

# **Study of Collagen Impregnation Critical Factors**

The attached report is based on an actual study performed to reduce rejects due to part performance variability. The names of company and team members are purposely withheld.

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## Analysis of Results

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### Study of Collagen Impregnation Critical Factors

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#### **Observations**

1. The *porosity* value in the normal production process (NPP) can be **reduced to less than 0.03** and its **variability can also be reduced by 40%** when the production process parameters are adjusted to the condition shown below. (See Table 1, Figures 1, 2, & 3)

<i>Optimum Process Condition</i>		
<b>Factors Studied</b>	<b>Levels Tested</b>	<b>Level Desirable</b>
<b>A: Number of Coats (43.9%)</b>	4 – 7 Coats	7 Coats
<b>B: Slurry Temp (15.1%)</b>	20 -37 Dg C	37 Deg. C
C: Impreg. Pressure (2.9)	7 – 20 psi	(Any level)
D: Roller Gap (6.7)	Low – High	High
<b>E: Number of Grafts (9.3)</b>	1 – 8 Grafts	1 Graft
F: Milking (3.8%)	No - Yes	(Any level)
<b>G: Slurry Viscosity (5.8%)</b>	15K– 45K	15000 C. Poise
<b>(Note: Level of G: changed to 1 because of influence of CLEANLINESS)</b>		

2. Conservatively estimated (Taguchi Loss Function), the reduction in variability due to the proposed process design is expected to result in a savings of 47 cents to a dollar of the 'current loss'.
3. Five of the seven factors selected & studied (from among 29 factors identified by the team) were found to be important. Factors **C: Impregnation pressure** and **F: Milking** have **least influence** on the porosity and may be set to any level for future production.
4. Factors studied have varying degree of influence on porosity data. Factors **A: Number of Coats** and **B: Slurry Temperature** has **most influence** on the variability of porosity.

5. Overall results of porosity indicate that the process modification from NPP to NP-2 or NPP-3 changes the performance for the better. The trend of average porosity data shows that NPP-2 and NPP-3 performances were about similar but both were significantly better (average S/N increased from 12 to >17) than the NPP (see Page 38, **Comparison of Results from THREE Different Sets**)
6. Even though all three processes offer opportunity for elimination of porosity, the influence of the same factor to the variability of results differs somewhat from process to process (NPP, NPP-2, and NPP-3, Figures 1, 2 & 3)
7. Because the factors influence the results differently depending on the process, the desirable conditions for the factors (optimum condition) are also different (See Table 1 & 2). For NPP-2, the two most important factors **A: Number of Coats at Level-2** and **D: Roller Gap at level 2** must be set. Likewise, for NPP-3, the most two important factors **A: Number of Coats at Level-2 (same for all processes)** and **E: Number of Grafts at Level-1** must be held.
8. Cleanliness results show that the influences of significant factors (G and B) factors are generally opposite to that on porosity. For most desirable cleanliness values, the levels of the two most important factors G: Slurry Viscosity (at Level-1) and B: Slurry Temperature (at Level-1) are opposite to those required for the porosity results (see Table 1). Considering that the team consensus weighted porosity as approximately five times more important than the cleanliness; the levels for these two factors can be set as dictated by the porosity results established in observation #1 above. However, since G: Slurry Viscosity has over 68% influence on CLEANLINESS and only about 6% influence on POSOSITY, the level of **Slurry Viscosity should be set to 15000 CP as dictated by Cleanliness results.**
9. Analysis (Std. analysis) of NPP data shows that the factors included in the studied had at least 65% influences to the variability of porosity. Which means that 35% of the influence to the variability of results come from sources not included in the studied (controllable and uncontrollable factors and set up, error % in ANOVA, Page 23)

#### **Key Observations (Set 1A):**

1. B: Slurry Temperature has the most influence on *Porosity*.
2. C: Impregnation Pressure. D: Roller Gap and E: Number of Grafts have least effect on *Porosity*.
3. *Porosity* can be almost eliminated by setting production parameters to the prescribed optimum condition
4. Variability can be reduced by about 38% (Std. Deviation reduced, Cpk increased)

#### **Key Observations (Set 2):**

1. A; Number of Coats has the most effect on *Porosity*.
2. F: Milking and G: Slurry Viscosity has least influence on *Porosity*.
3. In this case too, *Porosity* can be reduced to zero by setting production parameters to the prescribed optimum condition
4. Variability can be reduced by about 80% (Std. Deviation reduced, Cpk increased)

**Key Observations (Set 3):**

1. A: Number of Coats has the most influence on *Porosity*.
2. B: Slurry Temperature and C: Impregnation Pressure has least effect on *Porosity*.
3. In this set up also, *Porosity* can be eliminated by setting production parameters to the prescribed optimum condition.
4. Variability can be reduced by 26% (Std. Deviation reduced, Cpk increased)

**Key Observations (Set 1B):**

1. G: Slurry Viscosity has the most effect on *Cleanliness*.
2. E: Number of Grafts and F: Milking has least influence on *Cleanliness*
3. *Cleanliness* can be significantly reduced (from 280 to 228) by setting production parameters to the prescribed optimum condition
4. Variability can be reduced by 24% (Std. Deviation reduced, Cpk increased)

**Recommendations**

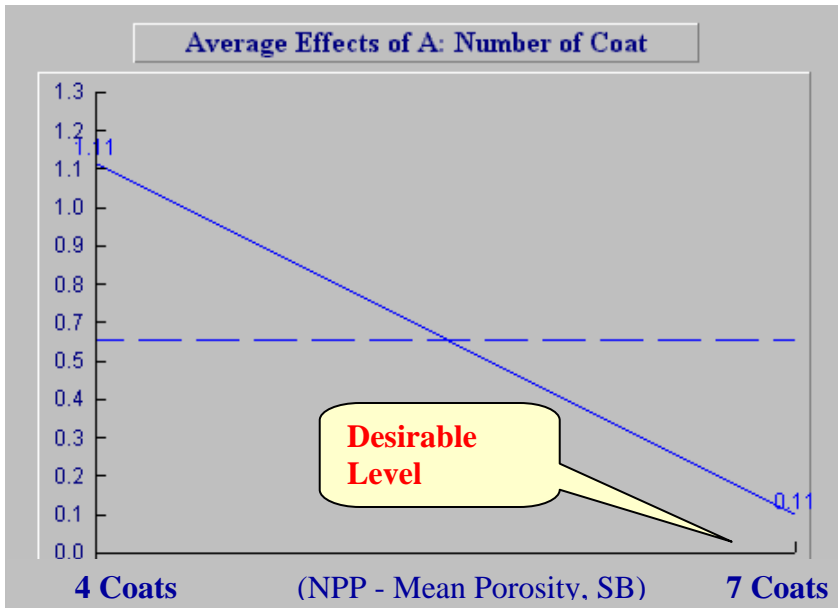
1. Run confirmation tests (at least 20 samples or more) and verify that the performance comes very close to the predicted (calculated) optimum performance. The confirmation test should be carried out the same way as the experimental samples. If you CONFIRM result, you should be satisfied that the experiment was successful, and confidently proceed to apply such structured approach to study other processes. If you do not confirm, you may need to perform additional smaller experiments to adjust for factor interactions or robustness studies.
2. Should you decide to incorporate a portion of the NPP-2 and/or NPP-3 processes in to your normal production process, review the enclosed data carefully and determine the most desirable factor level settings for lesser significant factors. For example, if you decide to incorporate NP-3 into your production process, you must pay special attention to the levels of the factors D: and E: which may contradict the levels suggested by the NPP process results.

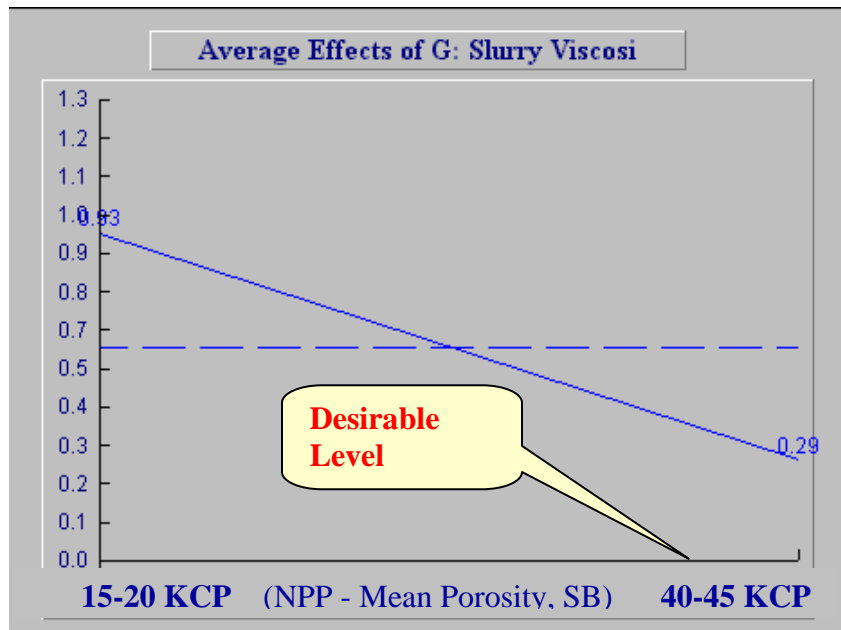
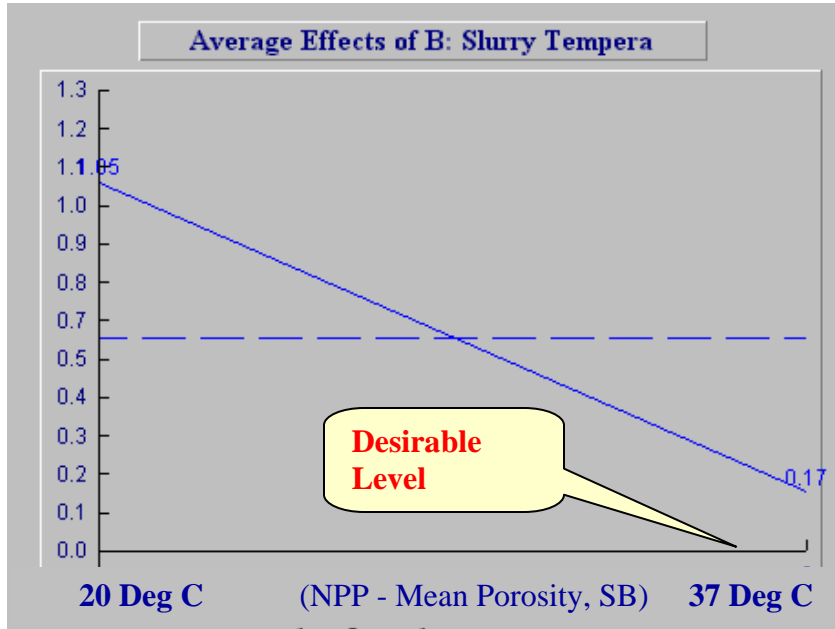
## II. Supporting Detail Findings

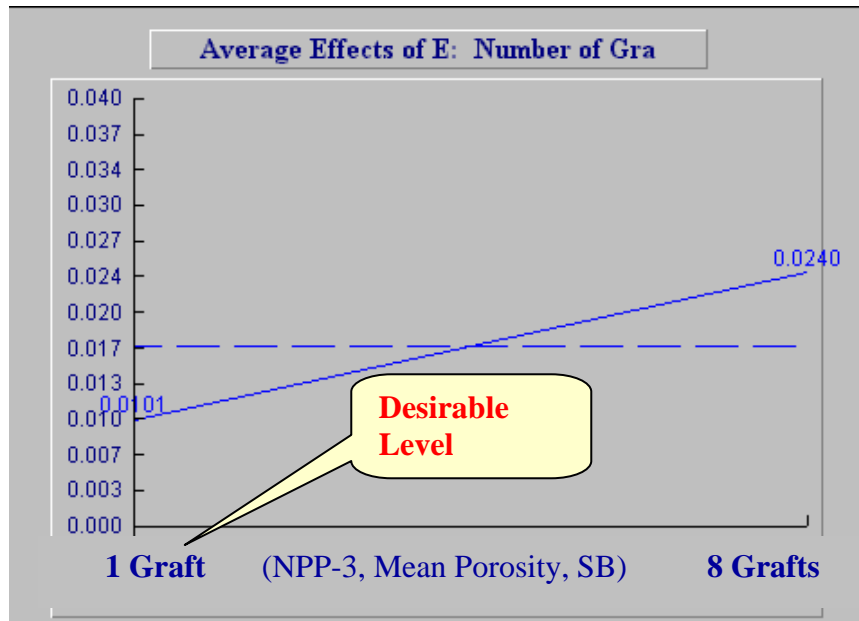
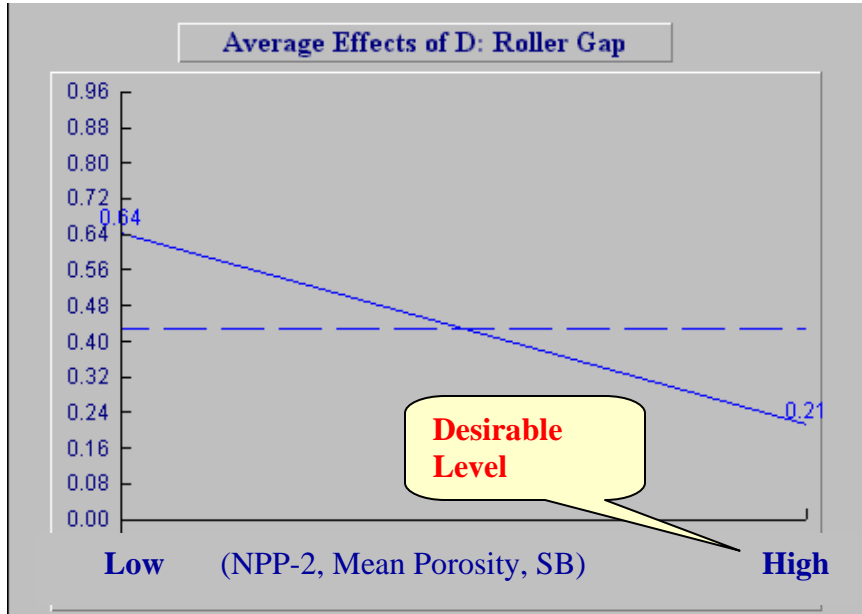
### Factor Influence Data and Factor Effect Graphs

Analyses Type	Factors =>						
	A:	B:	C:	D:	E:	F:	G:
NPP	31.5	27.8	6.3	0	0	6.8	12.6
NPP-2	48.75	17.6	2.6	11.4	5.6	0	0
NPP-3	51.8	0	0	8.7	22.4	5.05	4.8
Avg. Effects On Porosity	43.9	15.1	2.9	6.7	9.3	3.8	5.8
NPP-C	2.0	10.3	2.5	6.2	0	0	68.15

