

The SMC Consistency Program –

A Technique for Data Driven Improvement of Product Quality

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Conventional Quality Improvement Techniques

- Design of Experiments – Factorial Experiments
 - Requires brainstorming by panel of experts to define domain of investigation
 - Data collection away from production environment risks not reflecting reality
 - In-plant data collection can disrupt production
- Review of production process and material SPC data to identify “outliers & root causes”
 - Sheer volume of data to be reviewed can be overwhelming
 - This often leads us to depend on “conventional wisdom” on probable causes leading to sub-optimal solutions
 - Often USL/LSL levels have been set without adequate study



Overview – SMC Consistency Program

- Description of a data based quality improvement technique
- Presentation of two completed case studies (and a third ongoing study) that utilized this technique and yielded sustainable quality improvements
- Certain information is coded to protect proprietary information
 - Effort has been made to clearly bring out the key elements of the technique and show the benefits possible from its implementation



Consistency Improvement Plan

- Identify pilot program
- Recognize that improvement
 - Is possible
 - Is required
- Identify Quality Measureables - major causes of variance in manufacturing process
 - Rework
 - Scrap
- Seek out / Identify all the data gathering that already exists within the manufacturing process
 - Supplier processes if possible

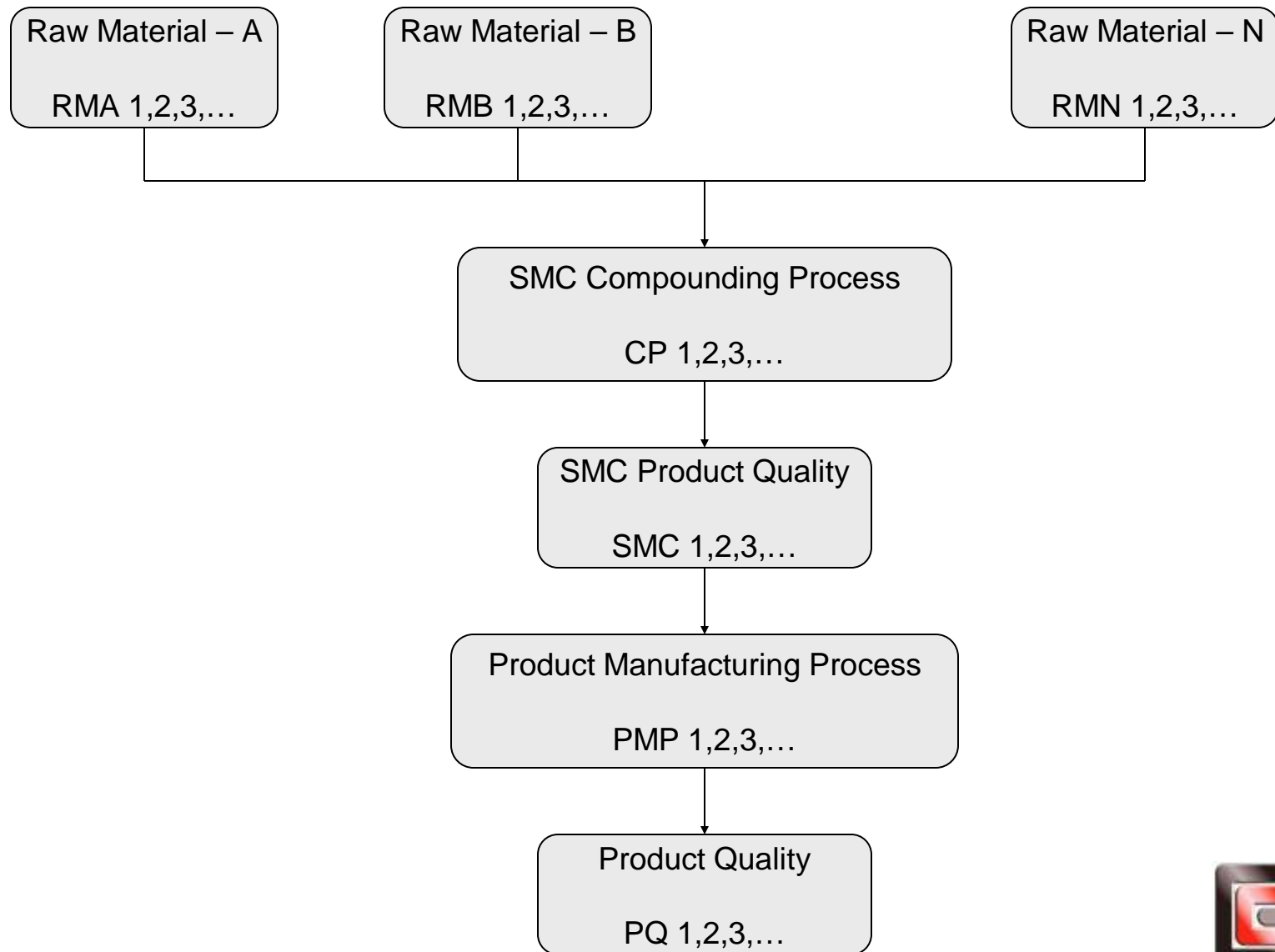


Consistency Improvement Plan

- Integrate all the information in one database
- Utilize statistical techniques to identify the major causes of variance in the manufacturing process
- Focus on implementation plans for elimination of major root causes identified thru the data analysis
 - Engineering effort to improve equipment capabilities
 - Engineering effort to re-establish USL/LSL for certain key factors
- Continue to monitor and review
 - Quality Measureables
 - Key Factors
- Broader implementation



Generic Manufacturing Process



Typical Raw Material Factors

- Molecular weight
- Acid Number
- Solids Level
- Viscosity
- Reactivity
- Particle Size



Typical SMC Compounding Factors

- Mix Time
- Mix Temperature
- Paste Viscosity
- A:B Ratio
- Plant Humidity
- Matrix Moisture
- Cutter Speed
- Ingredient Drop Weights



Typical Product Manufacturing Process Factors

- Press Tonnage
- Press Close Speeds
- Press Close Positions
- Vacuum Build Rate
- Vacuum @ Specific Positions
- Mold Temperatures
- Mold Dwell Time

