, start production run. If not, proceed to step 6.
6. Make color adjustment to initial stain mix, in the direction of color needed based on sample color numeric values and Hunter Color Scale.
7. After color adjustment is made, run 5 more character neutral sample boards down the line.
8. Check color with color meter and repeat above steps 4-7 until sample color falls with-in green range of color standard L,a,b charts.
9. Start Production run; check and document color readings (L,a,b) every 15 minutes. Adjust color as needed to stay with-in the green range.

Figure 15: Operator Color-Set Procedures

Off Color Improvement Project Results

Prior to the off-color improvement project it was common practice for pre-finish line operators to start productions runs when color-sets were close to matching the color standards visually, based on the operator's opinion. After implementing the use of the Color Spectrophotometer and an established process check list, production runs cannot proceed until color set-ups fall within a given range on the color standard. These process changes reduced off-color customer claims by an average of 10% between the years 2011-2012 and 2013-2014 as can be seen from Figure 24 below. This decrease represents a cost savings of $13,928 annually.

Table 11: Off Color Improvement Project; Chart shows an Average Reduction in Claim Payouts of 10% Between the Years of 2011-2012 and 2013-2014



Inconsistent Grading Project

Problem Description

The third and final improvement project involves inconsistent product grading. In the EGD Department, there are three flooring grader positions (Figure 16 and 17), in grader position one and two graders are required to identify and mark, with chalk, defects and unwanted natural character in each piece of flooring that passes them.

Source: Photo Courtesy of QEP

Figure 16: EGD Grading Stations One and Two

Source: Photo Courtesy of QEP

Figure 17: Grading Station Three

Results from observations made while watching the grading process over a period of five days, revealed that a great deal of variation exists in what graders considered defects. This resulted in a great deal of variation in what defects were being marked as bad material and what defects were let go as good material. At grading stations one and two, graders opinions varied as to what defects of similar nature they would mark, and what defects they would let go. At grading station three, downstream from grading stations one and two, it was also observed that graders would let some defects, marked at grading station one and two, go by as good, and mark for defecting out some defects not previously marked at grading stations one and two.

Background

The EGD department uses a standard set of grading rules for graders to follow. Specific size limits, in inches and/or fractions of an inch, are listed for graders to use when determining if a defect exceeds a specific limit for a given product. Grading rules are broken down into three distinct sections; section one covers product grading for premium (high end products), section two covers medium grade (less costly products), and section three covers scraped and textured (specialty products).

During the above mentioned observations, it was discovered that not only did graders opinions of what constitutes a defect vary, but all graders had a tendency to grade all products the same, without distinguishing between the three product grades. As a result of this variation in grading, and the general tendency of graders to grade all products the same, it was discovered that most products were being over graded, thus reducing production yields.

Although listed in the grading rules with specific dimensions, the following three defects were most commonly over graded by graders than any other defects; splits, knot holes, and raised grain in the face of the flooring (Figure 18 through 20). An additional observation noticed while observing the grading process was the position at which the graders marked defects to be cut out. Marking defects with chalk too far away from the actual defect causes waste as well, since the defects are cut at the location of the chalk mark (Figure 21).

