Reduce Defect/Scrap
in
Sand Core Making Department

ABC Company

Prepared by:

Kurt H. Hartwig, MBA
Certified Lean Six Sigma Black Belt

Executive Summary

ABC Company has seen an increase in sand core scrap and an increase in casting dimension defects of final Part #2453. These issues resulted in $260,000 in costs (or $18.80 estimate per unit) during period 2017 and thus, eroding into profits. In addition, the sales team has noted an increase in customer complaints, as well as increased time devoted to these issues. For these reasons, this project seeks to indentify the cause(s) that might explain the scrap/defect increase, with recommendations to reduce/prevent them.

Summary of Problem-Solving Approach

I conducted initial interviews with our two quality inspectors, and both state that core quality is highly dependent on the operators. This information provided me with the area, or department, to focus on. I applied the Six Sigma DMAIC method and proceeded with 3 observational studies and 1 experimental to collect qualitative data under current operation conditions. Data sampling and analysis will be related to:

Historical and Observational:

1) Differences between SOP's of Sand Core Making Operators.
2) Differences between Workstation Equipment.
3) Differences between Process Settings.
4) Differences in sand material used (note: purchased from 3 different suppliers).

Experimental:

1) Differences between current Wood Seal and New Composite Seal.

Project Findings

First, Our Special Experiment (OSE) test show the current wood seal, verses new composite seal, had defect rates of 79% and 77%. Second, a study shows an interesting trend that higher pressure settings, the less defects. Third, it appears that there are differences in sand quality among the 3 suppliers. For example, a study showed that using sand from supplier 1, resulted in high process variability of defects. Overall, the sample study revealed that the sand contributed to a overall 9% defect rate. Lastly, our project showed that operator 4 has the lowest defect rate, which could be the result of recently purchased equipment for workstation 4.

Projected Total Yearly Savings = $300,000

Projected Total Yearly Savings in Time = 600 hours

Define Phase

To remain profitable, it is paramount that we realize the cost impact of core scrap and related finished part defects that occur from the Sand Core Making Department.

2017 Cost = $260,000 ($21,670/month)

Therefore, it is essential we explore and identify the root-causes, and then, design and implement solutions that are sustainable and cost effective.

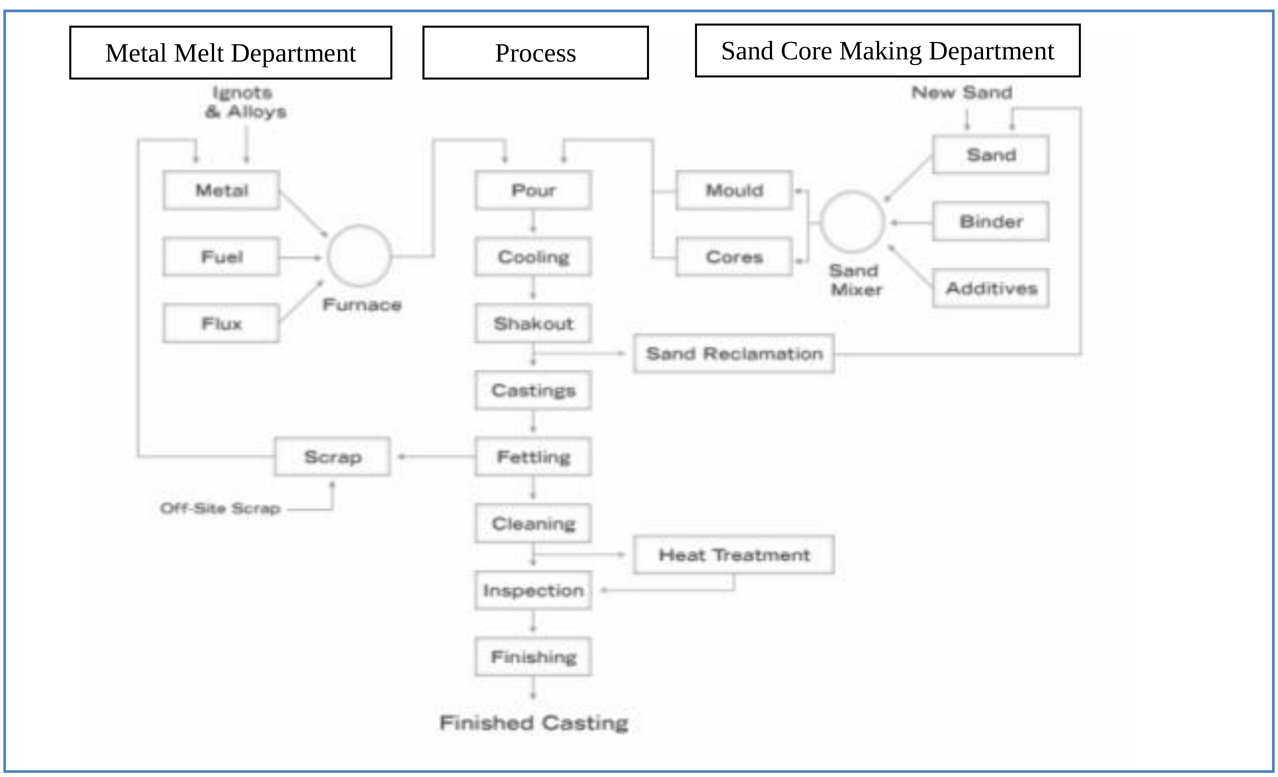
Stakeholder Return = $500,000 ($41,670/month)

To begin, I have set a goal of 2% scrap per day. There's some inherent variability in our process that we'll need to accept. Currently, the department is operating at 10% scrap rate.