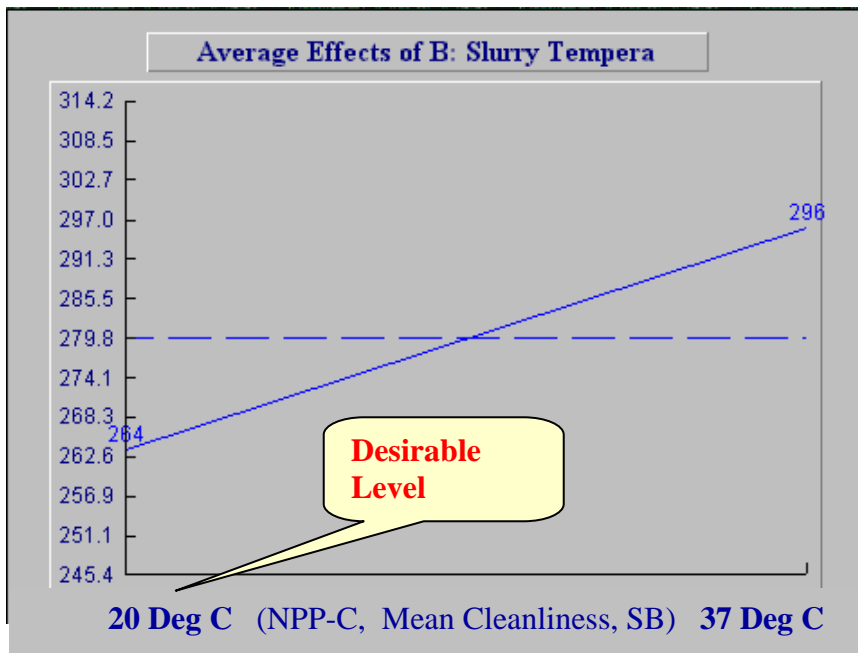
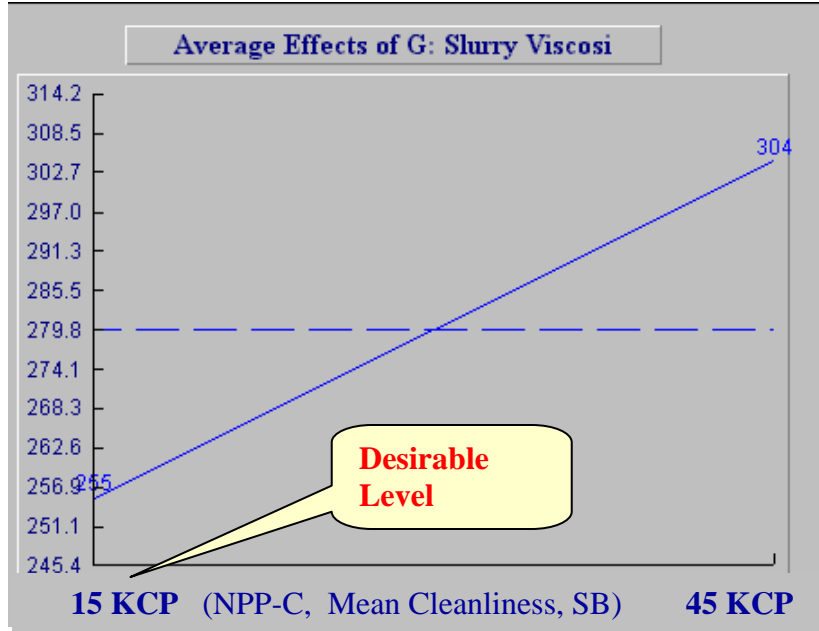
Factors A, B, E, D, and G have significant effects on POROSITY. The optimum levels for all are at Level-2, except for E which is at Level-1 as shown below (For main effect plots standard analysis with mean results performed.). The levels of factors C: Impregnation Pressure and F: Milking may be decided from cost and other considerations.



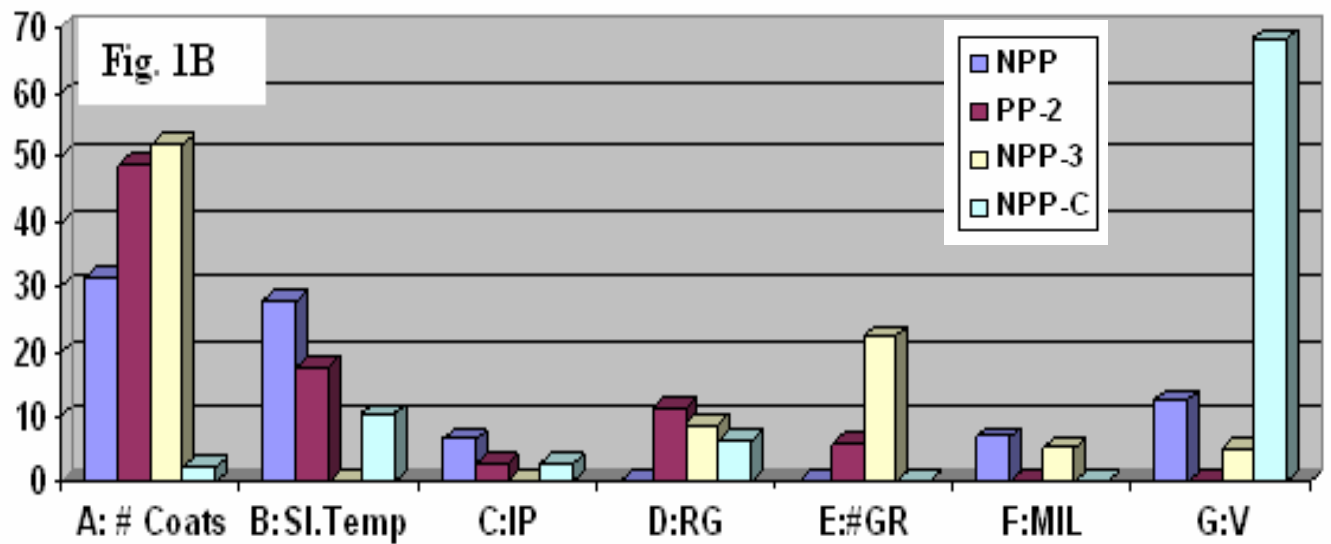
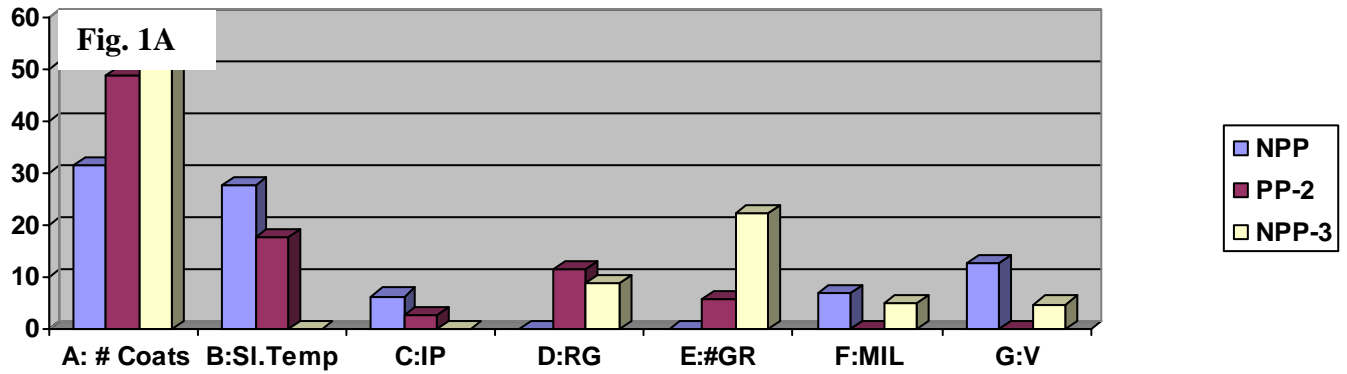




The factors with overwhelming effect of **CLEANLINERSS** are factor G: Slurry Viscosity and B: Slurry Temperature. Its effect is shown from the main effect plot below (Standard analysis). Level selection of all other factors has minimal influence.



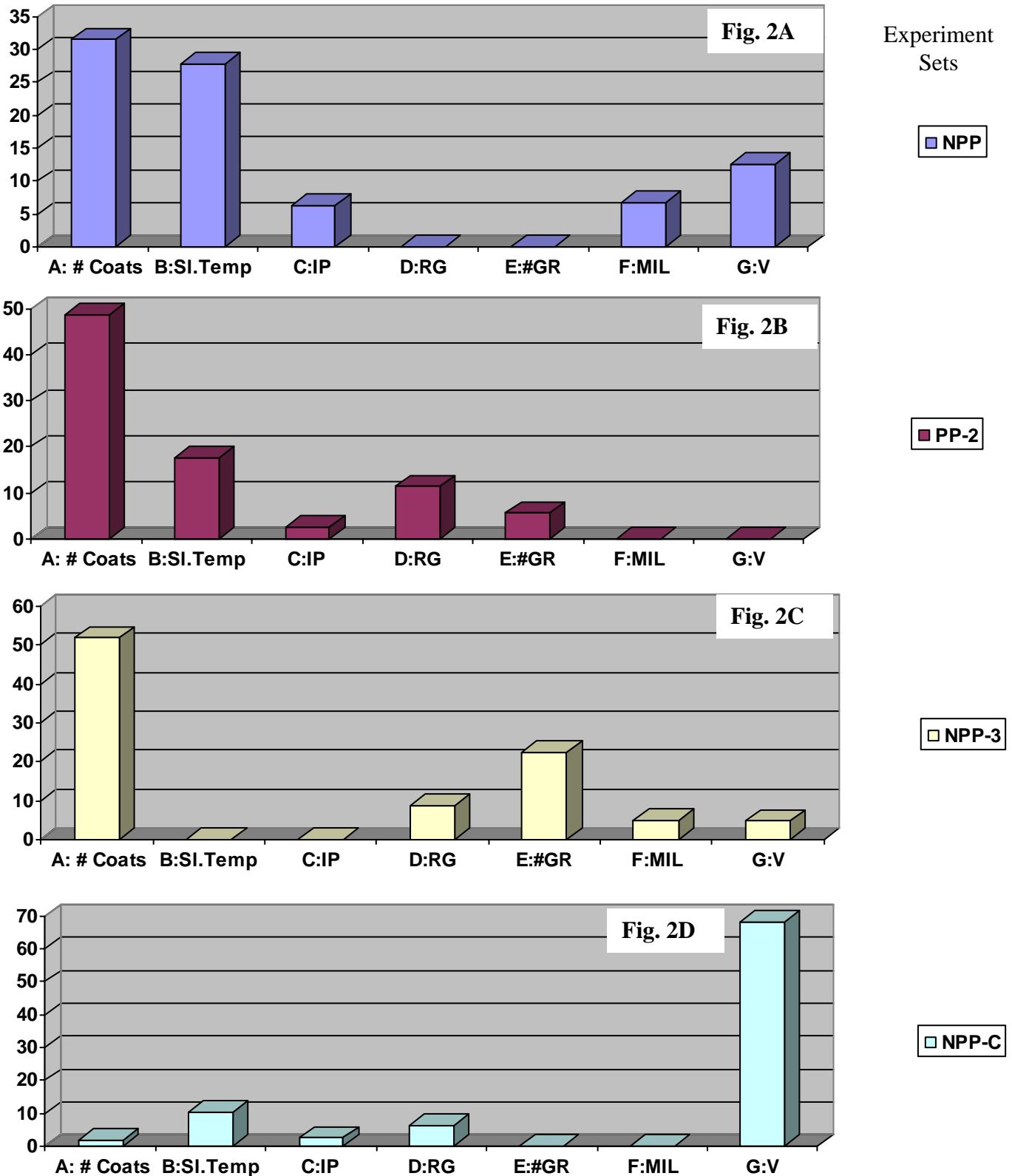
**Figure 1: Relative Factor Influence to the Variability of Results (Combined Sets)**



**Data for Plot Above** (Average influence from Std. Dev. & S/N analysis, ANOVA)

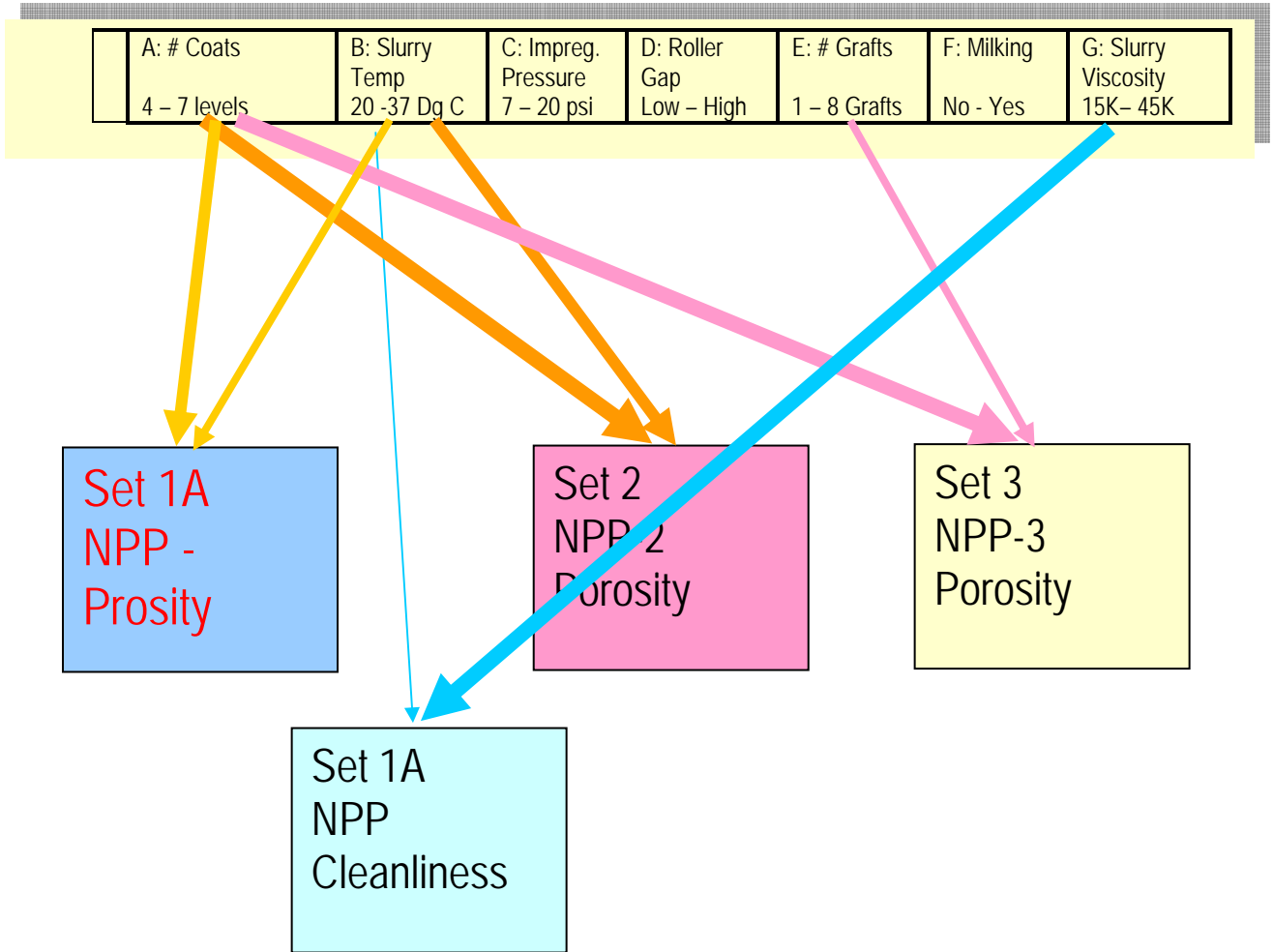
Analyses Type	Fcators=>						
	A:	B:	C:	D:	E:	F:	G:
NPP	31.5	27.8	6.3	0	4.5	6.8	12.6
NPP-2	48.75	17.6	2.6	11.4	5.6	0	0
NPP-3	51.8	0	0	8.7	22.4	5.05	4.8
NPP-C	2.0	10.3	2.5	6.2	0	0	68.15

**Figure 2: Relative Factor Influence to the Variability of Results (Individual Set)**



### Figure 3: Factor Influence to the Process/Characteristics

How are the different process & characteristics become influenced?  
 Which factors do what to the process characteristics?