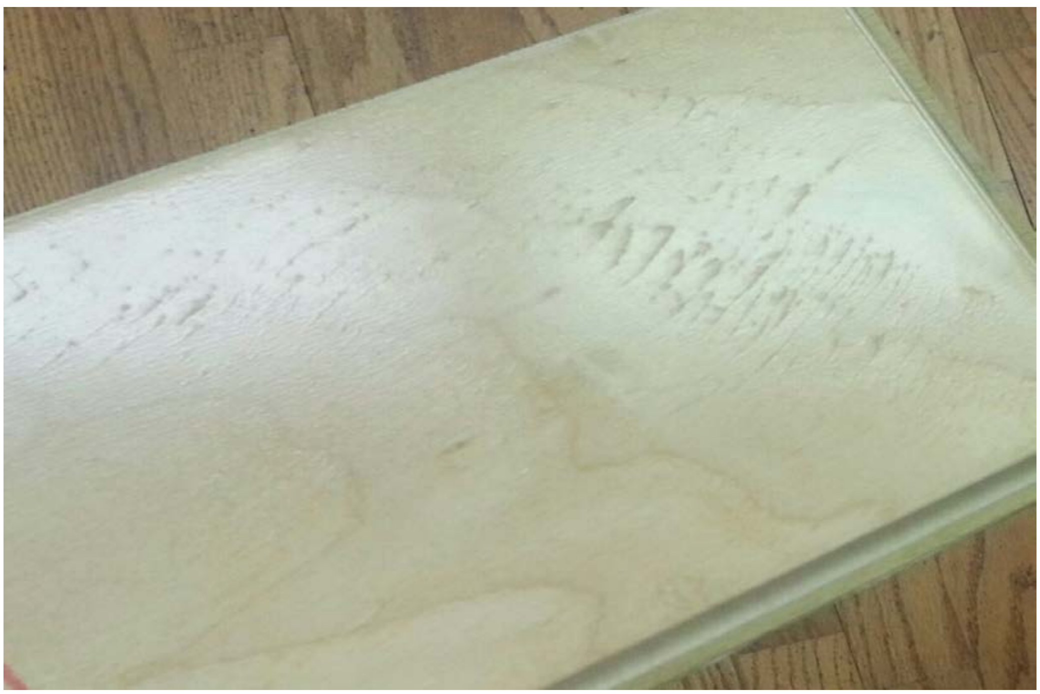
There is no documented training program for graders, nor is there a training plan in place to teach and monitor the state of the EGD grading process. The goal of the inconsistent grading project is to improve product yields in EGD department through initial grader and reoccurring training. This will be accomplished by using past yield rates for the EGD department as a base line for determining if establishing a grader training program will improve product yields in the EGD department. A one week adjustment period is given for training before yield data is collected and evaluated.

Source: Photo Courtesy of QEP

Figure18: Knot Holes in the Face

Source: Photo Courtesy of QEP

Figure 19: Splits in the Face



Source: Photo Courtesy of QEP

Figure 20: Raised Grain in the Face

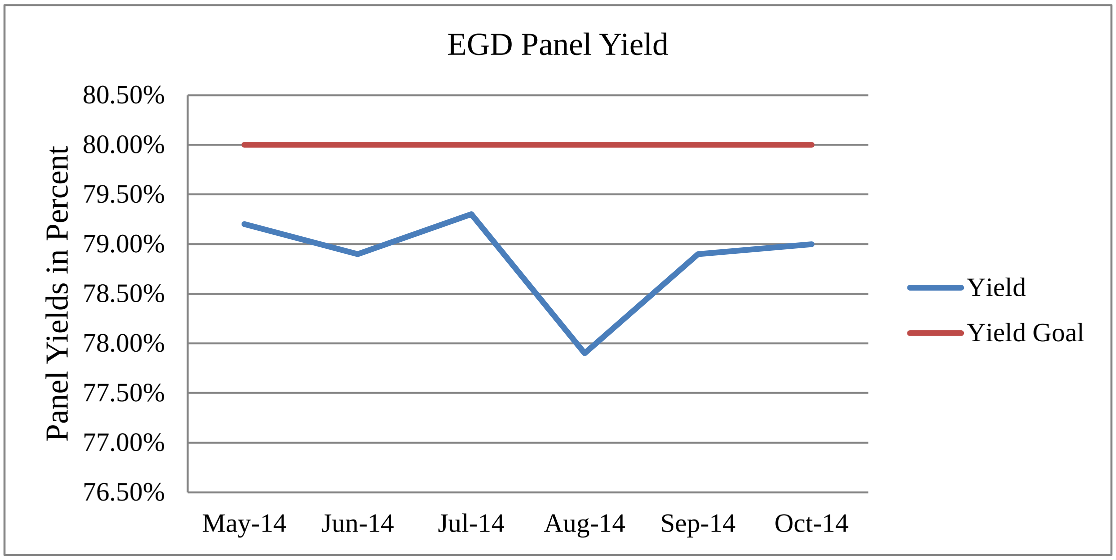
Source: Photo Courtesy of QEP

Figure 21: Chalk Mark Location too far Away from the Actual Defect

Inconsistent Grading Project Details

Two steps were involved in determining the successfulness of the inconsistent grading project. In step one, since no structured grading program is in place, current production yield trends in EGD were used as a base line to gage the effects of the newly established grader training program (Table 12). If successful, an increase in EGD production yields is expected at or above the goal of 80%. Step two, in order to achieve the largest gain in production yield possible with minimal effort, the top three most common defects were selected as the focus of the grader training process (splits, open knots, and raised grain). Although not a defect but still a contributing cause of yield loss, defect location marking is also included in grader training.