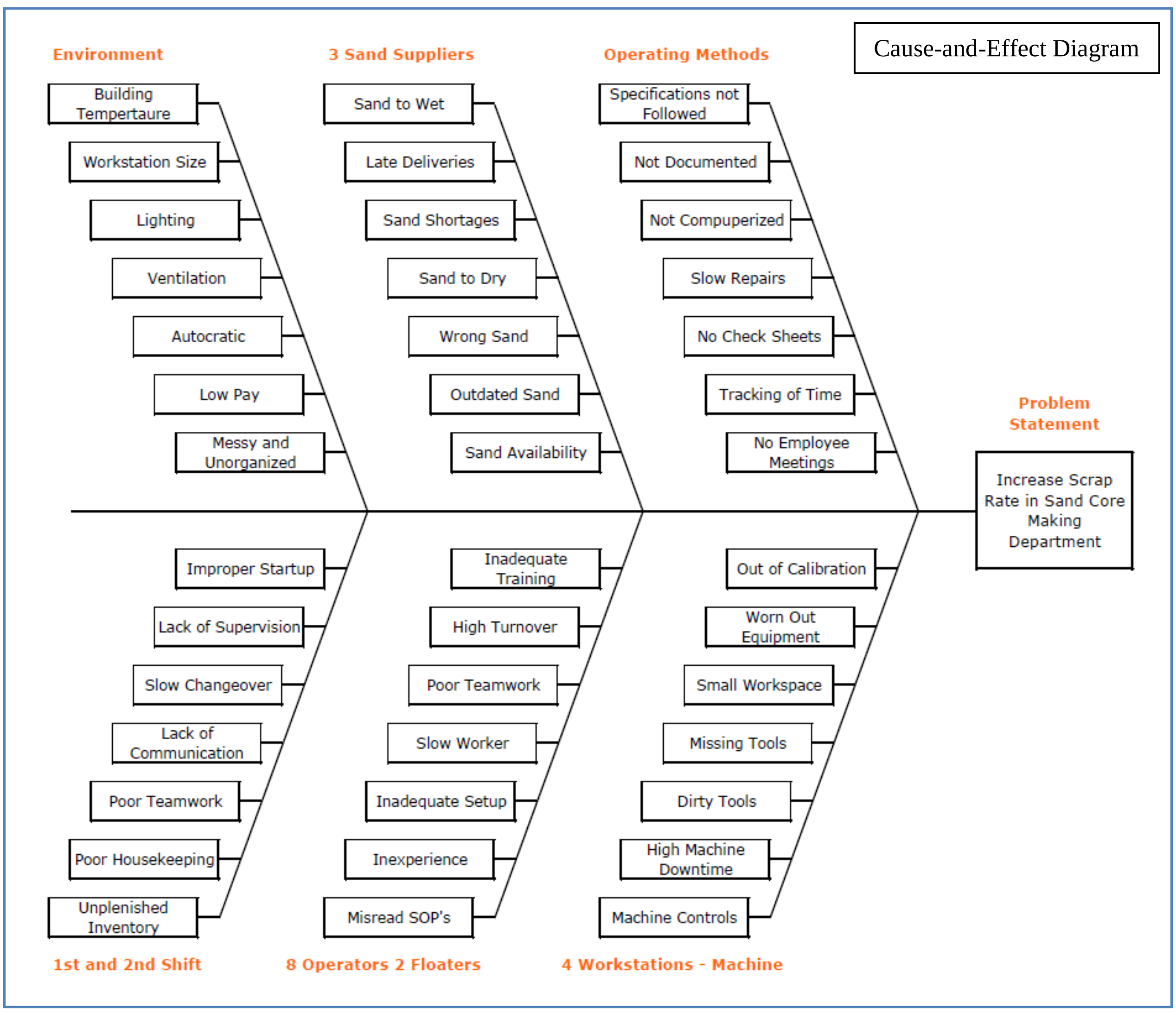
Core production - minimum at 72 per shift (18 per operator)

For part #2453, our customer has set a Nominal (0) +/- .040" tolerance for each of the 4 dimensions and set a refinement tolerance of +/- .040" from each other.

I have created a Process Flow Chart, SIPOC Diagram, and Cause-and-Effect Diagram to show process steps and boundaries. These visuals show lines of responsibly and possible areas for collecting meaningful and accurate data in our quest to find root-cause for the high defect rate.



SIPOC Diagram				
SUPPLIERS	**INPUTS**	**PROCESS**	**OUTPUTS**	**CUSTOMERS**
Sand Supplier A	8 Regular Employees	Shop Order Received	Cast Part #2453	Parts Cleaning
Sand Supplier B	4 Workstations	Sand Preparation	Reclaim Sand	Inspection
Sand Supplier C	Pressure Settings (PSI)	CO2 Mold Making	Castings	Heat Treatment
Production Scheduler	Holding Times (sec)	Baking		Finishing
Department Supervisor	Equipment Cleaning SOP's	Casting		Packaging/Shipping
Sales Team	Sand Quality	Cleaning		Boeing
Quality Inspectors	Shop Order Release			Raytheon
Delivery Contractor	SOP's			Sales Team
	Employee Training			Customer Service



Measure Phase

The measure phase is our data collection plan for the Sand Core Making Department, under its current state of operation. Ultimately, we want to uncover root-cause to high defect rate. The measure phase will help focus our attention to possible causes. We will establish base-line metrics and compare those against observed data.