**Table 1A: Average Factor Influence**

Analyses Type	Factors=>						
	A:	B:	C:	D:	E:	F:	G:
<b>NPP Std. Dev</b>	<b>31.5</b>	<b>27.8</b>	<b>6.3</b>	<b>0</b>	<b>0</b>	<b>6.8</b>	<b>12.6</b>
<b>NPP/ S/N</b>							
<b>NPP-2 Std. Dev</b>	<b>48.75</b>	<b>17.6</b>	<b>2.6</b>	<b>11.4</b>	<b>5.6</b>	<b>0</b>	<b>0</b>
<b>NPP-2/S/N</b>							
<b>NPP-3 Std. Dev</b>	<b>51.8</b>	<b>0</b>	<b>0</b>	<b>8.7</b>	<b>22.4</b>	<b>5.05</b>	<b>4.8</b>
<b>NPP-3/ S/N</b>							
<b>NPP-C Std. Dev</b>	<b>2.0</b>	<b>10.3</b>	<b>2.5</b>	<b>6.2</b>	<b>0</b>	<b>0</b>	<b>68.15</b>
<b>NPP-C/S/N</b>							

Note: Numbers represent average influence of the factors in a Set (Four sets)

**Table 1B: Desired Factor Levels**

Analyses Type	F	A	C	T	O	R	S
	A: # Coats 4 – 7 levels	B: Slurry Temp 20 -37 Dg C	C: Impreg. Pressure 7 – 20 psi	D: Roller Gap Low – High	E: # Grafts 1 – 8 Grafts	F: Milking No - Yes	G: Slurry Viscosity 15K– 45K
<b>NPP/Std. Dev</b>	Level-2	Level-2	Level-2	Level -0	Level-0	Level-2	Level-2
<b>NPP/ S/N</b>	Level-2	Level-2	Level-0	Level-0	Level -0	Level-2	Level-2
<b>NPP-2/Std. Dev</b>	Level-2	Level-2	Level-2	Level-2	Level-2	Level-0	Level-0
<b>NPP-2/ S/N</b>	Level-2	Level-2	Level-0	Level-2	Level-0	Level-0	Level-0
<b>NPP-3/Std. Dev</b>	Level-2	Level-0	Level-0	Level-1	Level-1	Level-2	Level-2
<b>NPP-3/ S/N</b>	Level-2	Level-0	Level-0	Level-2	Level-1	Level-0	Level-0
<b>NPP-C/Stdev</b>	Level-1	Level-2	Level-0	Level-0	Level-0	Level-0	Level-1
<b>NPP-C/S/N</b>	Level-0	Level-1	Level-1	Level-2	Level-0	Level-0	Level-1

**Table 2: Average Influence of Factors and their Desirable Levels**

Analyses Type	F	A	C	T	O	R	S
	A: # Coats 4 – 7 levels	B: Slurry Temp 20 -37 Dg C	C: Impreg. Pressure 7 – 20 psi	D: Roller Gap Low – High	E: # Grafts 1 – 8 Grafts	F: Milking No - Yes	G: Slurry Viscosity 15K– 45K
NPP Std. Dev	31.5 Level - 2	27.8 Level - 2	6.3 Level-2	0 Level -0	0 Level-0	6.8 Level-2	12.6 Level -2
NPP S/N	Level -2	Level-2	Level -0	Level-0	Level -0	Level-2	Level-2
NPP-2 Std. Dev	48.75 Level-2	17.6 Level-2	2.6 Level-2	11.4 Level-2	5.6 Level-2	0 Level-0	0 Level-0
NPP-2 S/N	Level-2	Level-2	Level-0	Level-2	Level-0	Level-0	Level-0
NPP-3 Std. Dev	51.8 Level-2	0 Level-0	0 Level -0	8.7 Level-1	22.4 Level-1	5.05 Level-2	4.8 Level-2
NPP-3 S/N	Level-2	Level-0	Level-0	Level-2	Level-1	Level-0	Level-0
NPP-C Std. Dev	2.0 Level-1	10.3 Level-2	2.5 Level-0	6.2 Level-0	0 Level-0	0 Level-0	68.15 Level-1
NPP-C S/N	Level-0	Level-1	Level-1	Level-2	Level-0	Level-0	Level-1

Note: Numbers represent average influence in a Set (Four sets), "0" Value for level indicates that the factor is pooled

**Table 3: Summary Observations**

Analyses Type	F	A	C	T	O	R	S
	A: # Coats 4 – 7 levels (% from ANOVA)	B: Slurry Temp 20 -37 Dg C	C: Impreg. Pressure 7 – 20 psi	D: Roller Gap Low – High	E: # Grafts 1 – 8 Grafts	F: Milking No - Yes	G: Slurry Viscosity 15K– 45K
NPP Std. Dev	31.7	19.1	12.5	0	0	8.8	11.6
NPP S/N	30.6	36.5	0	0	0	3.7	13.6
NPP-2 Std. Dev	42.4	10.4	5.1	14.5	11.1	0	0
NPP-2 S/N	55.1	24.8	0	8.3	0	0	0
NPP-3 Std. Dev	50.0	0	0	14.1	16.2	10.1	9.6
NPP-3 S/N	53.6	0	0	3.3	28.6	0	0
Avg. Influence on Porosity* =>	<b>43.9</b>	<b>15.1</b>	<b>2.9</b>	<b>6.7</b>	<b>9.3</b>	<b>3.8</b>	<b>5.8</b>
NPP-C Std. Dev	3.9	5.2	0	0	0	0	76.3
NPP-C S/N	0	15.3	5.0	12.3	0	0	60.0
Average Influ. of Cleanliness** =>	<b>2.0</b>	<b>10.25</b>	<b>2.5</b>	<b>6.2</b>	<b>0</b>	<b>0</b>	<b>68.15</b>

\* Average of SIX numbers.

\*\* Average of TWO numbers

Notes:

NPP = Normal Production Process (Porosity Results)

NPP-2 = NPP without Inspection and Air Porosity

NPP-3 = NPP without Inspection, Air Porosity, and Sterilization

NPP-C = Normal Production Process (Cleanliness results)

Std. Dev. = Analysis performed using standard deviation of results for variability study

S/N = Analysis performed using signal-to-noise analysis (for variability and mean)

### III. Analysis of Results

#### Project Title: Study of Collagen Impregnation Critical Factors

In this study, three separate sets of experiments were carried out. There were eight separate test conditions in each set. Results from 20 samples in Set 1 and Set 3, and 24 samples in each test condition were collected. Results comprised of water porosity in all sets except in Set 1 where cleanliness data also was collected.

#### FOUR PROCESS SETUPS

- Set 1A (NPP): Normal Production Process - **Water Porosity results** (*Porosity = amount of water in ml/sq. centimeter/unit time.*)
- Set 2 (NPP-2): Normal Production Process without Inspection & without Air Porosity - **Water Porosity** result
- Set 3 (NPP-3): Normal Production Process without Inspection, Air Porosity, and sterilization - **Water Porosity** result
- Set 1B (NPP-C): Normal Production Process - **CLEANLINESS** (*Time spent in seconds to clean the samples*) result

Note: Excess reading from Set 1 were recorded but found to be all zeros. Therefore, Excess characteristic was not analyzed.

#### Planning Meeting, Sept 30, 2003

#### Collagen Impregnation Study – Evaluation Criteria

Criteria	Worst Reading	Best	QC	Rel. Weight
1. Porosity (Cpk)	0.5	2.0	B (Cpk)	70%
2. Cleanliness	10	0	S	16%
3. Excess	8	3	N or S	14%

During the experiment planning sessions, the team identified 29 factors affecting the Collagen Impregnation Process. To keep the size of the experiment smaller, seven out of these 29 factors were selected for the study by consensus priority. In this meeting, the two levels for each factor, as shown below, also were identified. An L-8 orthogonal array was used to layout eight separate experimental conditions which were carried out and porosity (in three set ups) and cleanliness (in one set up only) were collected.

#### Factor and Level Descriptions and the Orthogonal Array

(Same for all sets of tests as the design and trial conditions remain unchanged)

Array Type: **L-8**

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	Factors	Level 1	Level 2
1	A: # of Coats	4	7
2	B: Slurry Tempera	25 C	37 C
3	C: Impregnation P	10 psi	27 psi
4	D: Roller Gap	1.5"	1.6"
5	E: # of Grafts Th	1	4 stacked
6	F: Milking	present	absent
7	G: Slurry Viscosi	15-20 kcp	40-45 kcps

Array Type: **L-8**

	1	2	3	4	5	6	7
1	1	1	1	1	1	1	1
2	1	1	1	2	2	2	2
3	1	2	2	1	1	2	2
4	1	2	2	2	2	1	1
5	2	1	2	1	2	1	2
6	2	1	2	2	1	2	1
7	2	2	1	1	2	2	1
8	2	2	1	2	1	1	2

## Trial Conditions (Same for all sets of tests)

Trial Condition 1 (Random order for running this Trial is 4)			Trial Condition 2 (Random order for running this Trial is 2)		
Factors	Level Description	Level #	Factors	Level Description	Level #
A: Number of Coats	4 Level	1	A: Number of Coats	4 Level	1
B: Slurry Temperat	25 Deg C	1	B: Slurry Temperat	25 Deg C	1
C: Impregnation Pr	10 PSI	1	C: Impregnation Pr	10 PSI	1
D: Roller Gap	1.51 inch	1	D: Roller Gap	1.6 inch	2
E: Number of graft	1 graft	1	E: Number of graft	4 grafts stac	2
F: Milking	No	1	F: Milking	Yes	2
G: Slurry Viscosit	15-20K CP	1	G: Slurry Viscosit	40-45K CPS	2

Trial Condition 3 (Random order for running this Trial is 7)			Trial Condition 4 (Random order for running this Trial is 4)		
Factors	Level Description	Level #	Factors	Level Description	Level #
A: Number of Coats	4 Level	1	A: Number of Coats	4 Level	1
B: Slurry Temperat	37 Deg C	2	B: Slurry Temperat	37 Deg C	2
C: Impregnation Pr	20 PSI	2	C: Impregnation Pr	20 PSI	2
D: Roller Gap	1.51 inch	1	D: Roller Gap	1.6 inch	2
E: Number of graft	1 graft	1	E: Number of graft	4 grafts stac	2
F: Milking	Yes	2	F: Milking	No	1
G: Slurry Viscosit	40-45K CPS	2	G: Slurry Viscosit	15-20K CP	1

Trial Condition 5 (Random order for running this Trial is 3)			Trial Condition 6 (Random order for running this Trial is 1)		
Factors	Level Description	Level #	Factors	Level Description	Level #
A: Number of Coats	7 Level	2	A: Number of Coats	7 Level	2
B: Slurry Temperat	25 Deg C	1	B: Slurry Temperat	25 Deg C	1
C: Impregnation Pr	20 PSI	2	C: Impregnation Pr	20 PSI	2
D: Roller Gap	1.51 inch	1	D: Roller Gap	1.6 inch	2
E: Number of graft	4 grafts stac	2	E: Number of graft	1 graft	1
F: Milking	No	1	F: Milking	Yes	2
G: Slurry Viscosit	40-45K CPS	2	G: Slurry Viscosit	15-20K CP	1

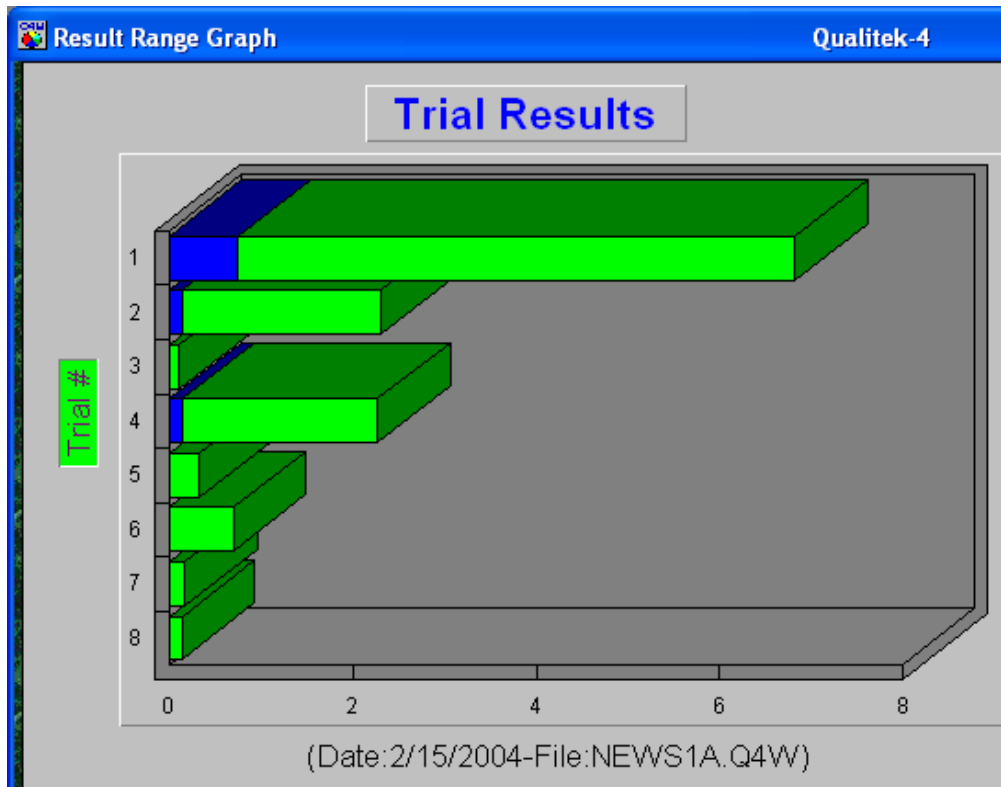
Trial Condition 7 (Random order for running this Trial is 5)			Trial Condition 8 (Random order for running this Trial is 8)		
Factors	Level Description	Level #	Factors	Level Description	Level #
A: Number of Coats	7 Level	2	A: Number of Coats	7 Level	2
B: Slurry Temperat	37 Deg C	2	B: Slurry Temperat	37 Deg C	2
C: Impregnation Pr	10 PSI	1	C: Impregnation Pr	10 PSI	1
D: Roller Gap	1.51 inch	1	D: Roller Gap	1.6 inch	2
E: Number of graft	4 grafts stac	2	E: Number of graft	1 graft	1
F: Milking	Yes	2	F: Milking	No	1
G: Slurry Viscosit	15-20K CP	1	G: Slurry Viscosit	40-45K CPS	2

# Set 1A: Normal Production Process (NPP)

Set1A: Porosity Results (20 Samples tested in each trial condition)

	Sample# 1	Sample# 2	Sample# 3	Sample# 4	Sample# 5	Sample# 6	Sample# 7	Sample# 8	Sample# 9	Sample# 10
Trial# 1	3.653	3.021	3.909	2.834	3.625	4.325	6.824	5.87	3.228	5.383
Trial# 2	0.866	0.596	0.782	1.094	1.566	2.237	0.689	2.31	1.971	0.861
Trial# 3	0.001	0.106	0.003	0	0.091	0.007	0.022	0.006	0.037	0.022
Trial# 4	0.447	0.231	0.203	0.403	0.909	0.361	0.587	0.394	0.733	0.909
Trial# 5	0	0.102	0.12	0.088	0.055	0.231	0.284	0.216	0.248	0.168
Trial# 6	0.138	0.252	0.095	0.385	0.121	0.694	0.126	0.075	0.293	0.28
Trial# 7	0.111	0.082	0.075	0.034	0.089	0.022	0.08	0.08	0.063	0.014
Trial# 8	0	0	0	0.029	0	0.133	0	0.007	0	0.001
Sample# 11	Sample# 12	Sample# 13	Sample# 14	Sample# 15	Sample# 16	Sample# 17	Sample# 18	Sample# 19	Sample# 20	Std.Dev.
1.895	1.213	0.747	1.577	1.455	1.083	2.201	2.274	1.566	1.58	1.696
0.52	0.216	0.44	0.671	0.696	0.533	0.66	0.861	0.82	0.149	0.616
0.007	0.031	0.019	0.003	0.108	0.003	0.019	0	0.07	0.046	0.035
0.19	0.138	0.708	0.161	0.613	0.497	0.36	0.447	2.274	0.649	0.465
0.231	0.156	0.227	0.106	0.141	0.097	0.149	0.284	0.208	0.326	0.085
0.158	0.123	0.011	0.018	0.136	0.18	0.031	0.007	0.145	0.235	0.158
0.166	0.151	0.053	0	0.075	0.044	0.02	0.029	0.022	0.014	0.045
0.007	0	0	0.02	0.01	0.017	0	0.007	0.087	0	0.034
										392