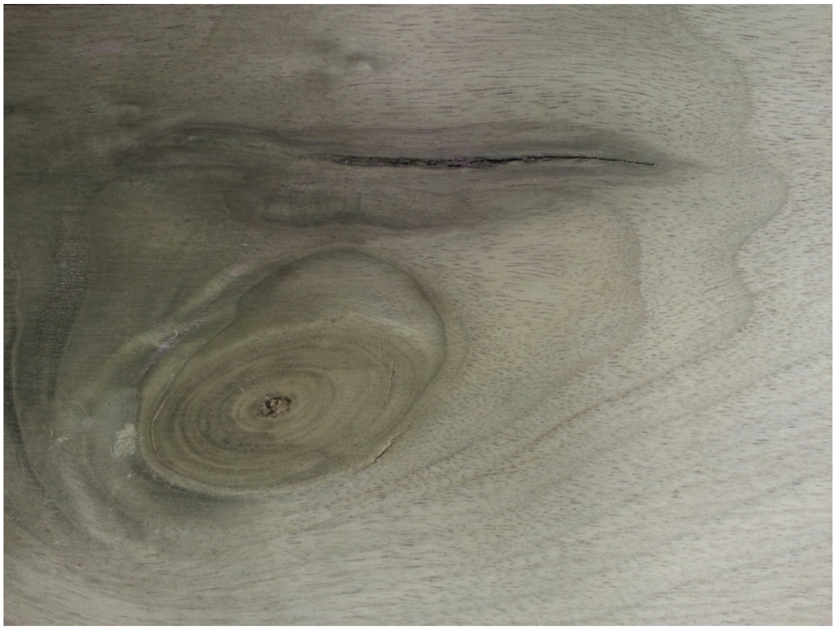
Table 12: EGD Panel Yield (6 Month Period Prior to Grader Training)



<u>Inconsistent Grading Project Corrective Actions</u>

Training was accomplished by meeting with all EGD graders to discuss and establish commonalities in the grading process based on current grading specifications. This process proved to be very helpful as many of the graders requested, for visual reference, that samples of defects be run down the pre-finish line and brought back to them to show what defects, if let go, will meet pre-finish grading specifications and which ones will not.

Figures 22 through 24 show common examples of defects that once thought to be too large to let go, and marked to be defected out, actually meet the minimum pre-finish grading specifications. In Figures 22 through 24 the upper photo was taken prior to the finishing process to show the defects as the graders see them, while the lower photo was taken after the finishing process. These visual samples also serve to help the graders relate visual defects with numeric size limits.

 (a)

 (b)

Source: Photo Courtesy of QEP

Figure 22: (a) Unfinished Elongated and Circular Defect; (b) Elongated Defect Filled During the Finish Process where as the Circular Defect Did Not Fill


(a)


(b)

Source: Photo Courtesy of QEP

Figure 23:(a) Unfinished Open Knot Defect;(b) Open Knot Defect Filled During the Finish Process


(a)


(b)