Historical and Observational Data was taken from:

- Employee time cards to include: cores produced, yield rates, and scrap rates. We will analyze 662 production samples from 2017 year.
- Data Log for part tolerance dimensions. Inputs from inspector. We will analyze 120 part samples from 2017 year.
- Data Log for machine settings, cleaning, and sand supplier (A,B, and C). Inputs from Operators. We will analyze 176 samples from March 2018 year.

Experiential Data was taken from:

- In year 2017, two different time trials were taken from workstations 3 and 4, using current verses new seal, and measuring total core output and scrap rate. Two inspectors were used for core review inspection to maintain consistent results.

Sand Core Making Base-Line Metrics

Historical Data **-** 662 Samples during 84 Day Period - Sept to Dec 2017

- 88,988 DPMO (each core may have more than 1 opportunity for a defect)
- 91.1% Yield (48,400 total cores, 4,307 defect or 8.9%)
- 2.85 Sigma Level
- Cost of Quality: $80,110. Yearly Cost: $240,300

Note: PPM Defective calculation has same above metrics (either the core is defective or not)

Observational Data **-** 176 Samples during 22 Day Period - March 2018

- 92,504 DPMO
- 90.8% Yield (12,821 total cores, 1,186 defects or 9.2%)
- 2.83 Sigma Level

Goal - 98% or better Yield - 2% or less Defect rate

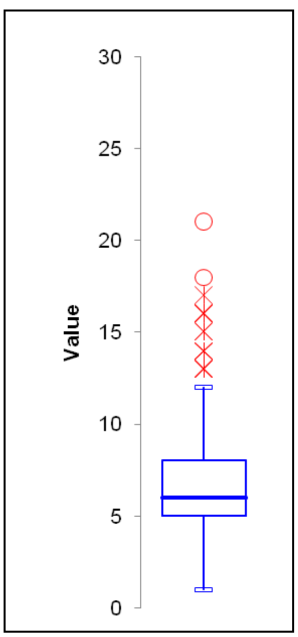
Example:
50,000 total sand cores produced during 4-month period, Sept to Dec
2% defect rate equals 968 total cores
Cost of Quality: $18,200. Yearly Cost $54,595

Measure Phase - con't.

Descriptive statistical comparison of Historical Performance verse Observational Performance. Interestingly, the mean averages are relatively close, and both data sets show a skewed distribution to the right. In either case, there are opportunities for improvement.

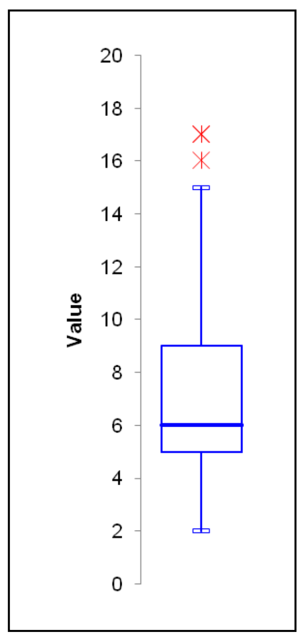
Historical Analysis
662 Samples during 84 Day Period
Sept to Dec 2017

	Scrap
USL	
LSL	
Sample, N	662
Mean	6.51
Q1	5.00
Median	6.00
Q3	8.00
StDev	2.75
Variance	7.55
Min	1.00
Max	21.00
Range	20.00
Sum	4307.00
Skewness	1.00
Kurtosis	2.12



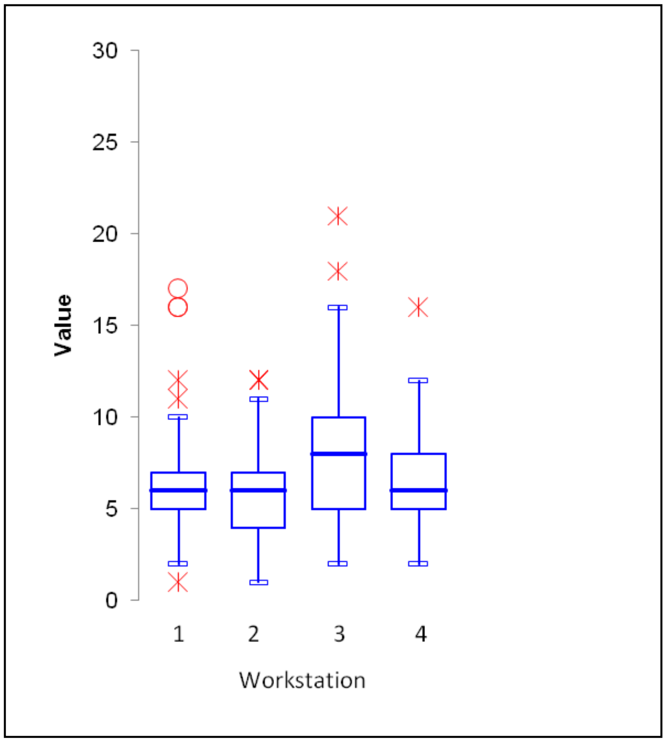
Observational Analysis
176 Samples during 22 Day Period
March 2018