**Set 1A: Variability of Results** (Between and within trial condition)



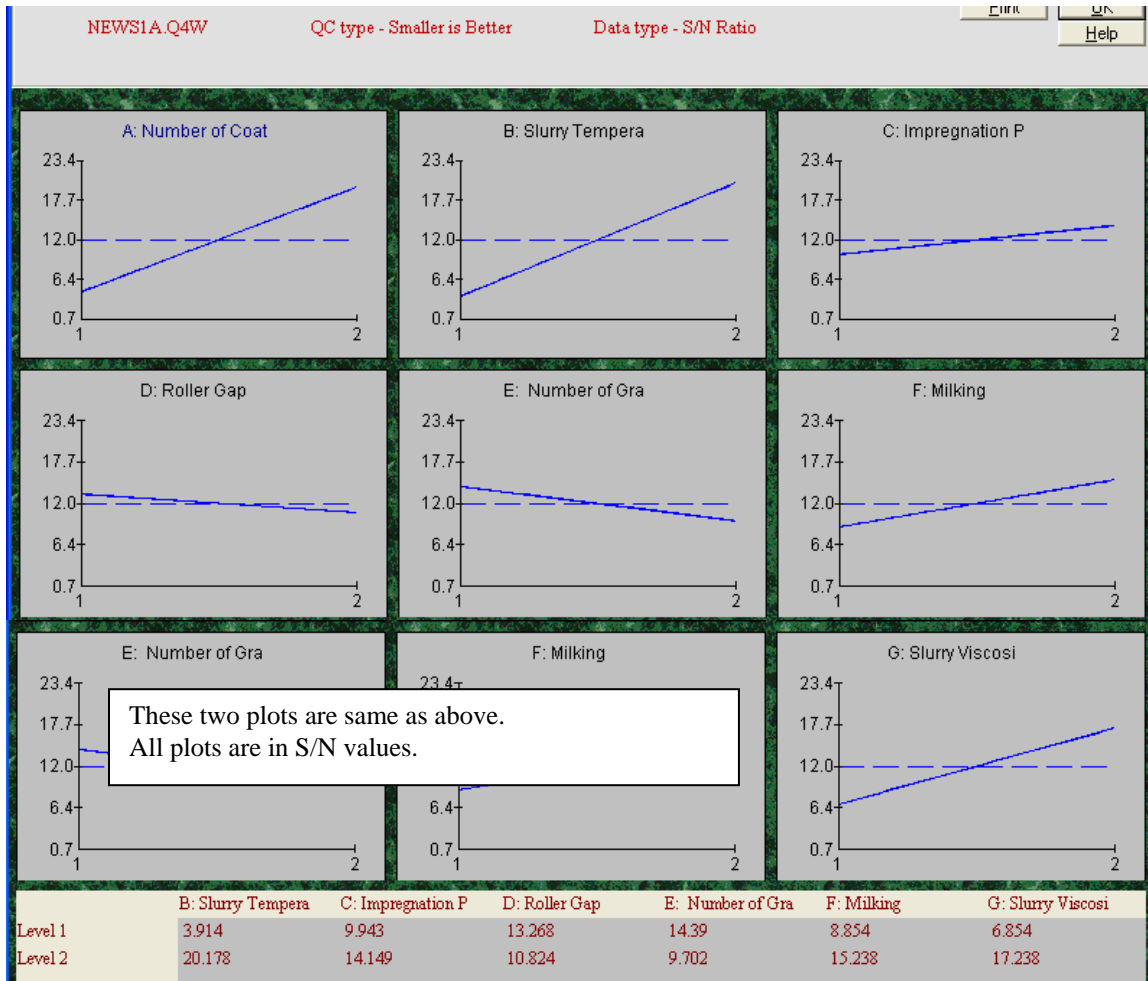
**Set 1A: Main Effects** (Analysis using Std. Dev. and S/N)

Column # / Factors	Level 1	Level 2
1 A: Number of Coat	.703	.08
2 B: Slurry Tempera	.639	.145
3 C: Impregnation P	.598	.186
4 D: Roller Gap	.465	.318
5 E: Number of Gra	.481	.303
6 F: Milking	.57	.214
7 G: Slurry Viscosi	.591	.192

Column # / Factors	Level 1	Level 2
1 A: Number of Coat	4.553	19.54
2 B: Slurry Tempera	3.914	20.178
3 C: Impregnation P	9.943	14.149
4 D: Roller Gap	13.268	10.824
5 E: Number of Gra	14.39	9.702
6 F: Milking	8.854	15.238
7 G: Slurry Viscosi	6.854	17.238

**Plots of Factor Effect (S/N Analysis, Higher S/N value is desirable even when the quality characteristic is *smaller is better*)**



**Set 1A: Interaction Information** (21 pairs among seven factors, S/N Analysis)

*Even though interaction was not an objective of the study, information about possible 21 interaction is available from the collected data. The indicator SI for each pair of interaction indicates the strength of presence of interaction (0 – 100%). This information can be used for future studies in the repeat experiments.*

Number of interactions between two factors calculated = 21

#	Interacting Factor Pairs (in Order of Severity)	Columns	SI(%)	Col	Opt.
1	D: Roller Gap x E: Number of Gra	4 x 5	76.17	1	[2,1]
2	D: Roller Gap x F: Milking	4 x 6	71.81	2	[1,2]
3	C: Impregnation P x D: Roller Gap	3 x 4	71.16	7	[2,1]
4	E: Number of Gra x G: Slurry Viscosi	5 x 7	61.03	2	[1,2]
5	F: Milking x G: Slurry Viscosi	6 x 7	59.07	1	[1,2]
6	C: Impregnation P x E: Number of Gra	3 x 5	57.65	6	[2,1]
7	A: Number of Coat x C: Impregnation P	1 x 3	52.04	2	[2,1]
8	B: Slurry Tempera x C: Impregnation P	2 x 3	47.95	1	[2,1]
9	C: Impregnation P x F: Milking	3 x 6	42.34	5	[2,2]
10	A: Number of Coat x F: Milking	1 x 6	40.92	7	[2,1]
11	B: Slurry Tempera x E: Number of Gra	2 x 5	38.96	7	[2,1]
12	E: Number of Gra x F: Milking	5 x 6	37.99	3	[1,2]
13	D: Roller Gap x G: Slurry Viscosi	4 x 7	28.83	3	[1,2]
14	B: Slurry Tempera x D: Roller Gap	2 x 4	28.18	6	[2,1]
15	A: Number of Coat x G: Slurry Viscosi	1 x 7	25.16	6	[2,2]
16	A: Number of Coat x D: Roller Gap	1 x 4	23.82	5	[2,2]
17	B: Slurry Tempera x G: Slurry Viscosi	2 x 7	17.59	5	[2,2]
18	C: Impregnation P x G: Slurry Viscosi	3 x 7	16.75	4	[2,2]
19	A: Number of Coat x B: Slurry Tempera	1 x 2	13.46	3	[2,2]
20	A: Number of Coat x E: Number of Gra	1 x 5	12.42	4	[2,1]
21	B: Slurry Tempera x F: Milking	2 x 6	10.79	4	[2,2]

Columns of chart explained:

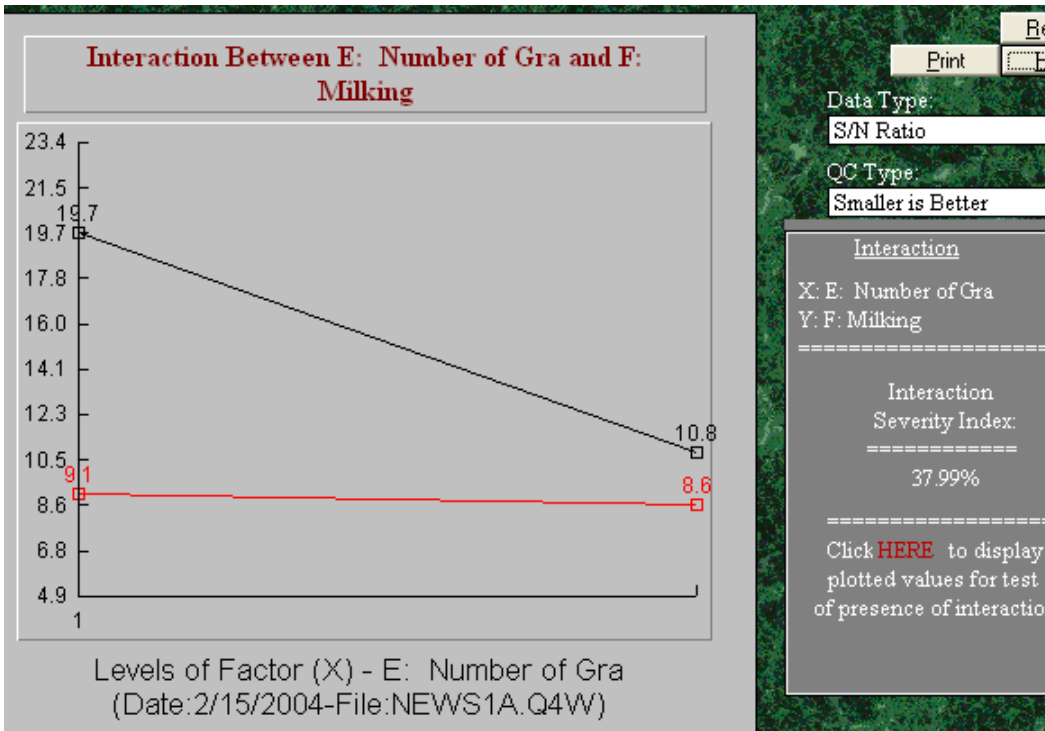
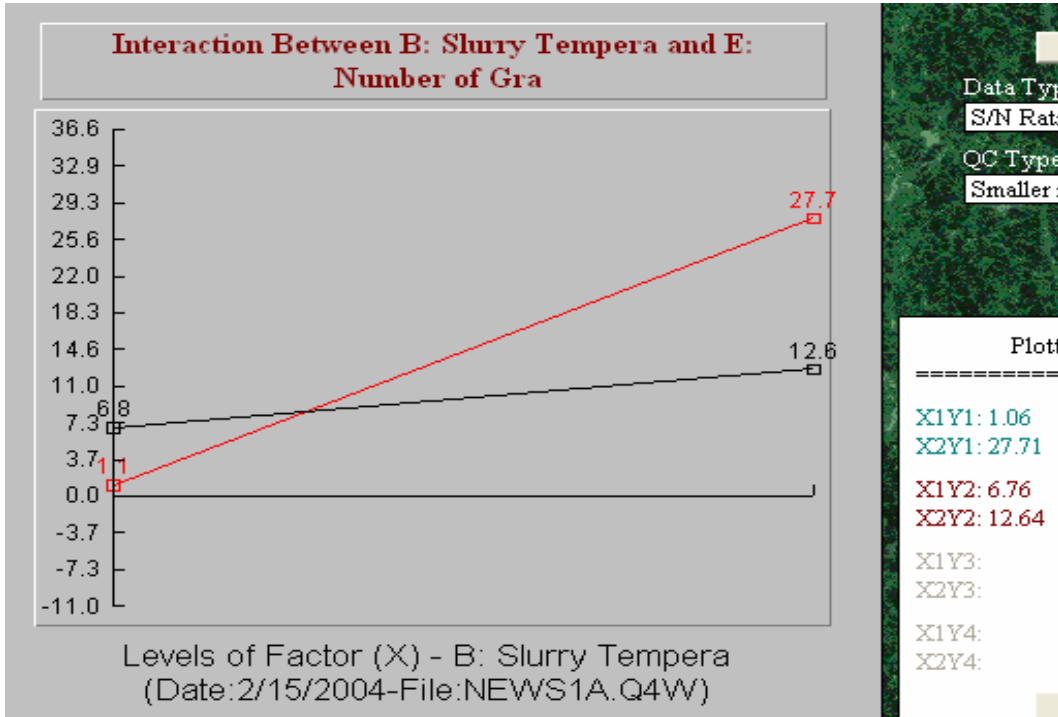
**Columns** - Represent the column locations to which the interacting factors are assigned.

**SI** - Interaction severity index (100% for 90 degrees angle between the lines, 0% for 0 degrees)

**Col** - Shows column that should be reserved if this interaction effect were to be studied

**Opt** - Indicates the factor levels desirable for the optimum condition (based strictly on main effects). If an interaction is included in the study and found significant (in ANOVA), the indicated levels are the factor levels identified for the optimum condition without considerations of any interactions.

**Typical Interaction Plot (S/N Analysis)**



**Set 1A: ANOVA (Analysis using Std. Dev. and S/N)\***

Expt. File: **NEWS1A.Q4W**      Data Type: **Average/St.Dev. Values**         
 QC Type: **Smaller is Better**     

Col # / Factor	DOF (f)	Sum of Sqrs. (S)	Variance (V)	F - Ratio (F)	Pure Sum (S')	Percent P (%)
1 A: Number of Coat	1	.775	.775	14.553	.722	31.681
2 B: Slurry Tempera	1	.488	.488	9.154	.434	19.062
3 C: Impregnation P	1	.339	.339	6.364	.286	12.54
4 D: Roller Gap	(1)	(.043)		<b>POOLED</b>	<b>(CL= *NC+)</b>	
5 E: Number of Gra	(1)	(.063)		<b>POOLED</b>	<b>(CL=100%)</b>	
6 F: Milking	1	.253	.253	4.759	.2	8.787
7 G: Slurry Viscosi	1	.317	.317	5.957	.264	11.588
<b>Other/Error</b>	<b>2</b>	<b>.106</b>	<b>.053</b>			<b>16.342</b>
<b>Total:</b>	<b>7</b>	<b>2.281</b>				<b>100.00%</b>

Expt. File: **NEWS1A.Q4W**      Data Type: **S/N Ratio**         
 QC Type: **Smaller is Better**     

Col # / Factor	DOF (f)	Sum of Sqrs. (S)	Variance (V)	F - Ratio (F)	Pure Sum (S')	Percent P (%)
1 A: Number of Coat	1	449.222	449.222	14.76	418.788	30.641
2 B: Slurry Tempera	1	529.072	529.072	17.383	498.637	36.483
3 C: Impregnation P	(1)	(35.391)		<b>POOLED</b>	<b>(CL=100%)</b>	
4 D: Roller Gap	(1)	(11.945)		<b>POOLED</b>	<b>(CL= *NC+)</b>	
5 E: Number of Gra	(1)	(43.966)		<b>POOLED</b>	<b>(CL=74.24%)</b>	
6 F: Milking	1	81.52	81.52	2.678	51.085	3.737
7 G: Slurry Viscosi	1	215.628	215.628	7.084	185.193	13.549
<b>Other/Error</b>	<b>3</b>	<b>91.304</b>	<b>30.434</b>			<b>15.59</b>
<b>Total:</b>	<b>7</b>	<b>1366.748</b>				<b>100.00%</b>

Factor: **F: Milking**

Confidence Level = 83.92

Pool this factor?

**Set 1A: Identification of Maximum Experimental Error**  
 (Analysis using Average only. Error: Set up, Noise Factors, Factors excluded)

ANOVA Table							Qualitek-4	
Expt. File: NEWS1A.Q4W		Data Type: Average/St.Dev. Values		Print		OK		
		QC Type: Smaller is Better		Help		Cancel		
Col# / Factor	DOF (f)	Sum of Sqrs. (S)	Variance (V)	F - Ratio (F)	Pure Sum (S')	Percent P(%)		
1 A: Number of Coat	1	40.134	40.134	91.428	39.695	19.621		
2 B: Slurry Tempera	1	30.961	30.961	70.533	30.522	15.087		
3 C: Impregnation P	1	22.192	22.192	50.555	21.753	10.752		
4 D: Roller Gap	1	5.606	5.606	12.773	5.168	2.554		
5 E: Number of Gra	1	4.995	4.995	11.38	4.556	2.252		
6 F: Milking	1	15.231	15.231	34.698	14.792	7.312		
7 G: Slurry Viscosi	1	16.454	16.454	37.484	16.015	7.916		
Other/Error	152	66.722	.438			34.506		
Total:	159	202.299				100.00%		

Factor: **E: Number of Gra**

Confidence Level = 99.92

Pool this factor?