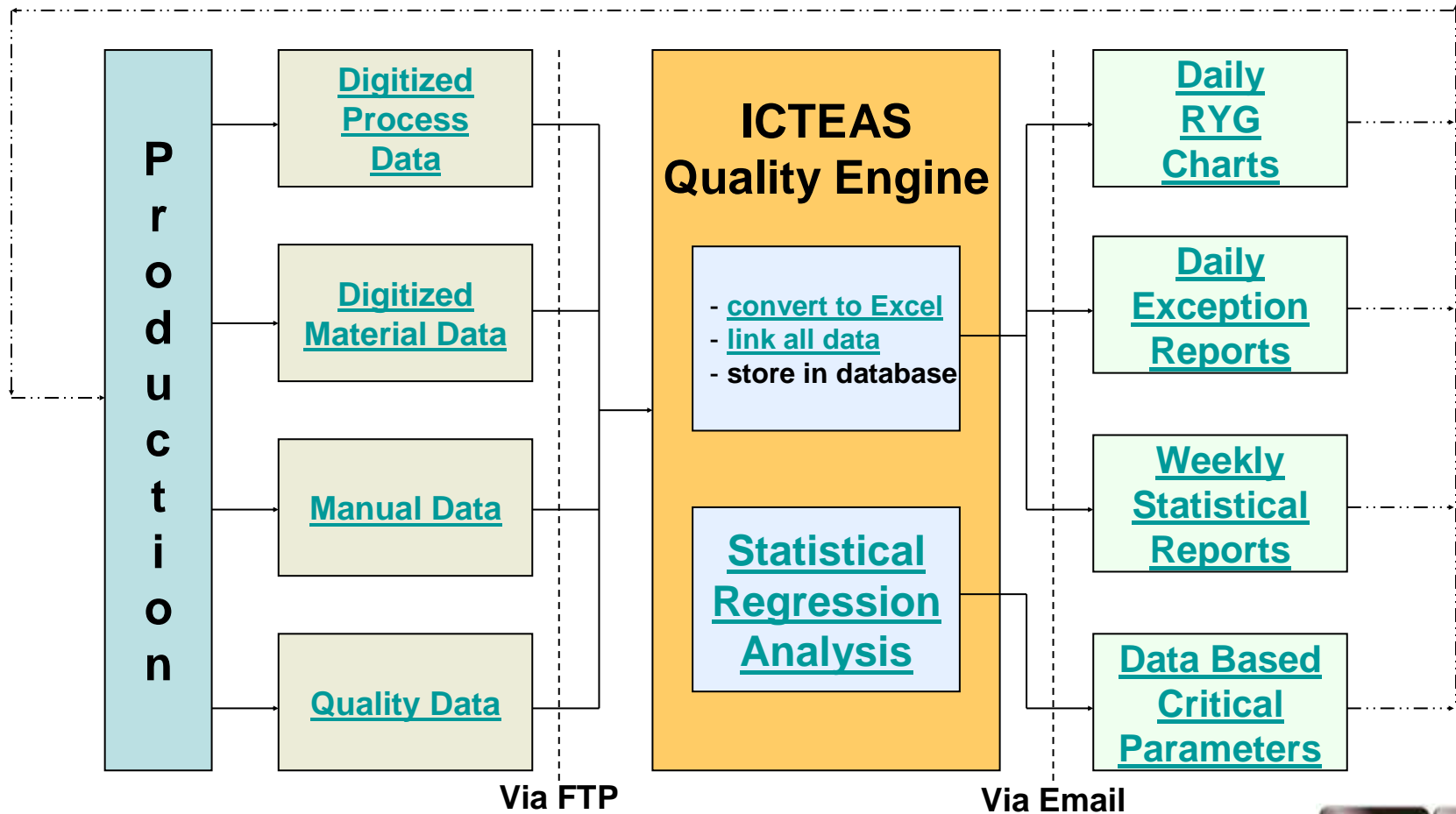


Typical Product Quality Attributes

- Dimensional Tolerance
- Strength / Stiffness Characteristics
- Paint Defects
- Surface Defects
- Non-fills
- Blisters



Quality Production Consistency Improvement Process



Application – Pickup Box

- Total number of Product Manufacturing Process Factors (PMP) – 56
- Total Number of SMC Compounding Process Factors (CP) – 23
- Total number of SMC Product Factors (SMC) – 4
- Number of Product Attributes being improved (PQ) – 2
- Total number of components utilized for analysis
 - 734 for manufacturing process analysis
 - 340 for SMC compounding / product analysis



Stepwise Regression Analysis – PQ1 (Product Quality) vs SMC Product Attribute

Regression Analysis Report for : **Continental Structural Plastics**

Output: **PQ1**

No of Significant Predictors in model		1	2	3	4	5
R-Sq	Const.	SMC1	SMC2	SMC4		
35.00	0.144	-0.013 (Coeff.) 0.000 (P-Value)				
63.03	0.094	-0.039 0.000	0.014 0.000			
63.94	0.100	-0.039 0.000	0.014 0.000	-0.0096 0.004		

Parameters used in the analysis

SMC1

SMC2

SMC3

SMC4



Stepwise Regression Analysis – SMC1(SMC Product Attribute) vs Compounding Process

Regression Analysis Report for : **Continental Structural Plastics**

Output: **SMC1**

No of Significant Predictors in model		1	2	3	4	5
R-Sq	Const.	CP21	CP9	CP22	CP10	CP17
57.84	-01.066	0.012 0.000 <i>(Coeff.) (P-Value)</i>				
70.15	-27.195	0.012 0.000	0.022 0.000			
79.51	-38.790	0.011 0.000	0.032 0.000	-0.007 0.000		
81.13	-57.681	0.011 0.000	0.026 0.000	-0.007 0.000	0.015 0.000	
83.99	-72.312	0.008 0.000	0.019 0.000	-0.004 0.000	0.026 0.000	0.150 0.000

Parameters used in the analysis

CP1	CP2	CP3	CP3	CP4	CP5
CP6	CP7	CP8	CP9	CP10	CP11
CP12	CP13	CP14	CP15	CP16	CP17
CP18	CP19	CP20	CP21	CP22	CP23



Stepwise Regression Analysis – SMC2 (SMC Product Attribute) vs Compounding Process