	Scrap
USL	
LSL	
Sample, N	176
Mean	6.74
Q1	5.00
Median	6.00
Q3	9.00
StDev	3.11
Variance	9.68
Min	2.00
Max	17.00
Range	15.00
Sum	1186.00
Skewness	1.10
Kurtosis	1.03

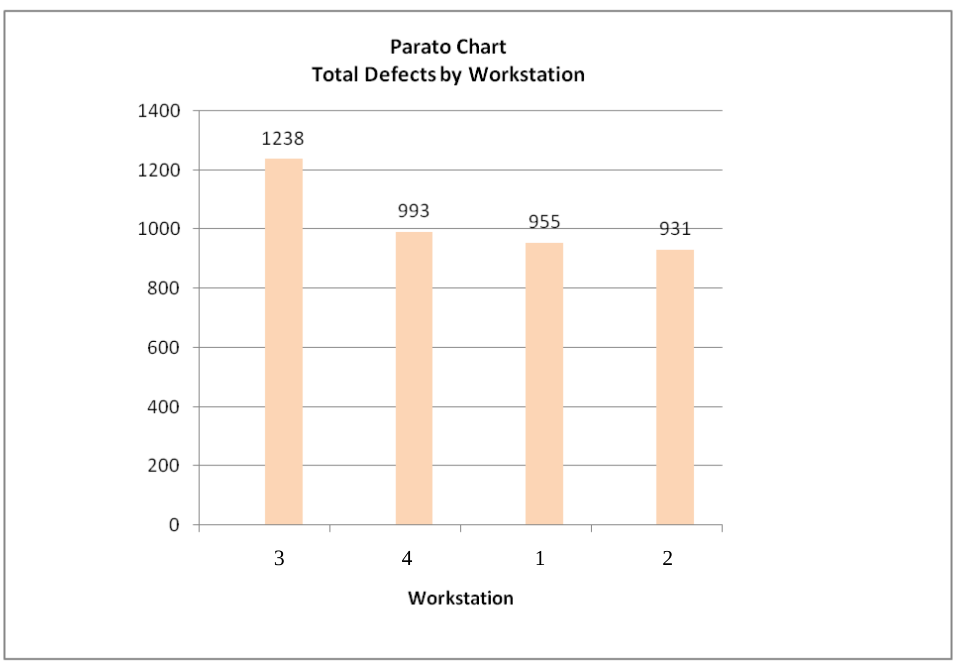


Analyze Phase

Analysis A (Data from Historical Study 1) - For this phase, we'll want to organize and analyze Total Defects by Workstation. The Box Plot and Pareto Charts below show that Workstation 3 has the highest total defects, as well as largest range and variation. Still, this information does not pinpoint a specific workstation as responsible for the majority of defects. However, it does tell us that each workstation needs further analysis on other input factors, such as the operator.



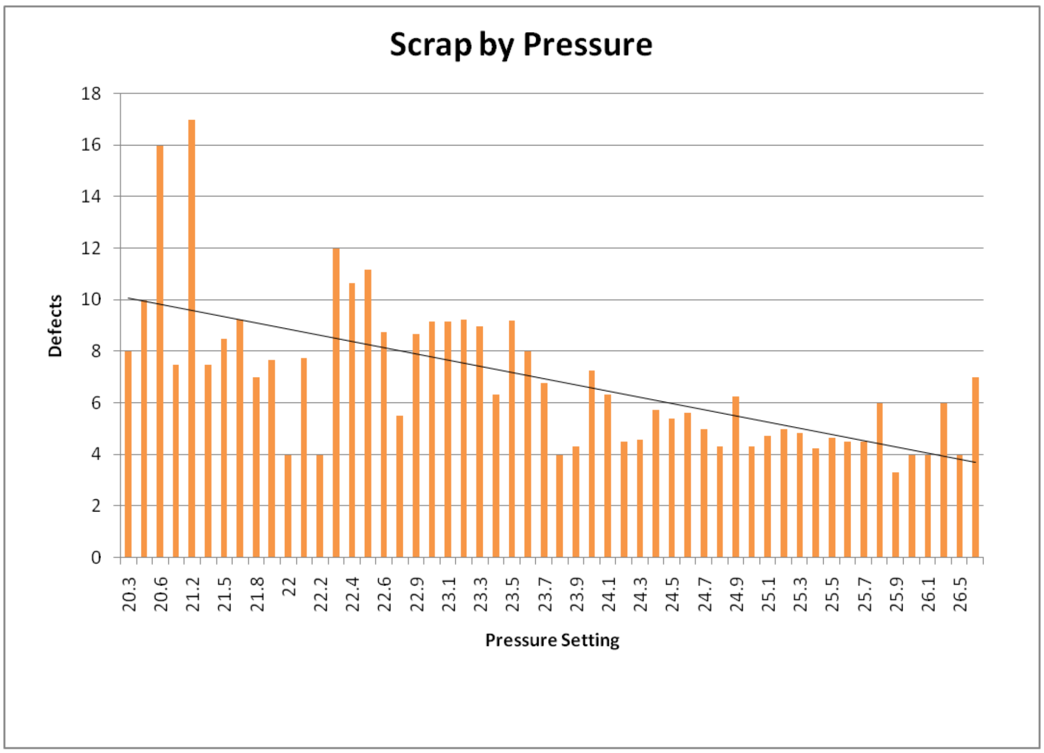
Workstation	Scrap_1	Scrap_2	Scrap_3	Scrap_4
USL				
LSL				
Sample, N	157	158	157	157
Mean	6.08	5.89	7.89	6.32
Q1	5.00	4.00	5.00	5.00
Median	6.00	6.00	8.00	6.00
Q3	7.00	7.00	10.00	8.00
StDev	2.47	2.35	3.30	2.36
Variance	6.09	5.51	10.88	5.58
Min	1.00	1.00	2.00	2.00
Max	17.00	12.00	21.00	16.00
Range	16.00	11.00	19.00	14.00
Sum	955.00	931.00	1238.00	993.00
Skewness	1.28	0.45	0.85	0.68
Kurtosis	4.28	-0.13	1.15	1.02