Above analysis was done using average of results as indicated by the large number of Error DOF.

Maximum Error = 35%

**Set 1A: Optimum Condition** (Analysis using Std. Dev. and S/N)

Expt. File: **NEWS1A.Q4W**      Data Type: **Average/St.Dev. Values**     

QC      **Smaller is Better**

Column # / Factor	Level Description	Level	Contribution
1 A: Number of Coat	7 Levels	2	-312
2 B: Slurry Tempera	37 Deg C	2	-248
3 C: Impregnation P	27 psi	2	-206
6 F: Milking	Yes	2	-179
7 G: Slurry Viscosi	40-45 kcps	2	-2
Total Contribution From All Factors...			-1.146
Current Grand Average Of Performance...			.392
Expected Result At Optimum Condition...			-.753

Expt. File: **NEWS1A.Q4W**      Data Type: **S/N Ratio**     

QC      **Smaller is Better**

Column # / Factor	Level Description	Level	Contribution
1 A: Number of Coat	7 Levels	2	7.493
2 B: Slurry Tempera	37 Deg C	2	8.132
6 F: Milking	Yes	2	3.192
7 G: Slurry Viscosi	40-45 kcps	2	5.191
Total Contribution From All Factors...			24.007
Current Grand Average Of Performance...			12.046
Expected Result At Optimum Condition...			36.054

**Optimum Condition and Expected Performance** (from S/N Analysis shown above)

## Transformation of S/N into measurable data (Units)

### Low and High ends of Expected Performance

**Confidence Interval** **Qualitek-4**

Print  
Help

Expression : C.I. =  $\text{sqr. Root}((F(1,n2) * Ve) / Ne)$   
 Where:  $F(n1, n2) = 2.1$  (Computed Value)  
 $n1 = 1$  Error DOF,  $n2 = 3$   
 $Ve =$  Error Variance = 30.43476  
 $Ne =$  Effective Number of Replications = 1.6  
 [Factor DOF's Included in the Estimate = 4]

Confidence Level = 80.  
 Confidence Interval = +/- 6.32

Expected Results at Optimum = 36.054 +/- 6.32  
 (Low Value = 29.734, High Value = 42.374)

**Transformation of C.I. in S/N - Low Value**

Expt File: NEWS1A.Q4W  
 Data Type: S/N Ratio  
 QC Type: Smaller is Better

Estimate of expected results from S/N ratio  
 $S/N = -10 \text{ Log (MSD)} = 29.7337$   
 or  $MSD = 10^{[-(S/N)/10]} = 0.001063$   
 where  
 $MSD = [(y1)^2 + (y2)^2 + \dots + (yn)^2] / n$   
 $= [\text{Avg. } (y)^2] = Y_{exp}^2$   
 or  $Y_{exp} = \text{SQR}(MSD)$

Expected performance in QC units  
 (or overall evaluation criteria) is:  
 $Y_{exp} = 0.033$  QC units  
 (Based on S/N = 29.734 at optimum)

**Transformation of C.I. in S/N - High Value**

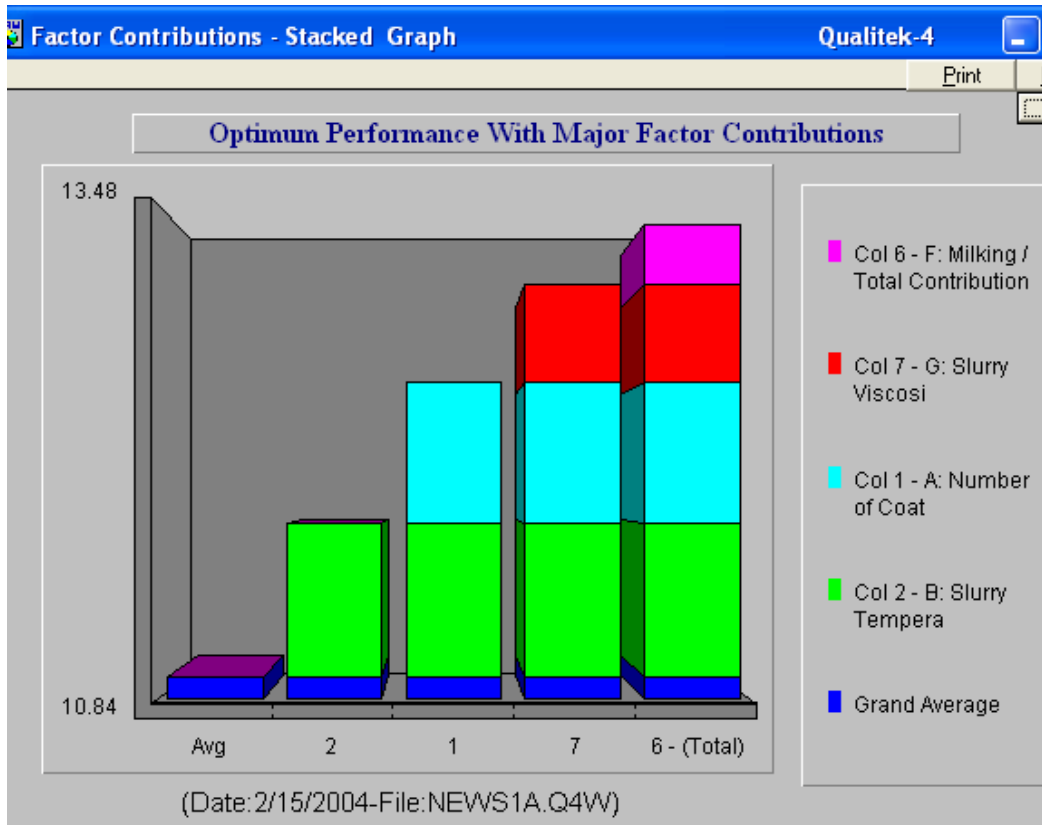
Expt File: NEWS1A.Q4W  
 Data Type: S/N Ratio  
 QC Type: Smaller is Better

Estimate of expected results from S/N ratio  
 $S/N = -10 \text{ Log (MSD)} = 42.3743$   
 or  $MSD = 10^{[-(S/N)/10]} = 0.000058$   
 where  
 $MSD = [(y1)^2 + (y2)^2 + \dots + (yn)^2] / n$   
 $= [\text{Avg. } (y)^2] = Y_{exp}^2$   
 or  $Y_{exp} = \text{SQR}(MSD)$

Expected performance in QC units  
 (or overall evaluation criteria) is:  
 $Y_{exp} = 0.008$  QC units  
 (Based on S/N = 42.374 at optimum)

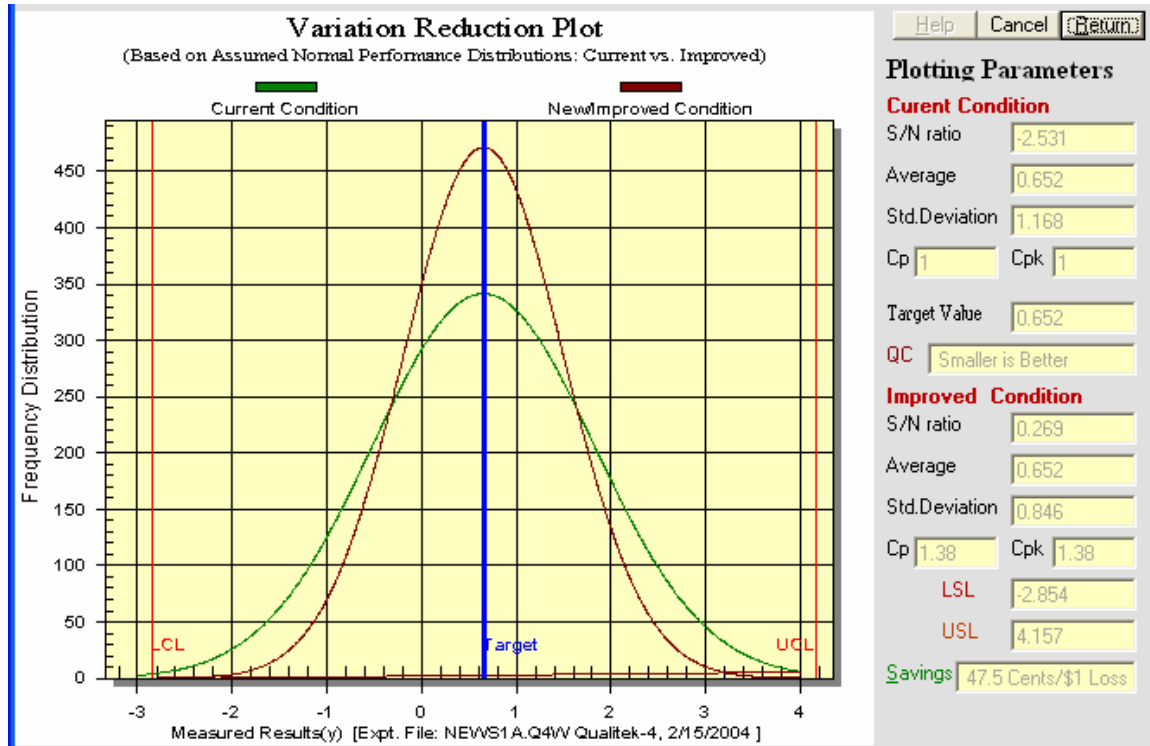
**Factor Contribution Plots (S/N Analysis)**

This stacked graph shows how the optimum performance results from the contributions of all the significant factors (Contributions from pooled/insignificant factors are not shown)



**Set 1A: Expected performance & C.I.** (Estimated from analysis using standard deviation of trial results)

Porosity: 0 – 0.01 (in the units of measured result) at 90% Confidence Level



**Key Observations (Set 1A):**

5. B: Slurry Temperature has the most influence on *Porosity*.
6. C: Impregnation Pressure. D: Roller Gap and E: Number of Grafts have least effect on *Porosity*.
7. *Porosity* can be almost eliminated by setting production parameters to the prescribed optimum condition
8. Variability can be reduced by about 38% (Std. Deviation reduced, Cpk increased)

# Set 2: Normal Production Process

(Without Inspection & without Air Porosity - Water Porosity result)

## Set 2: Porosity Results (20 Samples tested in each trial condition)

	Sample# 1	Sample# 2	Sample# 3	Sample# 4	Sample# 5	Sample# 6
Trial# 1	3.108	2.099	3.466	5.397	1.834	4.402
Trial# 2	0.525	1.247	0.606	1.609	0.385	0.537
Trial# 3	0.011	0.028	0	0.007	0	0.023
Trial# 4	0.071	0.028	0.007	0.238	0.117	0.136
Trial# 5	0.052	0.124	0.028	0.043	0.04	0.122
Trial# 6	0.213	0.068	0.035	0.161	0.074	0.067
Trial# 7	0.003	0.001	0.003	0.01	0.034	0.071
Trial# 8	0	0	0.007	0	0	0.003

	Sample# 7	Sample# 8	Sample# 9	Sample# 10	Sample# 11	Sample# 12
	1.542	3.742	3.683	2.467	1.877	2.895
	0.88	0.737	0.482	0.733	0.387	1.447
	0	0	0.003	0	0.003	0
	0.146	0.153	0.044	0.08	0.061	0.153
	0.059	0.088	0.071	0.095	0.036	0.056
	0.081	0.134	0.172	0.029	0.179	0.079
	0.002	0.101	0.001	0.01	0.003	0
	0	0	0.003	0	0	0.004

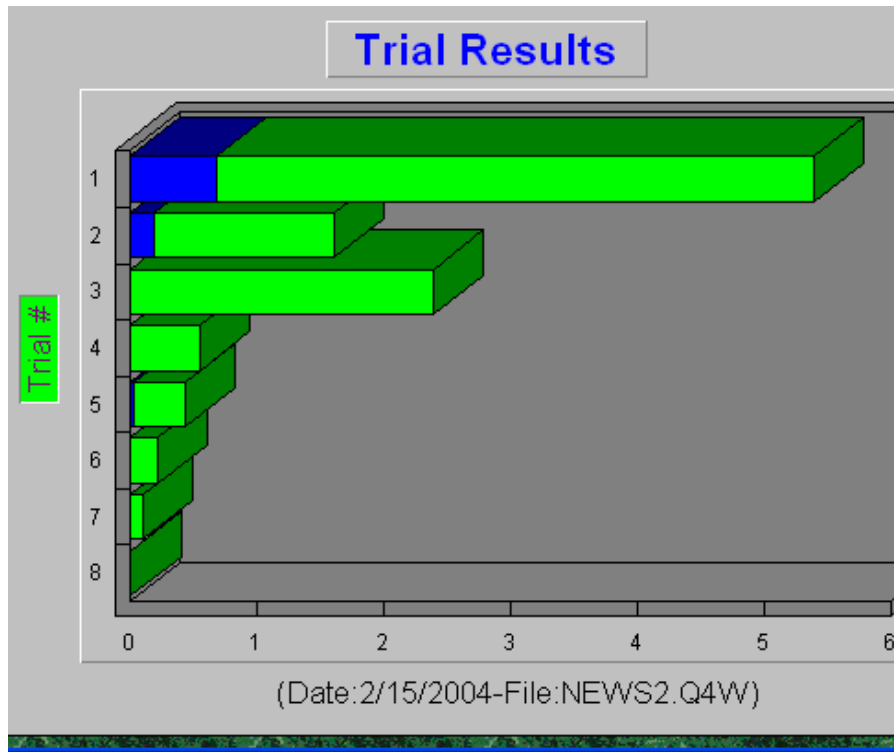
  

	Sample# 13	Sample# 14	Sample# 15	Sample# 16	Sample# 17	Sample# 18
	1.289	0.985	1.289	2.578	1.805	1.834
	0.197	0.209	0.53	0.186	0.234	0.424
	0	0.014	0.003	0.007	0.001	0.007
	0.021	0.092	0.061	0.549	0.077	0.151
	0.337	0.434	0.067	0.206	0.091	0.03
	0.058	0.036	0.007	0.111	0.052	0.057
	0	0.003	0	0.007	0	0.007
	0.001	0	0	0	0	0

	Sample# 19	Sample# 20	Sample# 21	Sample# 22	Sample# 23	Sample# 24	Std.Dev.
	1.1	0.963	3.033	2.745	0.682	1.592	1.193
	0.621	0.939	0.606	0.596	0.261	0.539	0.376
	0.001	0.015	0	0.011	0	2.392	0.487
	0.41	0.129	0.031	0.28	0.166	0.366	0.134
	0.049	0.08	0.106	0.058	0.071	0.049	0.097
	0.104	0.074	0.059	0.047	0.015	0.022	0.055
	0	0	0.007	0.022	0.029	0.007	0.024
	0	0	0	0	0	0	0.001

**Set 2: Variability of Trial Results (Also shows variability within the trial – Green)**



**Set 2: Main Effects (Analysis using Std. Dev. and S/N)**

NEWS2.Q4W Data Type: Average/St.Dev. Values  
QC Type: Smaller is Better

Column # / Factors	Level 1	Level 2
1 A: Number of Coat	.547	.044
2 B: Slurry Tempera	.43	.161
3 C: Impregnation P	.399	.193
4 D: Roller Gap	.45	.141
5 E: Number of Gra	.434	.158
6 F: Milking	.356	.235
7 G: Slurry Viscosi	.351	.24

NEWS2.Q4W Data Type: S/N Ratio  
QC Type: Smaller is Better

Column # / Factors	Level 1	Level 2
1 A: Number of Coat	3.68	30.811
2 B: Slurry Tempera	7.978	26.512
3 C: Impregnation P	20.052	14.439
4 D: Roller Gap	11.567	22.924
5 E: Number of Gra	18.166	16.325
6 F: Milking	19.362	15.129
7 G: Slurry Viscosi	14.286	20.204