Regression Analysis Report for : **Continental Structural Plastics**

Output: **SMC2**

No of Significant Predictors in model		1	2	3	4	5
R-Sq	Const.	CP10	CP9	CP20	CP18	CP15
71.66	0.485	-3.522 (Coeff.) 0.000 (P-Value)				
90.71	0.277	-2.361 0.000	-1.423 0.000			
95.61	0.190	-2.805 0.000	-1.942 0.000	-511.037 000.000		
97.90	0.132	-2.934 0.000	-1.904 0.000	-491.882 000.000	-15882.679 00000.000	
98.79	0.100	-2.790 0.000	-2.130 0.000	-586.853 000.000	-30498.100 00000.000	36.140 00.000

Parameters used in the analysis

CP1	CP2	CP3	CP3	CP4	CP5
CP6	CP7	CP8	CP9	CP10	CP11
CP12	CP13	CP14	CP15	CP16	CP17
CP18	CP19	CP20	CP21	CP22	CP23



Stepwise Regression Analysis – PQ1(Product Quality) vs Product Manufacturing Process

Regression Analysis Report for : **Continental Structural Plastics**

Output: **PQ1**

No of Significant Predictors in model		1	2	3	4	5
R-Sq	Const.	PMP34	PMP20	PMP11	PMP43	PMP53
35.91	0.109	-0.001 (Coeff.) 0.000 (P-Value)				
75.29	0.228	-0.002 0.000	-0.006 0.000			
80.86	0.242	-0.003 0.000	-0.008 0.000	0.007 0.000		
86.23	-2.919	-0.002 0.000	-0.007 0.000	0.008 0.000	0.009 0.000	
92.37	-1.629	-0.002 0.000	-0.008 0.000	0.009 0.000	0.011 0.000	-0.006 0.000

Parameters used in the analysis

PMP1	PMP2	PMP3	PMP4	PMP5	PMP6	PMP7
PMP8	PMP9	PMP10	PMP11	PMP12	PMP13	PMP14
PMP15	PMP16	PMP17	PMP18	PMP19	PMP20	PMP21
PMP22	PMP23	PMP24	PMP25	PMP26	PMP27	PMP28
PMP29	PMP30	PMP31	PMP32	PMP33	PMP34	PMP35
PMP36	PMP37	PMP38	PMP39	PMP40	PMP41	PMP42
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PMP50	PMP51	PMP52	PMP53	PMP54	PMP55	PMP56