Analyze Phase - con't.

Analysis B (Data from Special 1-month Study 3) - To drill down further, I applied a One-Way ANOVA method to compare Pressure Setting with 176 Defect samples, collected over a 22 day period (March 2018). Visually, it is evident that as the pressure settings increase, defects decrease. Statistically, the P-Value suggest a significant confidence there is a mean difference.

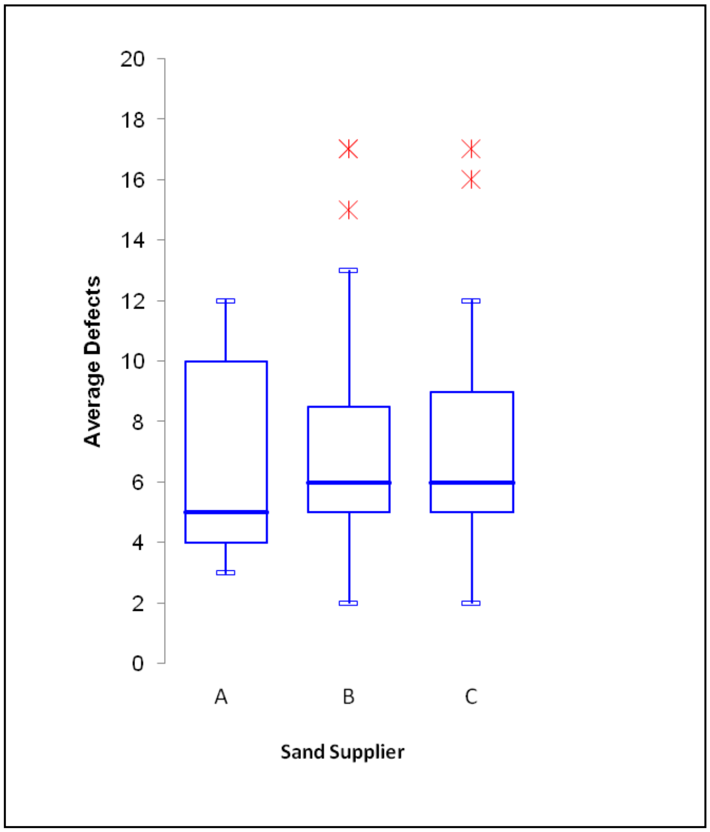
Moving on, I wanted to see if there's a relationship between scrap and hold time, so conducted another ANOVA test, and discovered a P-value .57 and a R-squared value 0. Thus, suggesting no mean difference (there are no reasons to pursue further studies between scrap and hold time).



	Alpha	0.05				
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	949.902	53	17.923	2.939	0.000	1.446
Within Groups	744.075	122	6.099			
Total	1693.977	175				
DESCRIPTIVE STATISTICS						
N	176					
Mean	6.7386					
StDev(Pooled)	2.4696					
StDev(Overall)	3.1112					
MODEL PREDICTION						
R-squared	56.08%					
R-squared(Adj)	36.99%					

Analyze Phase - con't.

Analysis C (Data from Special 1-month Study 3) - To further analyze data for root-cause, I utilized a Box Plot to show Defect Rate by Sand Supplier: A, B, and C. I collected over 176 Samples over a 22 day period (March 2018), totaling 12,821 sand core units. The matrix below shows Supplier B as supplying the most total sand within this study. However, the suppliers average a 90.7% yield on acceptable cores. Supplier A shows high variation, especially within Inter Quartile Range (IQR). Supplier B has a tighter IQR or a lower mean variance. All 3 data sets are right skewed distributed. From this analysis, I would chose B as the primary sand used; however, this needs further testing and validation.