**Set 2: ANOVA (Analysis using Std. Dev. and S/N)**

Expt. File: NEWS2.Q4W      Data Type: Average/St.Dev. Values      Print      OK  
 Help      Cancel

QC Type: Smaller is Better

Col# / Factor	DOF (f)	Sum of Sqrs. (S)	Variance (V)	F - Ratio (F)	Pure Sum (S')	Percent P(%)
1 A: Number of Coat	1	.506	.506	18.829	.479	42.373
2 B: Slurry Tempera	1	.144	.144	5.372	.117	10.39
3 C: Impregnation P	1	.084	.084	3.146	.057	5.1
4 D: Roller Gap	1	.19	.19	7.085	.163	14.462
5 E: Number of Gra	1	.152	.152	5.675	.125	11.112
6 F: Milking	(1)	(.029)		<b>POOLED</b>	<b>(CL=100%)</b>	
7 G: Slurry Viscosi	(1)	(.024)		<b>POOLED</b>	<b>(CL= *NC*)</b>	
<b>Other/Error</b>	<b>2</b>	<b>.052</b>	<b>.026</b>			<b>16.563</b>
<b>Total:</b>	<b>7</b>	<b>1.131</b>				<b>100.00%</b>

Expt. File: NEWS2.Q4W      Data Type: S/N Ratio      Print      OK  
 Help      Cancel

QC Type: Smaller is Better

Col# / Factor	DOF (f)	Sum of Sqrs. (S)	Variance (V)	F - Ratio (F)	Pure Sum (S')	Percent P(%)
1 A: Number of Coat	1	1472.196	1472.196	33.519	1428.276	55.085
2 B: Slurry Tempera	1	687.013	687.013	15.642	643.093	24.802
3 C: Impregnation P	(1)	(63.019)		<b>POOLED</b>	<b>(CL=81.75%)</b>	
4 D: Roller Gap	1	257.956	257.956	5.873	214.036	8.254
5 E: Number of Gra	(1)	(6.776)		<b>POOLED</b>	<b>(CL= *NC*)</b>	
6 F: Milking	(1)	(35.831)		<b>POOLED</b>	<b>(CL=100%)</b>	
7 G: Slurry Viscosi	(1)	(70.053)		<b>POOLED</b>	<b>(CL=79.06%)</b>	
<b>Other/Error</b>	<b>4</b>	<b>175.679</b>	<b>43.919</b>			<b>11.859</b>
<b>Total:</b>	<b>7</b>	<b>2592.846</b>				<b>100.00%</b>

**Set 2: Optimum Condition** (Analysis using Std. Dev. and S/N)

Expt. File: **NEWS2.Q4W**      Data Type: **Average/St.Dev. Values**        
 QC      **Smaller is Better**     

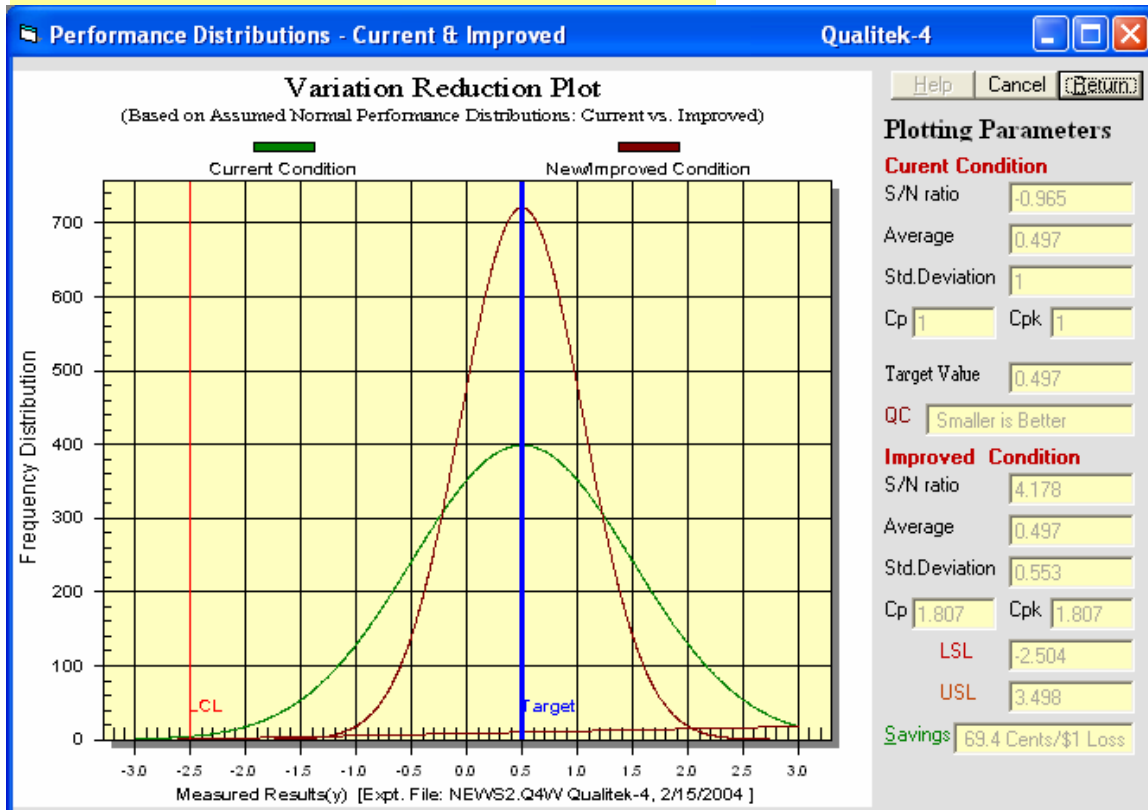
Column # / Factor	Level Description	Level	Contribution
1 A: Number of Coat	7 Levels	2	- .252
2 B: Slurry Tempera	37 Deg C	2	- .135
3 C: Impregnation P	27 psi	2	- .103
4 D: Roller Gap	1.6 inch	2	- .155
5 E: Number of Gra	4 graf stkd.	2	- .139
Total Contribution From All Factors...			- .785
Current Grand Average Of Performance...			.296
Expected Result At Optimum Condition...			- .488

Expt. File: **NEWS2.Q4W**      Data Type: **S/N Ratio**        
 QC      **Smaller is Better**     

Column # / Factor	Level Description	Level	Contribution
1 A: Number of Coat	7 Levels	2	13.565
2 B: Slurry Tempera	37 Deg C	2	9.266
4 D: Roller Gap	1.6 inch	2	5.678
Total Contribution From All Factors...			28.509
Current Grand Average Of Performance...			17.245
Expected Result At Optimum Condition...			45.754

**Set 2: Expected performance & C.I. (Estimated from standard deviation Analysis)**

Porosity: 0 – 0.005 (in the units of measured result) at 90% Confidence Level

**Set 2: Analysis using Std. Dev.****Key Observations (Set 2):**

5. A; Number of Coats has the most effect on *Porosity*.
6. F: Milking and G: Slurry Viscosity has least influence on *Porosity*.
7. In this case too, *Porosity* can be reduced to zero by setting production parameters to the prescribed optimum condition
8. Variability can be reduced by about 80% (Std. Deviation reduced, Cpk increased)

**Set 2: Variability of Trial Results (Also shows variability within the trial – Green)**

# Set 3: Normal Production Process

(without Inspection, Air Porosity, and sterilization - Water Porosity result)

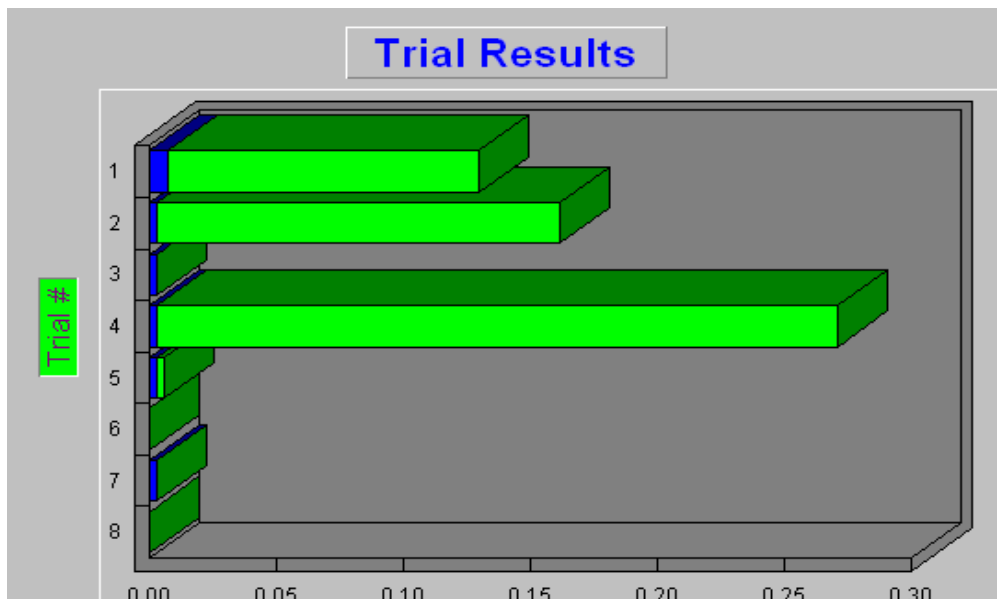
Set 3: Porosity Results (20 Samples tested in each trial condition, Original results)

	Sample# 1	Sample# 2	Sample# 3	Sample# 4	Sample# 5	Sample# 6	Sample# 7	Sample# 8	Sample# 9	Sample# 10
Trial# 1	0.036	0.019	0.06	0.014	0.073	0.13	0.063	0.025	0.012	0.043
Trial# 2	0.014	0.083	0.162	0.012	0	0.053	0.081	0.003	0.044	0.065
Trial# 3	0	0	0	0	0	0	0	0	0	0
Trial# 4	0.007	0.019	0.003	0.012	0.051	0.012	0.019	0.003	0.003	0.01
Trial# 5	0	0	0.003	0	0	0	0.003	0	0	0
Trial# 6	0	0	0	0	0	0	0	0	0	0
Trial# 7	0	0	0.003	0	0	0	0	0	0	0
Trial# 8	0	0	0	0	0	0	0	0	0	0

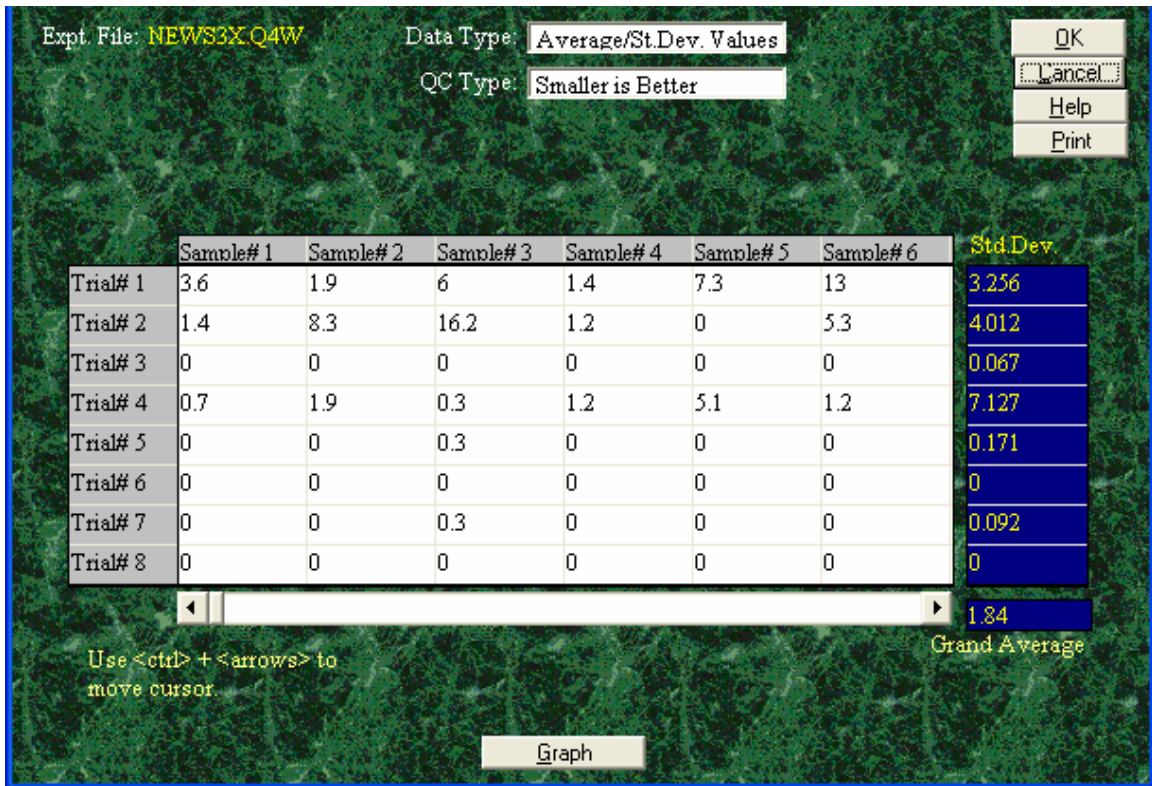
  

Sample# 11	Sample# 12	Sample# 13	Sample# 14	Sample# 15	Sample# 16	Sample# 17	Sample# 18	Sample# 19	Sample# 20	Std.Dev.
0.019	0.014	0.017	0.007	0.096	0.02	0.007	0.039	0.049	0.061	0.032
0.022	0.065	0.046	0.066	0.006	0.012	0.019	0.003	0.003	0.027	0.04
0	0	0.003	0	0	0	0	0	0	0	0
0.113	0.043	0.011	0.08	0.144	0.271	0.059	0.007	0.068	0.176	0.071
0	0.003	0.006	0	0	0	0.003	0	0	0	0.001
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0.003	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0.018

Set 3: Variability of Result (Between and within trial condition)



**Set 3: Results x 100 (For analyses only. Six of 20 sample results shown)**



**Set 3: Main Effects (Analysis using Std. Dev. and S/N, results x 100)**

Column # / Factors	Level 1	Level 2
1 A: Number of Coat	3.615	.065
2 B: Slurry Tempera	1.86	1.821
3 C: Impregnation P	1.84	1.841
4 D: Roller Gap	.896	2.784
5 E: Number of Gra	.83	2.85
6 F: Milking	2.638	1.043
7 G: Slurry Viscosi	2.619	1.062

Column # / Factors	Level 1	Level 2
1 A: Number of Coat	-6.146	43.723
2 B: Slurry Tempera	13.842	23.735
3 C: Impregnation P	15.347	22.23
4 D: Roller Gap	11.043	26.535
5 E: Number of Gra	37.319	.258
6 F: Milking	12.816	24.762
7 G: Slurry Viscosi	14.321	23.256

**Set 3: ANOVA (Analysis using Std. Dev. and S/N, result x 100)**

Expt. File: NEWS3X.Q4W      Data Type: Average/St.Dev. Values      Print      OK  
 Help      Cancel

QC Type: Smaller is Better

Col# / Factor	DOF (f)	Sum of Sqrs. (S)	Variance (V)	F - Ratio (F)	Pure Sum (S')	Percent P(%)
1 A: Number of Coat	1	25.204	25.204	17005.375	25.203	49.971
2 B: Slurry Tempera	(1)	(.002)		<b>POOLED (CL=100%)</b>		
3 C: Impregnation P	(1)	(0)		<b>POOLED (CL= *NC*)</b>		
4 D: Roller Gap	1	7.129	7.129	4810.51	7.128	14.134
5 E: Number of Gra	1	8.16	8.16	5505.81	8.159	16.177
6 F: Milking	1	5.093	5.093	3436.392	5.091	10.095
7 G: Slurry Viscosi	1	4.844	4.844	3268.303	4.842	9.601
<b>Other/Error</b>	<b>2</b>	<b>.002</b>	<b>.001</b>			<b>.022</b>
<b>Total:</b>	<b>7</b>	<b>50.435</b>				<b>100.00%</b>