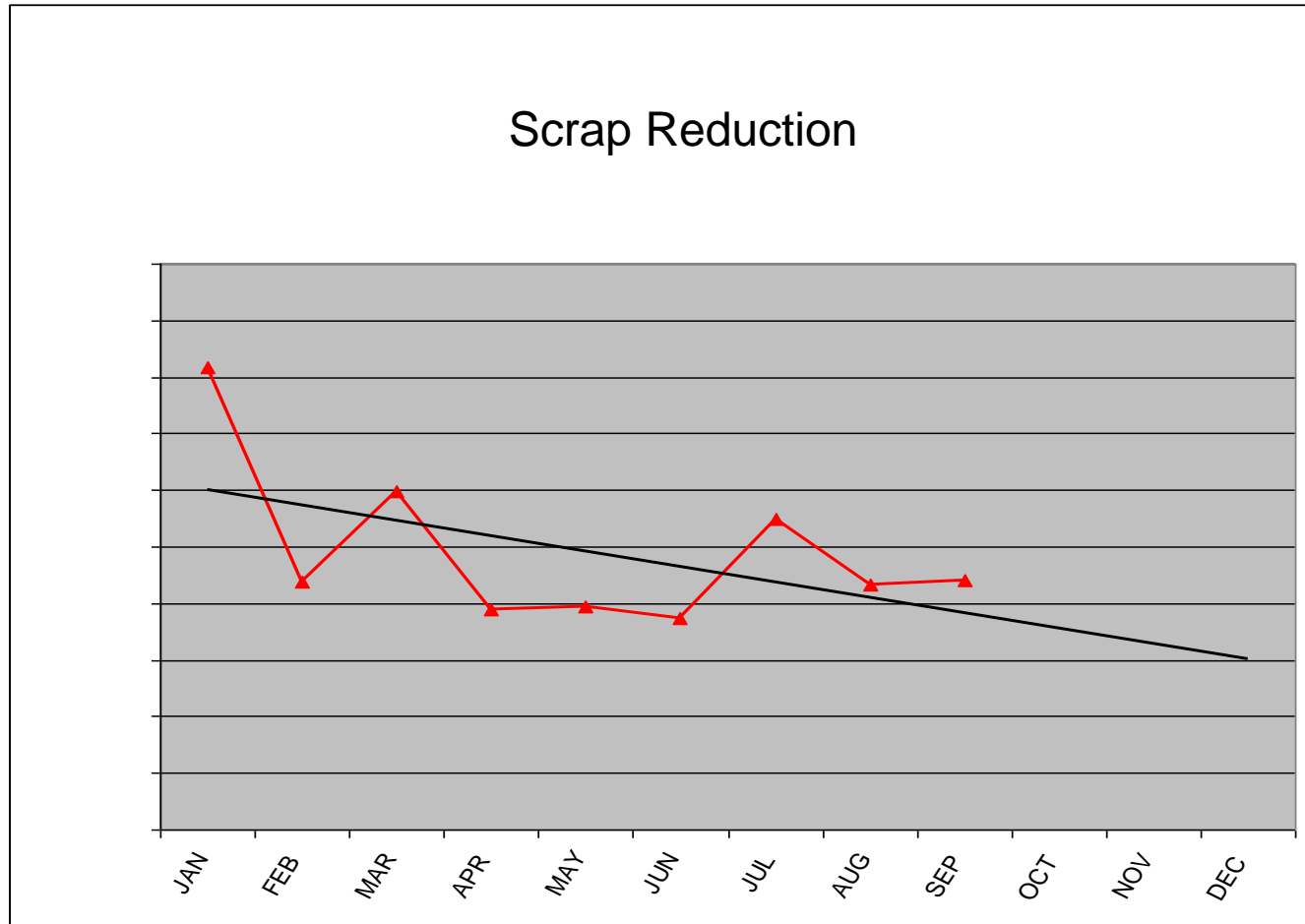


Pickup Box Improvements

- Statistical Analysis based on
 - Up to 734 parts
 - 83 different factors
- Analysis narrowed down significant factors to
 - 2 SMC product attributes
 - 8 SMC compounding factors
 - 5 product manufacturing factors
- The plant manufacturing engineering teams now focused on these factors
- This led to a sustained improvement in the product quality attribute that was targeted for improvement



Product Quality Improvement – Pickup Box



Application – Hood (I)

- Total number of Product Manufacturing Process Factors (PMP) – 24
- Number of Product Attributes being improved (PQ) – 2
- Total number of components utilized for analysis
 - 1087 for manufacturing process analysis



Stepwise Regression Analysis – PQ1 (Product Quality) vs Product Manufacturing Process

Regression Analysis Report for : **Continental Structural Plastics**

Output: **PQ1**

No of Significant Predictors in model		1	2	3	4	5
R-Sq	Const.	PMP2	PMP8	PMP5	PMP9	PMP23