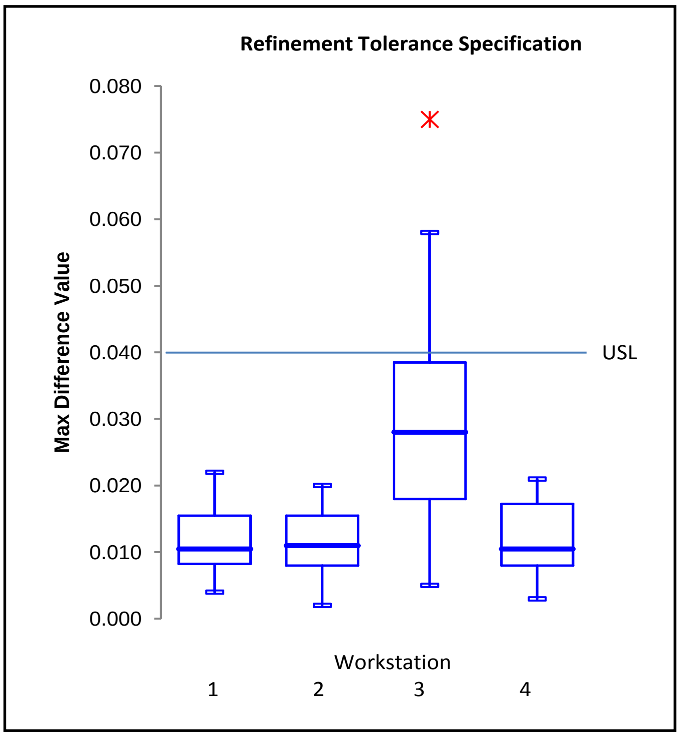
	A	B	C
USL			
LSL			
Sample,N	16	115	45
Mean	6.56	6.69	6.93
Q1	4.00	5.00	5.00
Median	5.00	6.00	6.00
Q3	10.00	8.50	9.00
StDev	3.35	3.01	3.34
Variance	11.20	9.06	11.15
Min	3.00	2.00	2.00
Max	12.00	17.00	17.00
Range	9.00	15.00	15.00
Defects	105.00	769.00	312.00
Skewness	0.63	1.11	1.26
Kurtosis	-1.35	1.34	1.34
Total Sand Cores Produced per Supplier Sand			
Sum	1165	8383	3273

Analyze Phase - con't.

Analysis D (Data from Study 2) - To further the root-cause investigation, I conducted a Box Plot method on 120 samples on Measurement Dimensions 1-4 at Workstations 1-4. Chart 1 shows that Workstation 3 is **not** conforming to the customers' Refinement Tolerance Specification of < 0.040" and ultimately a contributor to defects.

Chart 2 (Appendix) shows that all 4 measurements are within the customer specified tolerance of Nominal (0) +/- .040" tolerance, except for workstation 2, dimension 3 category at 0.0410". Also, workstation 3, dimension 3 category has a few outliers.