Expt. File: NEWS3X.Q4W      Data Type: S/N Ratio      Print      OK  
 Help      Cancel

QC Type: Smaller is Better

Col# / Factor	DOF (f)	Sum of Sqrs. (S)	Variance (V)	F - Ratio (F)	Pure Sum (S')	Percent P(%)
1 A: Number of Coat	1	4973.809	4973.809	27.047	4789.916	53.6
2 B: Slurry Tempera	(1)	(195.742)		<b>POOLED (CL=70.68%)</b>		
3 C: Impregnation P	(1)	(94.742)		<b>POOLED (CL= *NC*)</b>		
4 D: Roller Gap	1	479.984	479.984	2.61	296.091	3.313
5 E: Number of Gra	1	2747.042	2747.042	14.938	2563.15	28.682
6 F: Milking	(1)	(285.401)		<b>POOLED (CL=78.25%)</b>		
7 G: Slurry Viscosi	(1)	(159.683)		<b>POOLED (CL=100%)</b>		
<b>Other/Error</b>	<b>4</b>	<b>735.569</b>	<b>183.892</b>			<b>14.405</b>
<b>Total:</b>	<b>7</b>	<b>8936.406</b>				<b>100.00%</b>

**Set 3: Optimum Condition** (Analysis using Std. Dev. and S/N, **result x 100**)

Expt. File: **NEWS3X.Q4W**      Data Type: **Average/St.Dev. Values**     

QC: **Smaller is Better**

Column # / Factor	Level Description	Level	Contribution
1 A: Number of Coat	7 Levels	2	-1.775
4 D: Roller Gap	1.51 inch	1	-.945
5 E: Number of Gra	1 graft	1	-1.01
6 F: Milking	Yes	2	-.798
7 G: Slurry Viscosi	40-45 kcps	2	-.779
Total Contribution From All Factors...			-5.307
Current Grand Average Of Performance...			1.84
Expected Result At Optimum Condition...			-3.467

Expt. File: **NEWS3X.Q4W**      Data Type: **S/N Ratio**     

QC: **Smaller is Better**

Column # / Factor	Level Description	Level	Contribution
1 A: Number of Coat	7 Levels	2	24.934
4 D: Roller Gap	1.6 inch	2	7.745
5 E: Number of Gra	1 graft	1	18.53
Total Contribution From All Factors...			51.209
Current Grand Average Of Performance...			18.789
Expected Result At Optimum Condition...			69.998

**Transformation of Performance at Optimum**

Expt File: **NEWS3X.Q4W**  
 Data Type: **S/N Ratio**  
 QC Type: **Smaller is Better**

Estimate of expected results from S/N ratio

$$S/N = -10 \text{ Log (MSD)} = 69.998$$

or  $MSD = 10^{[-(S/N)/10]} = 0.0$   
 where

$$MSD = [(y_1)^2 + (y_2)^2 + \dots + (y_n)^2] / n$$

$$= [\text{Avg. } (y)^2] = Y_{exp}^2$$

or  $Y_{exp} = \text{SQR}(MSD)$

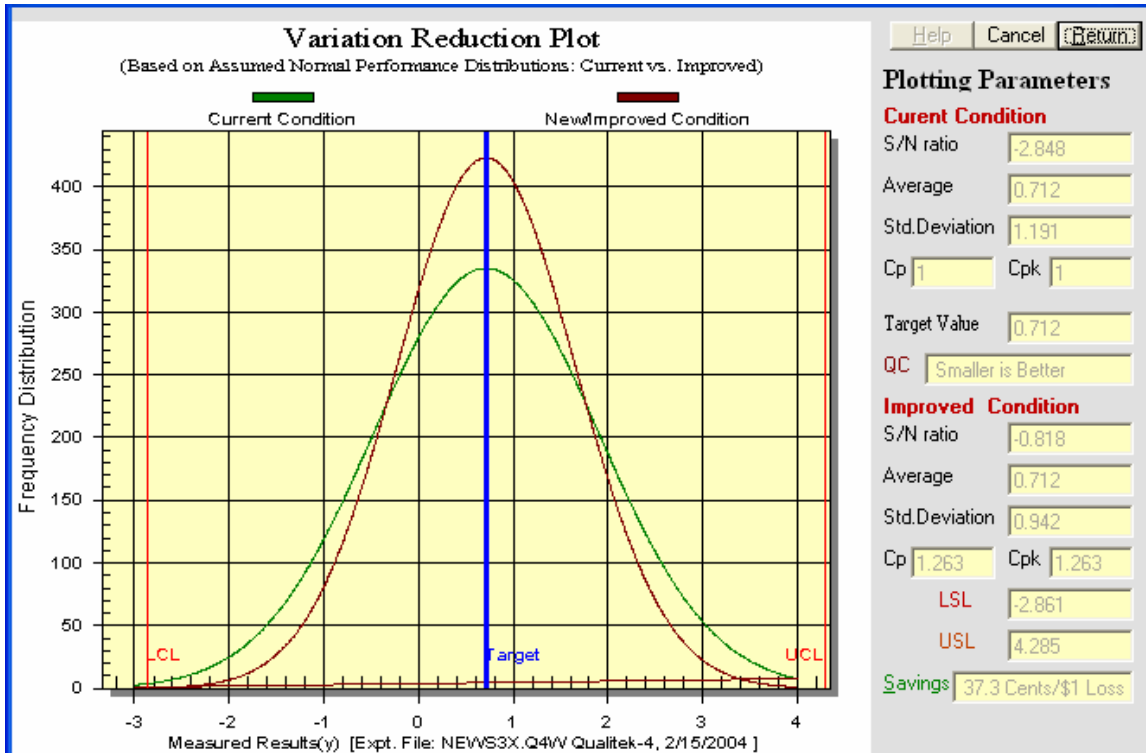
Expected performance in QC units  
 (or overall evaluation criteria) is:

$$Y_{exp} = 0.0 \text{ QC units}$$

(Based on S/N = 69.998 at optimum)

**Set 3: Expected performance & C.I. (Estimated from standard deviation analysis)**

Porosity: 0 – 0.01 (in the units of measured result) at 90% Confidence Level

**Set 3: Analysis using Std. Dev. (Result x 100)****Key Observations (Set 3):**

5. A: Number of Coats has the most influence on *Porosity*.
6. B: Slurry Temperature and C: Impregnation Pressure has least effect on *Porosity*.
7. In this set up also, *Porosity* can be eliminated by setting production parameters to the prescribed optimum condition.
8. Variability can be reduced by 26% (Std. Deviation reduced, Cpk increased)

**Comparison of Porosity Results from THREE Different Sets**

The results shown are only six among 20 (24 for set 2). The S/N in each trail was calculated based on all results. Comparison of individual trial or average S/N of all trial conditions yield some trend of performance variation from Set to set (process changes). Comparison of average S/N from all trial condition indicates that Set 2 & 3 is significantly better than Set 1A.

**Set 1A  
NPP**

	Sample# 1	Sample# 2	Sample# 3	Sample# 4	Sample# 5	Sample# 6	S/N Ratio
Trial# 1	3.653	3.021	3.909	2.834	3.625	4.325	-10.501
Trial# 2	0.866	0.596	0.782	1.094	1.566	2.237	-0.866
Trial# 3	0.001	0.106	0.003	0	0.091	0.007	26.738
Trial# 4	0.447	0.231	0.203	0.403	0.909	0.361	2.838
Trial# 5	0	0.102	0.12	0.088	0.055	0.231	14.388
Trial# 6	0.138	0.252	0.095	0.385	0.121	0.694	12.633
Trial# 7	0.111	0.082	0.075	0.034	0.089	0.022	22.447
Trial# 8	0	0	0	0.029	0	0.133	28.69
							12.046

**Set 2  
NPP-2**

	Sample# 1	Sample# 2	Sample# 3	Sample# 4	Sample# 5	Sample# 6	S/N Ratio
Trial# 1	3.108	2.099	3.466	5.397	1.834	4.402	-8.381
Trial# 2	0.525	1.247	0.606	1.609	0.385	0.537	2.82
Trial# 3	0.011	0.028	0	0.007	0	0.023	6.225
Trial# 4	0.071	0.028	0.007	0.238	0.117	0.136	14.055
Trial# 5	0.052	0.124	0.028	0.043	0.04	0.122	17.214
Trial# 6	0.213	0.068	0.035	0.161	0.074	0.067	20.26
Trial# 7	0.003	0.001	0.003	0.01	0.034	0.071	31.21
Trial# 8	0	0	0.007	0	0	0.003	54.559
							17.245

**Set 3  
NPP-3**

	Sample# 1	Sample# 2	Sample# 3	Sample# 4	Sample# 5	Sample# 6	S/N Ratio
Trial# 1	0.036	0.019	0.06	0.014	0.073	0.13	25.811
Trial# 2	0.014	0.083	0.162	0.012	0	0.053	25.122
Trial# 3	0	0	0	0	0	0	63.467
Trial# 4	0.007	0.019	0.003	0.012	0.051	0.012	21.017
Trial# 5	0	0	0.003	0	0	0	54.436
Trial# 6	0	0	0	0	0	0	70
Trial# 7	0	0	0.003	0	0	0	60.457
Trial# 8	0	0	0	0	0	0	70
							48.789

# Set 1B: Normal Production Process – Cleanliness Results

Set 1B: Cleanliness Results (20 Samples tested in each trial condition)

Trial#	Sample# 1	Sample# 2	Sample# 3	Sample# 4	Sample# 5	Sample# 6	Sample# 7	Sample# 8	Sample# 9	Sample# 10
Trial# 1	170	280	255	254	145	230	242	285	233	287
Trial# 2	330	150	160	210	230	300	165	330	315	465
Trial# 3	345	465	323	360	350	285	330	385	285	485
Trial# 4	240	263	237	238	287	292	253	271	231	227
Trial# 5	300	330	235	190	315	405	195	415	405	320
Trial# 6	245	257	191	238	231	281	230	190	200	380
Trial# 7	332	290	250	215	350	180	310	350	240	270
Trial# 8	220	385	340	525	235	293	270	202	232	347

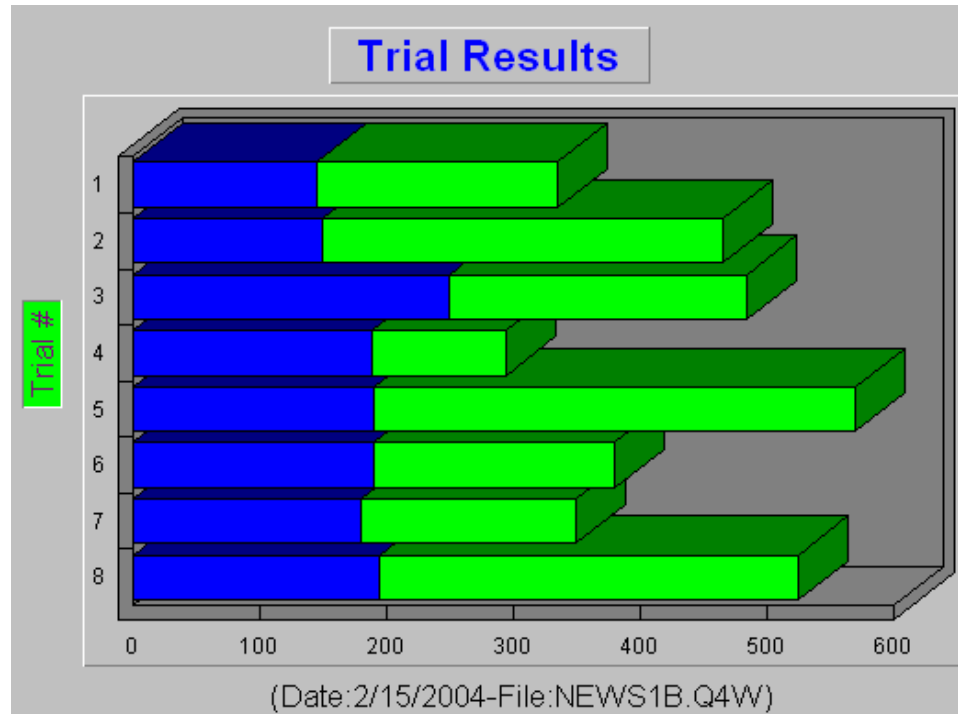
  

Sample# 11	Sample# 12	Sample# 13	Sample# 14	Sample# 15	Sample# 16	Sample# 17	Sample# 18	Sample# 19	Sample# 20	Std.Dev.
290	335	240	202	277	185	228	292	230	300	47.552
180	165	200	295	270	270	315	245	200	315	79.767
385	325	250	285	280	315	360	365	365	460	63.754
225	277	241	188	294	283	295	267	290	281	29.57
570	320	255	190	210	225	240	285	330	375	95.983
270	244	206	231	260	264	249	255	255	235	40.612
290	280	205	210	230	315	245	235	275	295	48.916
285	375	285	300	195	336	318	357	289	339	76.175
										60.291

## Averages of All Trial Results (For average performance reference, 6 of 20 results shown))

Trial#	Sample# 1	Sample# 2	Sample# 3	Sample# 4	Sample# 5	Sample# 6	Averages
Trial# 1	170	280	255	254	145	230	248
Trial# 2	330	150	160	210	230	300	255.5
Trial# 3	345	465	323	360	350	285	350.15
Trial# 4	240	263	237	238	287	292	259
Trial# 5	300	330	235	190	315	405	305.5
Trial# 6	245	257	191	238	231	281	245.6
Trial# 7	332	290	250	215	350	180	268.35
Trial# 8	220	385	340	525	235	293	306.4
							279.812
							Grand Average

**Set 1B: Variability of Results (Within and between trial conditions)**



**Set 1B: Main Effects (Analysis using Std. Dev. and S/N)**

Column # / Factors	Level 1	Level 2
1 A: Number of Coat	55.161	65.422
2 B: Slurry Tempera	65.979	54.604
3 C: Impregnation P	63.103	57.48
4 D: Roller Gap	64.052	56.531
5 E: Number of Gra	57.024	63.559
6 F: Milking	62.32	58.263
7 G: Slurry Viscosi	41.663	78.92

Column # / Factors	Level 1	Level 2
1 A: Number of Coat	-48.978	-49.173
2 B: Slurry Tempera	-48.645	-49.506
3 C: Impregnation P	-48.814	-49.337
4 D: Roller Gap	-49.465	-48.686
5 E: Number of Gra	-49.237	-48.913
6 F: Milking	-49.106	-49.045
7 G: Slurry Viscosi	-48.246	-49.904