Source: Photo Courtesy of QEP

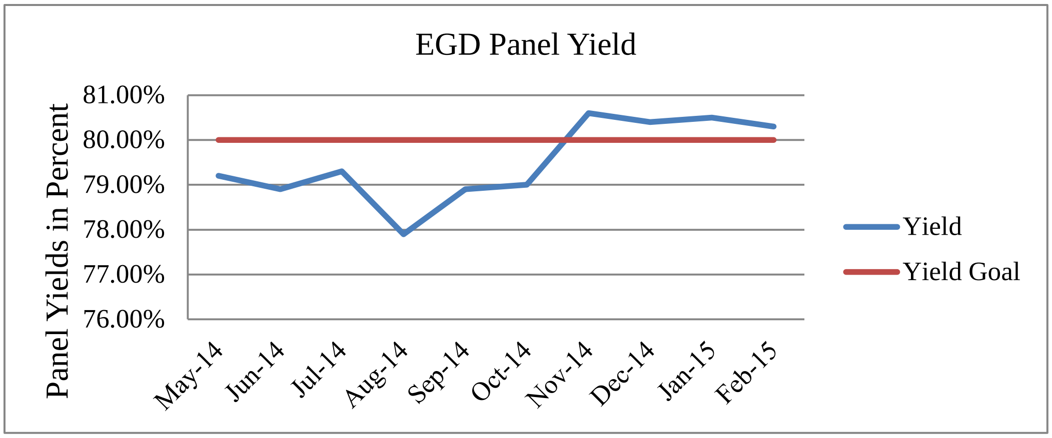
Figure 24:(a)Unfinished Small Split in the Face;(b) Small Split Filled During the Finishing Process

The grader training process was conducted by meeting with the graders as a group, first on a weekly basis for 3 weeks, then bi-weekly for another 3 weeks, ending in an ongoing monthly meeting. Defect sample boards were also built and are used during the grader training sessions; the sample boards are stored at the grading stations for use as a quick reference example. These efforts highlighted the fact that grading in EGD is an important job and if not performed properly can result in waste, low yield, and increased cost. During training meetings, graders offer input on various situations that others in the group learn from thus bonding the graders in EGD as a cohesive team that now work together.

Inconsistent Grading Improvement Project Results

In the past, product grading or grader training was not looked at with any serious focus so historical data for EGD production yields are considered to be a good baseline for past grader performance. At the completion of the inconsistent grading project, data collected over a relatively short period of time showed an immediate improvement in EGD panel yield. Overall panel yield increased on average by 1.7% as shown in Table 13 below. This increase in panel yield represents a $167,500 dollar savings annually for QEP.

Table 13: EGD Panel Yield Increase of 1.7%



CHAPTER 4

BEST PRACTICES

QEP's Johnson City facility has been in business for over 100 years, and during this time many established cultures have come and gone. In 2012, at the start of the improvement projects outlined in this thesis, the culture that existed at QPE limited their ability to become more productive and provide better quality products, this is because little to no standardized processes were in place for employees to follow. The lack of these processes, and the fact that product quality was being maintained by non-traditional methods, did not allow for continuous improvement opportunities to be realized.

Talking with supervisors and hourly workers at QEP, it become apparent that overall yields, defect reduction, and product quality could easily be improved; in some areas, as much as 20%. The chip-out project decreased defects by 20.5%, and customer claim payout cost decreased by 38%. Details of these improvements were established and formally documented as best practices to follow and improve-upon going forward. These improvements also paved the way for continuous improvement projects, and the development of a quality control manual.

Best practices are important to a company because it makes known the willingness of the company to identify deficiencies in their processes and to show what improvements work and are adopted to overcome these deficiencies. The best practices adopted at QEP and outlined in this thesis are a culmination of some traditional quality methods as well as standards in use by ISO 9000. A natural step moving forward in the continuous improvement process for QEP is to work to become ISO 9000 certified. This achievement will establish QEP among many other companies that have chosen to adopt proven industry standards to operate within.

CHAPTER 5

CONCLUSION

While U.S. and World Markets continue to recover from the resent recession, U.S. based hardwood flooring companies are learning to operate more efficiently in order to stay competitive in the market place. QEP is one of those companies; through the use of simple but effective quality tools, QEP developed a strategy to reduce waste, while improving yields and overall product quality.

The three improvement projects (chip-out, off-color, and inconsistent grading) QEP initially focused their efforts on proved to be successful in reducing waste, while improving yields and product quality. These improvement projects also served as stepping stones to future continuous improvement projects.