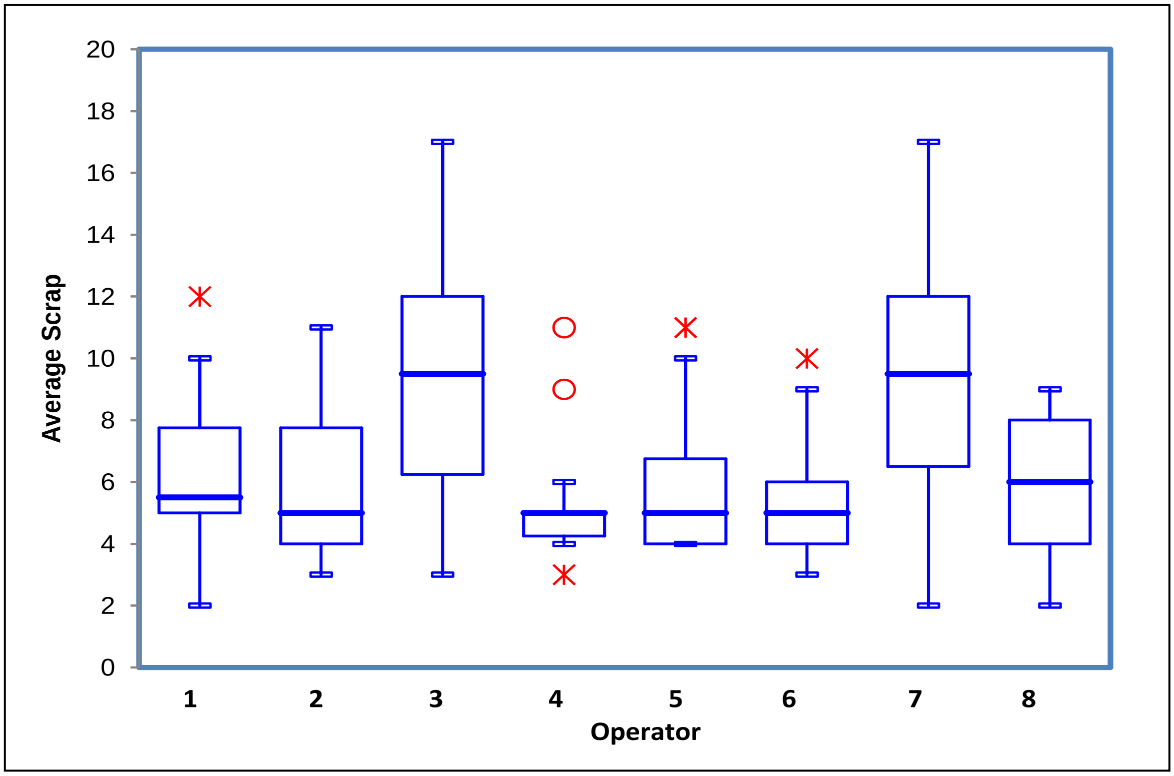
Chart 1



	MaxDiff_1	MaxDiff_2	MaxDiff_3	MaxDiff_4
USL	< 0.040"	< 0.040"	< 0.040"	< 0.040"
LSL				
Sample, N	14	47	43	16
Mean	0.0121	0.0114	0.0297	0.0118
Q1	0.0083	0.0080	0.0180	0.0080
Median	0.0105	0.0110	0.0280	0.0105
Q3	0.0155	0.0155	0.0385	0.0173
StDev	0.0058	0.0049	0.0145	0.0057
Variance	0.0000	0.0000	0.0002	0.0000
Min	0.0040	0.0020	0.0050	0.0030
Max	0.0220	0.0200	0.0750	0.0210
Range	0.0180	0.0180	0.0700	0.0180
Sum	0.1690	0.5360	1.2760	0.1880
Skewness	0.46	-0.10	0.67	0.17
Kurtosis	-0.74	-0.87	0.83	-1.08

Analyze Phase - con't.

Analysis E (Data from Special 1-month Study 3) The charts below show the performance outputs from each of the 8 operators, measured by core defects of 1186 units and collecting and documenting 12,821 units from a 22 day observation. Operators 3 and 7 show the worst overall performance, representing 35% of total defects, and having the highest variance levels among all data sets. Operator 4 demonstrates the best performance levels, even though there are a few outliers (these can be explored further as to origin). But the fact remains that the data suggests to interview and observe operator 4 to understand what h/she is doing differently from all others.

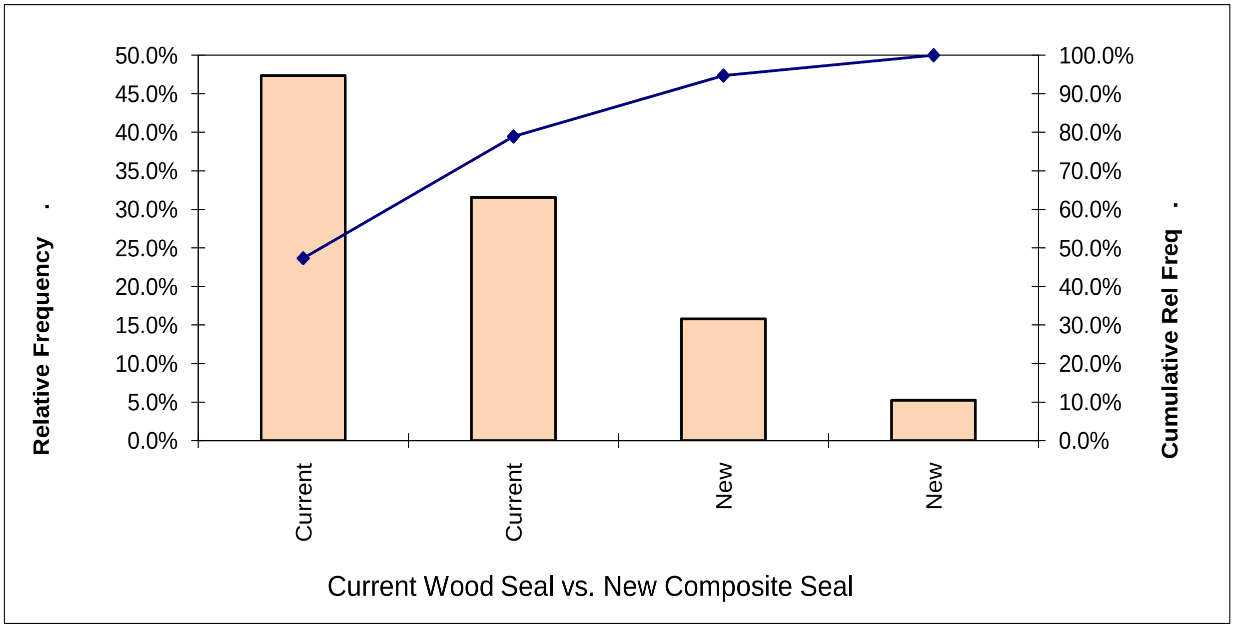


	Scrap_1	Scrap_2	Scrap_3	Scrap_4	Scrap_5	Scrap_6	Scrap_7	Scrap_8
USL								
LSL								
Sample, N	22	22	22	22	22	22	22	22
Mean	6.27	5.95	9.68	5.23	5.95	5.36	9.41	6.05
Q1	5.00	4.00	6.25	4.25	4.00	4.00	6.50	4.00
Median	5.50	5.00	9.50	5.00	5.00	5.00	9.50	6.00
Q3	7.75	7.75	12.00	5.00	6.75	6.00	12.00	8.00
StDev	2.57	2.40	4.00	1.72	2.30	1.73	3.54	2.36
Variance	6.59	5.76	16.04	2.95	5.28	3.00	12.54	5.57
Min	2.00	3.00	3.00	3.00	4.00	3.00	2.00	2.00
Max	12.00	11.00	17.00	11.00	11.00	10.00	17.00	9.00
Range	10.00	8.00	14.00	8.00	7.00	7.00	15.00	7.00
Sum	138.00	131.00	213.00	115.00	131.00	118.00	207.00	133.00
Skewness	0.56	0.79	0.34	2.35	1.28	1.13	-0.03	-0.27
Kurtosis	-0.15	-0.52	-0.64	6.38	0.51	1.64	0.13	-1.48