50.36	-0.282	0.149 (Coeff.) 0.000 (P-Value)				
52.56	0.351	0.145 0.000	-0.031 0.000			
54.68	0.186	0.107 0.000	-0.040 0.000	0.017 0.000		
59.48	-0.012	0.075 0.000	-0.056 0.000	0.032 0.000	0.012 0.000	
60.90	-0.208	0.080 0.000	-0.054 0.000	0.031 0.000	0.016 0.000	0.850 0.000

Parameters used in the analysis

PMP1	PMP2	PMP3	PMP4	PMP5	PMP6	PMP7
PMP8	PMP9	PMP10	PMP11	PMP12	PMP13	PMP14
PMP15	PMP16	PMP17	PMP18	PMP19	PMP20	PMP21
PMP22	PMP23	PMP24				



Stepwise Regression Analysis – PQ2 (Product Quality) vs Product Manufacturing Process

Regression Analysis Report for : **Continental Structural Plastics**

Output: **PQ2**

No of Significant Predictors in model		1	2	3	4	5
R-Sq	Const.	PMP21	PMP2	PMP5	PMP6	PMP13
50.68	0.373	-1.231 (Coeff.) 0.000 (P-Value)				
55.34	0.376	-1.197 0.000	-0.007 0.000			
68.40	0.139	-1.429 0.000	-0.023 0.000	0.013 0.000		
72.63	0.350	-1.493 0.000	-0.028 0.000	0.016 0.000	-0.014 0.000	
73.55	0.314	-1.304 0.000	-0.030 0.000	0.018 0.000	-0.015 0.000	-0.002 0.000