From 2008-2010 QEP's Johnson City Facility averaged 6,700,000 square feet of EGD flooring sales, in 2014 they sold just under 11 million square feet of EGD flooring, and thus far for 2015 they are on track to sell at least11 million square feet. QEP is currently securing a deal with Home Depot to continue to supply innovative flooring designs to over 1,900 of their U.S. based stores. This is partly due to the confidence Home Depot has in QEP's ability to supply quality flooring products at competitive prices.

Limitations

While working on the three improvement projects listed in this thesis, one factor that continually plays a role in limiting consistent project results is raw materials received for processing. As wood is a natural grown product, environmental factors such as geographical growing and harvest locations, weather, length of growing seasons, and so on all contribute in making the raw materials used in manufacturing hard wood flooring anything but consistent.

Unlike man made materials, natural color variation, wood character, fiber structure, species etc. vary from truck load to truck load. This natural variation continually plays a role in how flooring will mill and how the materials natural color will affect stains and top coats when they are applied. As a result of this, consideration is given to all final tests results when considering variation as a factor to consistent project test results.

Future Recommendations

An observation that was noted in each improvement project was the absence of daily involvement from department supervisors in the monitoring of manufacturing processes. Efforts by department supervisors to continually monitor manufacturing processes in order to identify negative process shifts are needed in order to prevent stagnation of continuous improvement ideas as well as employee motivation.

Setting monthly, bi-monthly and/or even quarterly manufacturing improvement goals, starting with easily achievable goals in order to show initial improvement, is a valuable tool in motivating employees to continuously strive to improve processes. Employees who perform daily manufacturing tasks are in the best position to make improvement suggestions. Offering rewards for improvement suggestions can have a positive impact on sustained continuous improvement and employee motivation with-in departments. Daily supervisor involvement can play a significant role in continuous improvement out comes with-in departments and should be exploited to the fullest extent possible.

BIBLIOGRAPHY

Catalina Report, 2014. Executive summary, Section 1, US Wood Flooring Industry Trends, Pg. 1 http://c.ymcdn.com/sites/member.nwfa.org/resource/resmgr/Docs/CatalinaReport_April2014.pdf Retrieval date: October 2014.

Harris Wood, 2015. Harris Wood History http://www.harriswoodfloors.com/company.php?s=history. Retrieval date: January 2015.

Berardinelli, Carl F. 2012 November. Quality Progress, Back to the Basics, To DMAIC or not to DMAIC. http://asq.org/quality-progress/2012/11/back-to-basics/to-dmaic-or-not-to-dmaic.html. Retrieval date: December 2014.

Tague, Nancy R., 2005. The Quality toolbox, Second Edition, ASO Quality Press, pages 247-249.

National Wood Flooring Association Technical Publication No. A100, 1996. Water and Wood, How Moisture Affects Wood Flooring, page5. https://c.ymcdn.com/sites/member.nwfa.org/resource/resmgr/tech_chapters/water_and_wood.pdf?hhSearchTerms=%22Wood+and+Flooring+and+Moisture+and+Content%22. Retrieval date: February 2015.

National Wood Flooring Association, 2015. NWFA/NOFMA Grade Photos. http://www.nwfa.org/nofma-grade-photos.aspx. Retrieval date: December 2014.

ASTM4442-92, American Society for Testing and Materials, 2003. Standard Test Method for Direct Moisture Content Measurement of Wood, and Wood-Based Materials, Pages 507-509. http://law.resource.org/pub/us/cfr/ibr/003/astm.d4442.1992.pdf. Retrieval date: December 2014.

Hunter L,a,b Color Scale, Insight on color, vol.8, no. 9, 2008. http://www.hunterlab.se/wp-content/uploads/2012/11/Hunter-L-a-b.pdf. Retrieval date: February 2015.

VITA

STEVE BLACK

Education: Public Schools, Akron, Ohio

B.A. Professional Aviation. Embry Riddle Aeronautical University, Daytona Beach, Florida 2003

M.S. Technology with a concentration in Engineering Technology, East Tennessee State University, Johnson City, Tennessee 2015

Professional Experience: United States Air Force, Jet Engine/Aircraft Technology, Worldwide, 1984-2005

Quality Manager, QEP, Johnson City, Tennessee 2006-Current.