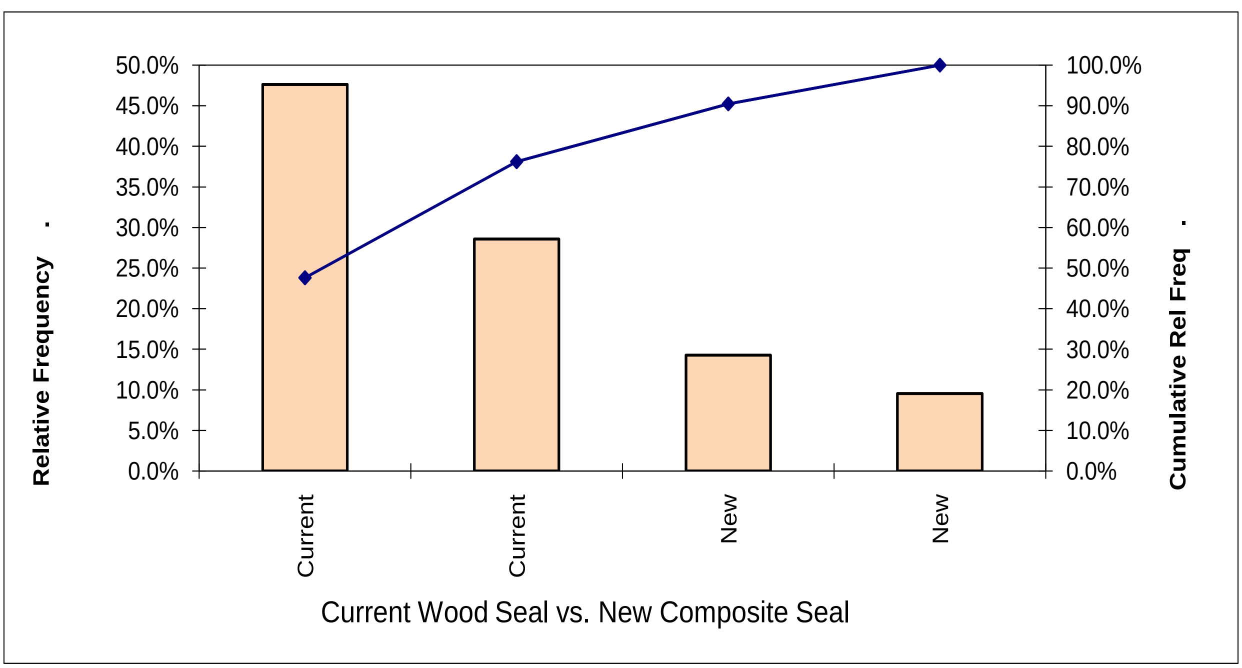
Analyze Phase - con't.

Analysis F (Special Experiment Study 4) The graphs below show a two test experiment, comparing current wood seal vs. new composite seal and the total defects incurred. Both tests indicate that the current wood seal produces far more defects than new. In fact, the current wood seal in Test 1 shows a defect rate of 79%, and Test 2 shows a defect rate of 77%.

Test 1



Test 2



Improve/Control Phase

Overall, the data collected and analyzed offers several areas to focus our attention:

- From analysis B, the One-Way ANOVA method, which compares Pressure Settings against Defect samples, shows an interesting trend with using certain settings--higher the temp setting, the less defects. Recommendation is to select and program USL and LSL settings (Poka-Yoke) and apply to workstations and track for 6-month period to validate. Train operators on new SOP and monitor and review data daily. Communicate and report results on a shop display board.

- From analysis C, sand supplier B shows the most promise as being the primary supplier. Recommendation is to use sand only from supplier B and brainstorm with team to identify solutions to reduce variation (see cause-and-effect diagram). Have supplier B visit and meet with team to see how their sand is being used in the manufacturing process. Have supplier create plan, with performance metrics, on how they will maintain consistency in sand quality.

- From analysis D, workstation 3 is not conforming to the customers' Refinement Tolerance Specification. A quick-win recommendation is to perform 100% in-process inspection, and then, seek root-cause (perform cause-and-effect) with team.

- From analysis E, operator 4 has the lowest defect rate. This could be the result of recently purchased equipment at workstation 4. Recommendation is to interview and observe operator 4 to understand what h/she is doing differently from all others. Another approach is to update the equipment at workstations 1, 2, and 3.

- From analysis F, my team noticed workstation 3 has a smaller diameter SO_2 gassing pipe and uses a different wood gasket seal. Our Special Experiment test shows the current wood seal, verses new composite seal, has defect rates of 79% and 77%. Recommendation is to conduct further validation tests on larger sample size using New Composite Seal, and increase SO_2 pipe size diameter. A possible long-term solution is to change all 4 workstations to using new composite seal.

- Further Recommendations:
  Implement Lean Programs such as 5S, Kaizen, TPM, Muda, and Kanban (Pull).
  Install Andon in the Sand Core Making department.
  Implement an ISO 9001:2015 program.

APPENDIX

Chart 2