Parameters used in the analysis

PMP1	PMP2	PMP3	PMP4	PMP5	PMP6	PMP7
PMP8	PMP9	PMP10	PMP11	PMP12	PMP13	PMP14
PMP15	PMP16	PMP17	PMP18	PMP19	PMP20	PMP21
PMP22	PMP23	PMP24				

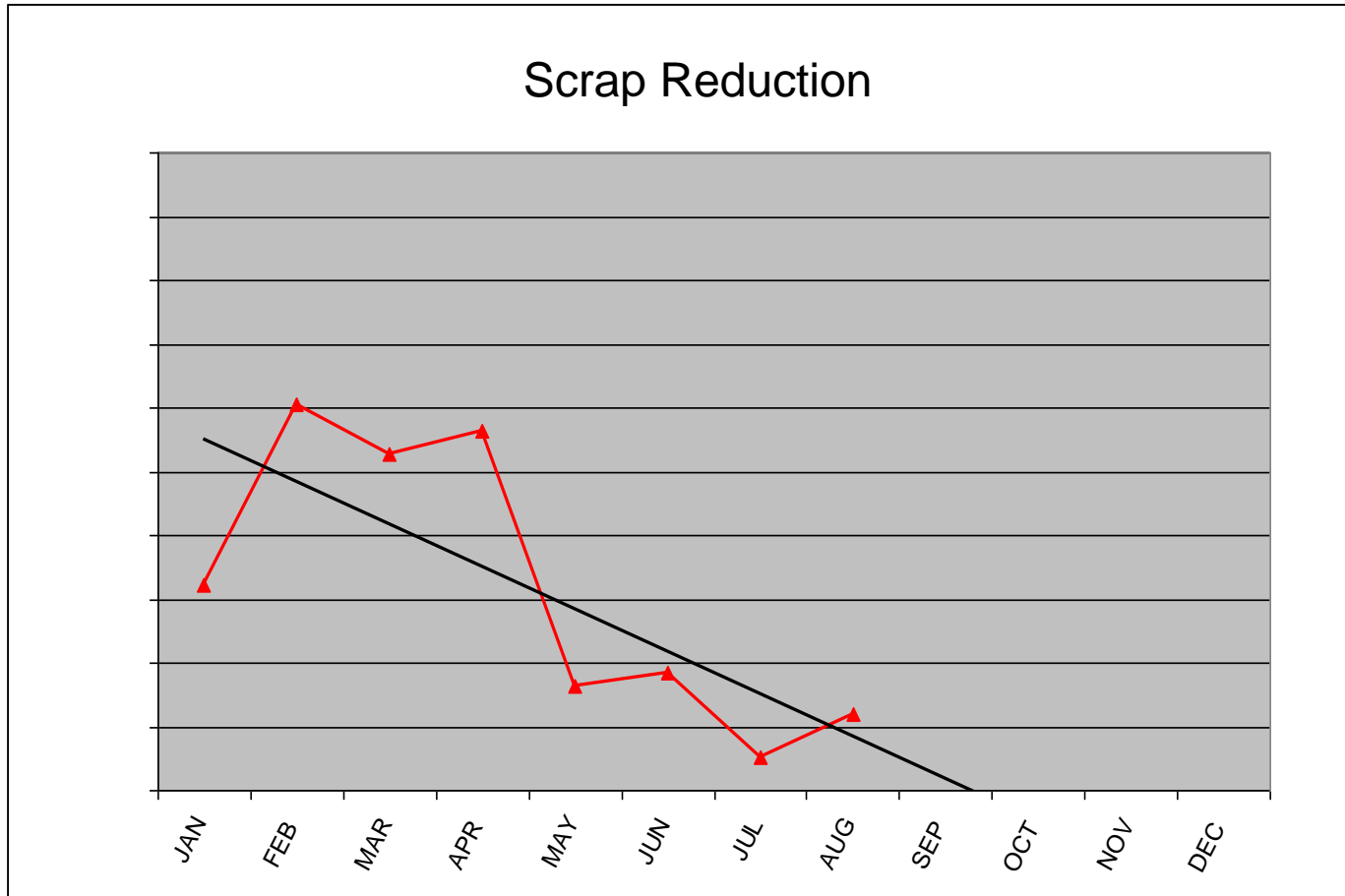


Hood (I) Improvements

- Statistical Analysis based on
 - 1087 parts
- Analysis narrowed down significant factors to
 - 9 product manufacturing factors
 - Analysis indicated
 - High confidence that these factors were affecting the product quality outcome
 - The significant factors were affecting 65% - 75% of the variability in the product quality attributes
- The plant manufacturing engineering teams then focused on these factors
- This led to a sustained improvement in the product quality attribute that was targeted for improvement



Product Quality Improvement – Hood (I)



Application – Hood (II)

- Total number of Product Manufacturing Process Factors (PMP) – 37
- Total Number of SMC Raw Material Factors (RM) – 29
- Total number of SMC Product Factors (SMC) – 9
- Number of Product Attributes being improved (PQ) – 2
- Total number of components utilized for analysis - 3091



Stepwise Regression Analysis – PQ1 (Product Quality) vs Compounding Process / Raw Materials

Regression Analysis Report for : **Continental Structural Plastics**

Output: **PQ1**

No of Significant Predictors in model		1	2	3	4	5
R-Sq	Const.	RME2	SMC9	RMG1		
24.86	079.09	-09.600 00.025 (Coeff.) (P-Value)				
51.72	090.61	-11.000 00.004	0.026 0.007			
69.37	120.25	-12.700 00.000	0.036 0.000	-0.197 0.008		

Parameters used in the analysis

SMC4	SMC5	SMC6	SMC7	SMC8	SMC9	RMA1
RMA2	RMA3	RMA4	RMA5	RMB1	RMB2	RMB3
RMB4	RMB5	RMC1	RMC2	RMC3	RMC4	RMC5
RMD1	RMD2	RMD3	RMD4	RME1	RME2	RMF1
RMF2	RMF3	RMF4	RMG1	RMH1		



Stepwise Regression Analysis – PQ1 (Product Quality) vs Product Manufacturing Process