**Set 1B: ANOVA (Analysis using Std. Dev. and S/N)**

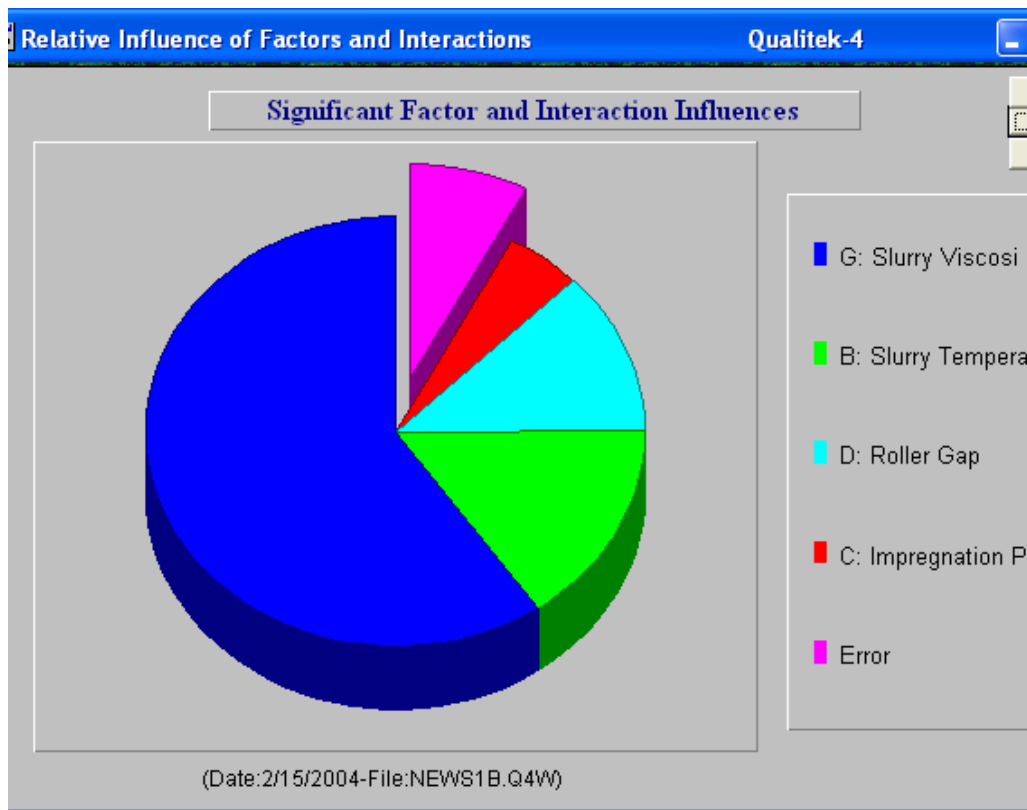
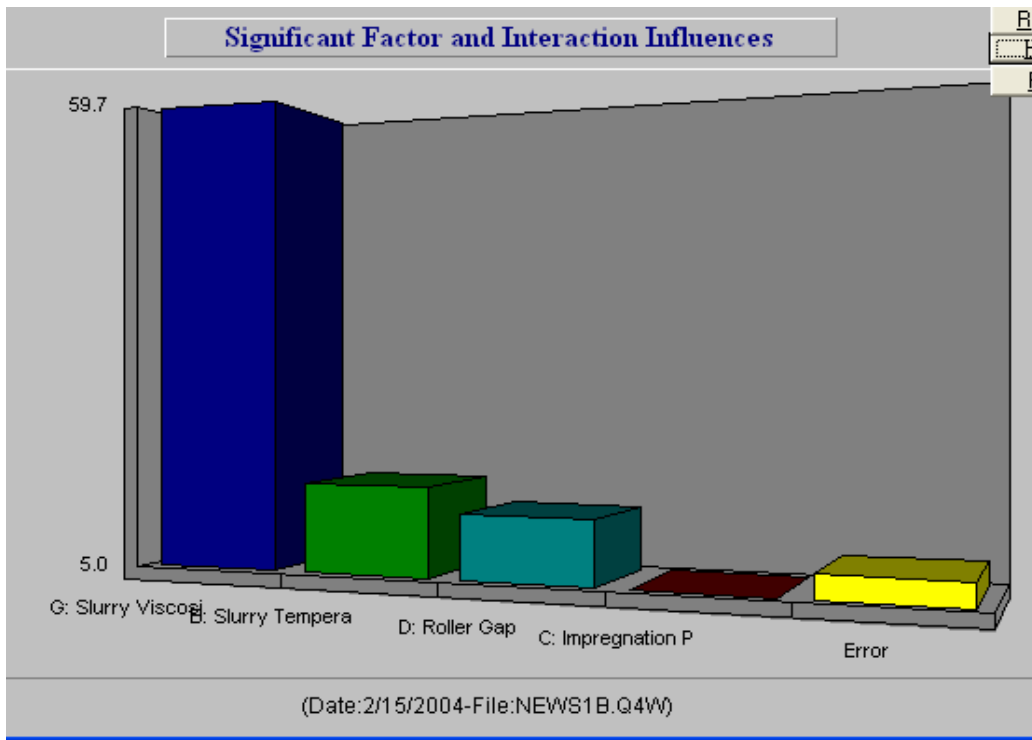
Expt. File: **NEWS1B.Q4W**      Data Type: **Average/St.Dev. Values**         
 QC Type: **Smaller is Better**     

Col # / Factor	DOF (f)	Sum of Sqrs. (S)	Variance (V)	F - Ratio (F)	Pure Sum (S')	Percent P (%)
1 A: Number of Coat	1	210.574	210.574	2.858	136.9	3.866
2 B: Slurry Tempera	1	258.769	258.769	3.512	185.095	5.228
3 C: Impregnation P	(1)	(63.232)		<b>POOLED</b>	<b>(CL=100%)</b>	
4 D: Roller Gap	(1)	(113.108)		<b>POOLED</b>	<b>(CL=77.93%)</b>	
5 E: Number of Gra	(1)	(85.43)		<b>POOLED</b>	<b>(CL=73.43%)</b>	
6 F: Milking	(1)	(32.927)		<b>POOLED</b>	<b>(CL= *NC*)</b>	
7 G: Slurry Viscosi	1	2776.204	2776.204	37.681	2702.53	76.337
<b>Other/Error</b>	<b>4</b>	<b>294.701</b>	<b>73.675</b>			<b>14.569</b>
<b>Total:</b>	<b>7</b>	<b>3540.251</b>				<b>100.00%</b>

Expt. File: **NEWS1B.Q4W**      Data Type: **S/N Ratio**         
 QC Type: **Smaller is Better**     

Col # / Factor	DOF (f)	Sum of Sqrs. (S)	Variance (V)	F - Ratio (F)	Pure Sum (S')	Percent P (%)
1 A: Number of Coat	(1)	(.076)		<b>POOLED</b>	<b>(CL=100%)</b>	
2 B: Slurry Tempera	1	1.486	1.486	15.005	1.387	15.335
3 C: Impregnation P	1	.549	.549	5.542	.449	4.973
4 D: Roller Gap	1	1.215	1.215	12.267	1.116	12.336
5 E: Number of Gra	(1)	(.212)		<b>POOLED</b>	<b>(CL=88.11%)</b>	
6 F: Milking	(1)	(.008)		<b>POOLED</b>	<b>(CL= *NC*)</b>	
7 G: Slurry Viscosi	1	5.499	5.499	55.522	5.4	59.697
<b>Other/Error</b>	<b>3</b>	<b>.296</b>	<b>.098</b>			<b>7.659</b>
<b>Total:</b>	<b>7</b>	<b>9.047</b>				<b>100.00%</b>

### Set 1B: Bar and Pie Graphs from S/N Nalysis



**Optimum Condition** (Analysis using Std. Dev. and S/N)

Based on Std. Dev analysis, variability is reduced from 60 to 18.

Expt. File: **NEWS1B.Q4W**      Data Type: **Average/St.Dev. Values**     

QC      **Smaller is Better**

Column # / Factor	Level Description	Level	Contribution
1 A: Number of Coat	4 Levels	1	-5.131
2 B: Slurry Tempera	37 Deg C	2	-5.688
7 G: Slurry Viscosi	15-20 kcp	1	-18.629
Total Contribution From All Factors...			-29.449
Current Grand Average Of Performance...			60.291
Expected Result At Optimum Condition...			30.843

Expt. File: **NEWS1B.Q4W**      Data Type: **S/N Ratio**     

QC      **Smaller is Better**

Column # / Factor	Level Description	Level	Contribution
2 B: Slurry Tempera	25 Deg C	1	.43
3 C: Impregnation P	10 psi	1	.261
4 D: Roller Gap	1.6 inch	2	.389
7 G: Slurry Viscosi	15-20 kcp	1	.829
Total Contribution From All Factors...			1.908
Current Grand Average Of Performance...			-49.075
Expected Result At Optimum Condition...			-47.166

Expected performance range is calculated from S/N prediction.

Low value: 216, High value: 240, Most likely value = 228 units. (90% C.L.)

**Transformation of C.I. in S/N - Low Value**

Expt File: **NEWS1A.Q4W**  
 Data Type: **S/N Ratio**  
 QC Type: **Smaller is Better**

Estimate of expected results from S/N ratio

$$S/N = -10 \text{ Log (MSD)} = -47.6315$$

or  $MSD = 10^{[-(S/N)/10]} = 57962.839844$   
 where  
 $MSD = [(y_1)^2 + (y_2)^2 + \dots + (y_n)^2] / n$   
 $= [ \text{Avg. } (y_i)^2 ] = Y_{exp}^2$   
 or  $Y_{exp} = \text{SQR}(MSD)$

Expected performance in QC units  
 (or overall evaluation criteria) is:  
 $Y_{exp} = 240.755$  QC units  
 (Based on S/N = -47.631 at optimum)

**Transformation of C.I. in S/N - High Value**

Expt File: **NEWS1B.Q4W**  
 Data Type: **S/N Ratio**  
 QC Type: **Smaller is Better**

Estimate of expected results from S/N ratio

$$S/N = -10 \text{ Log (MSD)} = -46.7005$$

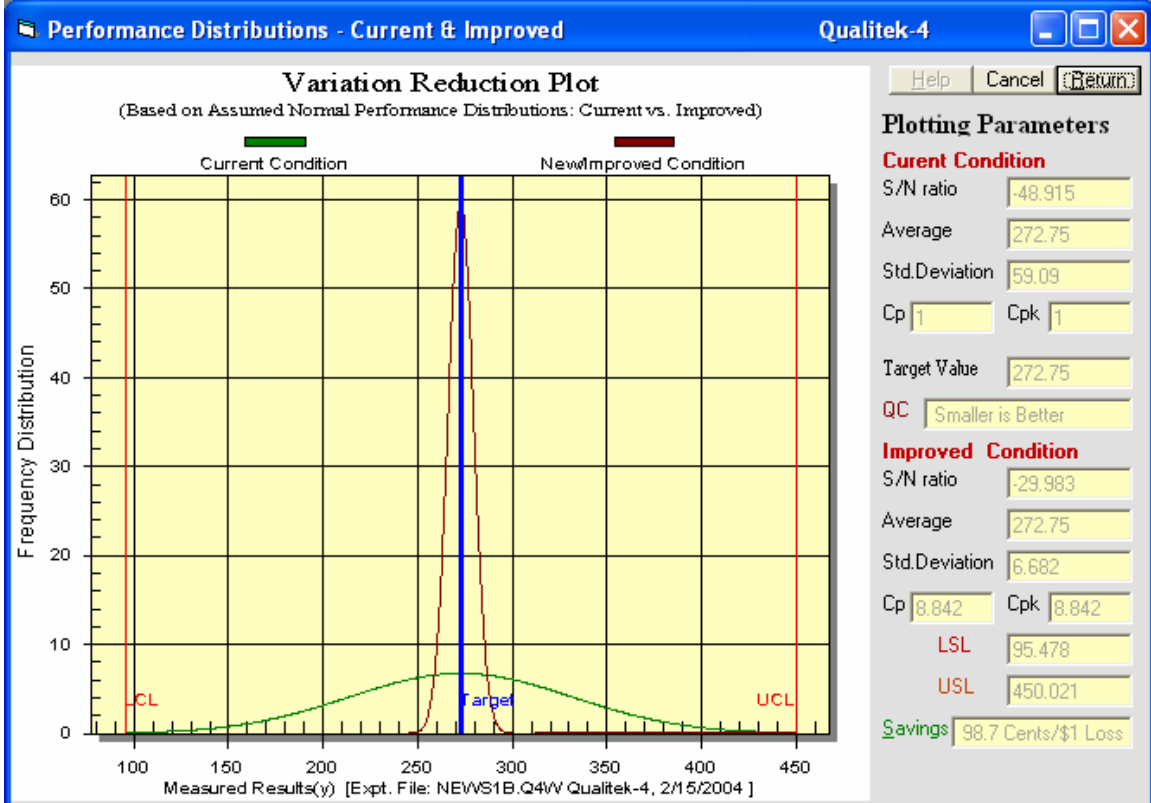
or  $MSD = 10^{[-(S/N)/10]} = 46778.90625$   
 where  
 $MSD = [(y_1)^2 + (y_2)^2 + \dots + (y_n)^2] / n$   
 $= [ \text{Avg. } (y_i)^2 ] = Y_{exp}^2$   
 or  $Y_{exp} = \text{SQR}(MSD)$

Expected performance in QC units  
 (or overall evaluation criteria) is:  
 $Y_{exp} = 216.284$  QC units  
 (Based on S/N = -46.701 at optimum)

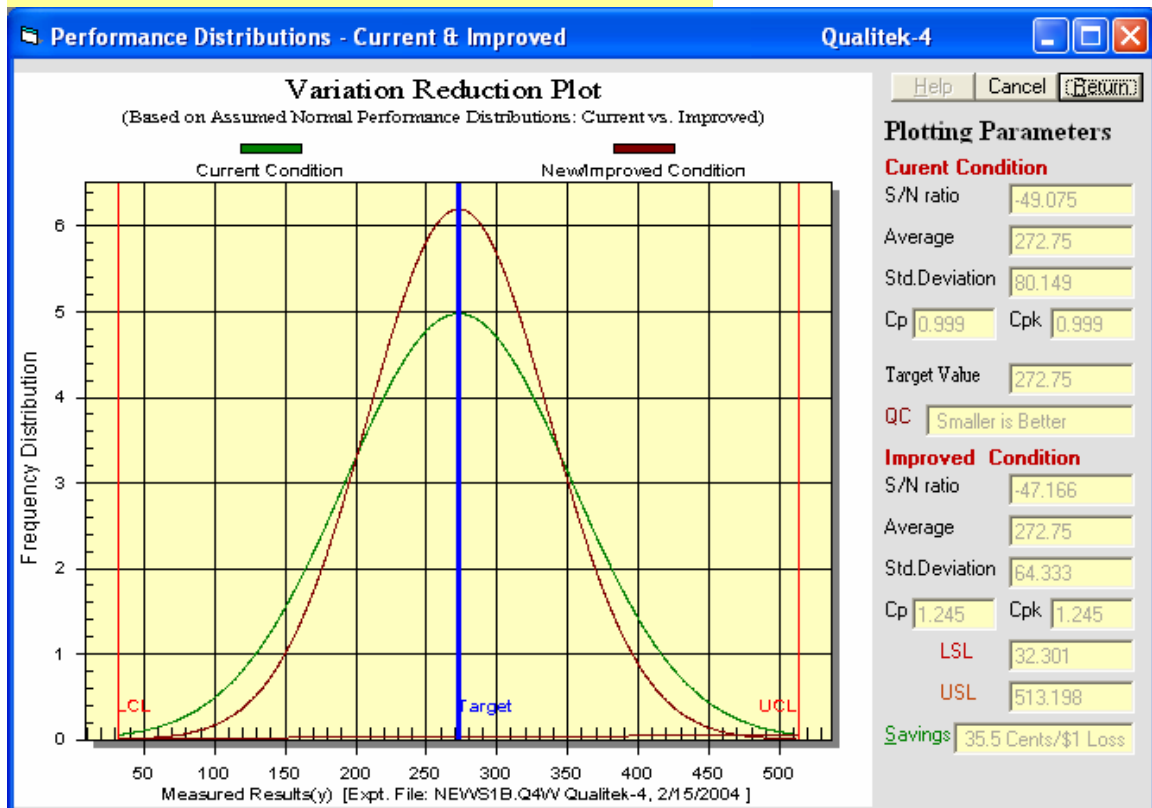
**Set 1B: Expected performance & C.I. (From S/N Analysis)**

Porosity: 213 - 243 Cleanliness (in the units of measured result) at 90% CL.

**Set 1B: Analysis using Std. Dev.**



### Set 1B: Analysis using S/N Analysis



### Key Observations (Set 1B):

5. G: Slurry Viscosity has the most effect on *Cleanliness*.
6. E: Number of Grafts and F: Milking has least influence on *Cleanliness*
7. *Cleanliness* can be significantly reduced (from 280 to 228) by setting production parameters to the prescribed optimum condition
8. Variability can be reduced by 24% (Std. Deviation reduced, Cpk increased)