Regression Analysis Report for : **Continental Structural Plastics**

Output: **PQ1**

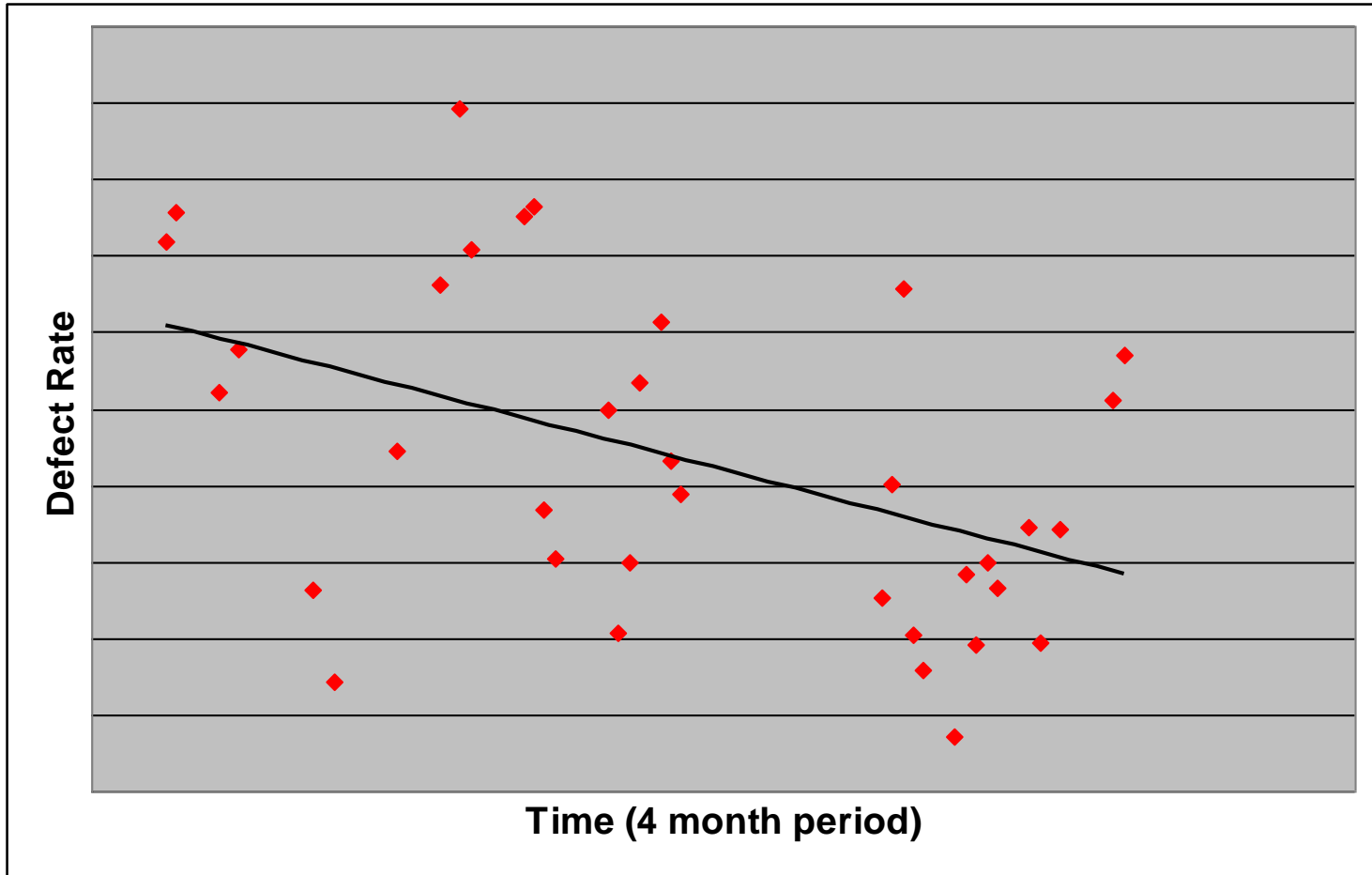
No of Significant Predictors in model		1	2	3	4	5
R-Sq	Const.	PMP31	PMP18	PMP37	PMP32	PMP34
26.96	039.839	-1.328 (Coeff.) 0.001 (P-Value)				
35.63	149.525	-1.444 0.000	-0.066 0.048			
43.28	147.898	-1.499 0.000	-0.065 0.038	0.536 0.048		
52.87	099.840	-1.870 0.000	-0.057 0.048	0.732 0.005	1.520 0.015	
62.28	091.208	-1.798 0.000	-0.044 0.093	0.751 0.002	2.322 0.000	-1.278 0.000

Parameters used in the analysis

PMP1	PMP2	PMP3	PMP4	PMP5	PMP6	PMP7
PMP8	PMP9	PMP10	PMP11	PMP12	PMP13	PMP14
PMP15	PMP16	PMP17	PMP18	PMP19	PMP20	PMP21
PMP22	PMP23	PMP24	PMP25	PMP26	PMP27	PMP28
PMP29	PMP30	PMP31	PMP32	PMP33	PMP34	PMP35
PMP36	PMP37					



Hood (II) Improvements – Defect Rate vs. Time



Hood (II) Improvements

- The Statistical Analysis based on
 - 3091 parts (Defect vs. Time chart reflects 11221 parts)
 - 75 different factors
- Analysis narrowed down significant factors to
 - 1 SMC product attributes
 - 2 SMC raw material factors
 - 5 product manufacturing factors
- Observations
 - Confidence levels are somewhat lower
 - As low as 97% compared to the 99.99% in the first 2 case studies
 - 55% to 65% of the variability is being explained by the significant factors
 - There is a possibility that we may still be missing some significant factors
- The team is
 - Focusing on improvements in the significant factors identified to date
 - Reviewing the processes and ingredients to see if other factors could be introduced to the analysis matrix



Summary

- Pilot SMC Consistency Program (Pickup box and Hood (I)) results
 - Noticeable reduction in scrap
 - Saved \$\$\$
 - Got everyone to “buy in” to program
 - Focused the quality control effort
 - Narrowed the field of critical factors
- Ongoing SMC Consistency Program
 - Create a proactive quality system
 - More effectively use the data we have always collected
 - Simplify access to critical data
 - Continue to employ on more programs



Questions / Comments

