Controlling Composition C-4 Processing Parameters and Physical Properties to Predict Energy Output Performance Results of M112 Demolition Charges

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Dr. Jeremy Headrick
R&D Analytical Chemist

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Briefing Outline

- Background
- Modified Energy Output Testing
  - Results
  - Process Capability
  - Analysis – Input/Output Issues
- M112 Block Variability
  - Results
  - Analysis
- Production Process Variability
  - Results
  - Analysis
- Conclusions

Background

- Composition C-4 is a white plastic-bonded explosive material that can be molded and shaped by hand
- Composition C-4 is a legacy explosive formulation with decades of use.
  - Contains: RDX, High molecular weight polyisobutylene (PIB), Dioctyladipate (DOA), Lightweight process oil (Oil)

Background

- Due to its exceptionally high brisance characteristics, (The shattering capability of a high explosive determined mainly by its detonation pressure.) Composition C-4 is mainly used for demolition purposes
  - M112 Demolition Charge
  - M183 Demolition Kit
  - MICLIC
  - M18A1 Claymore Mine

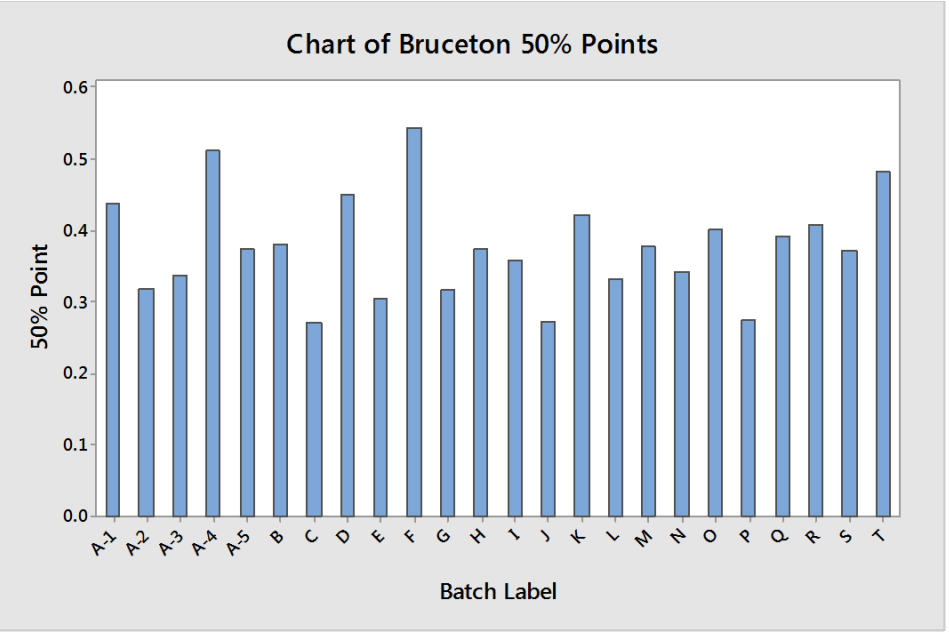
MOD EOF setup

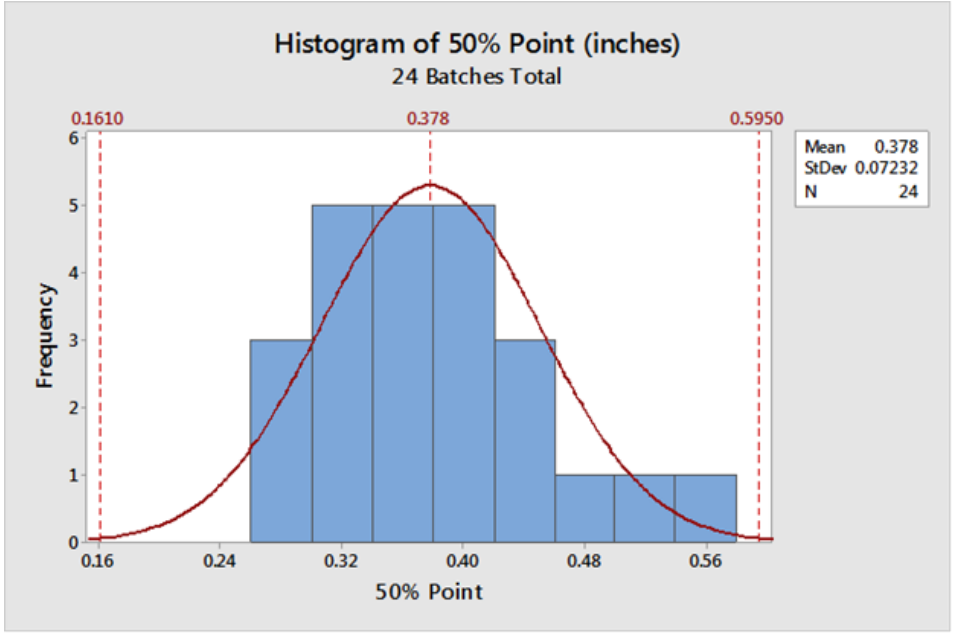
- The Energy Output Test is the standard test method to evaluate Composition C-4 in the M112 Demolition Block configuration. The test measures the effectiveness of the explosive against a steel witness plate.
- Procedure: (MIL-DTL-50523A)
  - 0.5 x 1.5 x 10.0 inch cut M112 block
  - 1.0 x 10.0 x 10.0 inch ASTM A36 steel witness plate
  - Center prime with M6 blasting cap covered with 0.5 x 1.0 x 4.0 inch tab of Composition C-4, secure with tape
  - PASS = Plate cut completely into two (2) sections
- The testing at HSAAP utilized the exact setup listed in the Procedure above with the exception of the 0.5 inch dimension of the cut M112 block. This dimension was variable in our testing and was modified up/down by a 0.03 inch spacer based on the preceding test. Testing was conducted per the Bruceton 50% analysis using an approximate 5 shot pre-test to establish the GO/NOGO threshold.

MOD EOF - PASS/FAIL Photos

MOD EOF Results

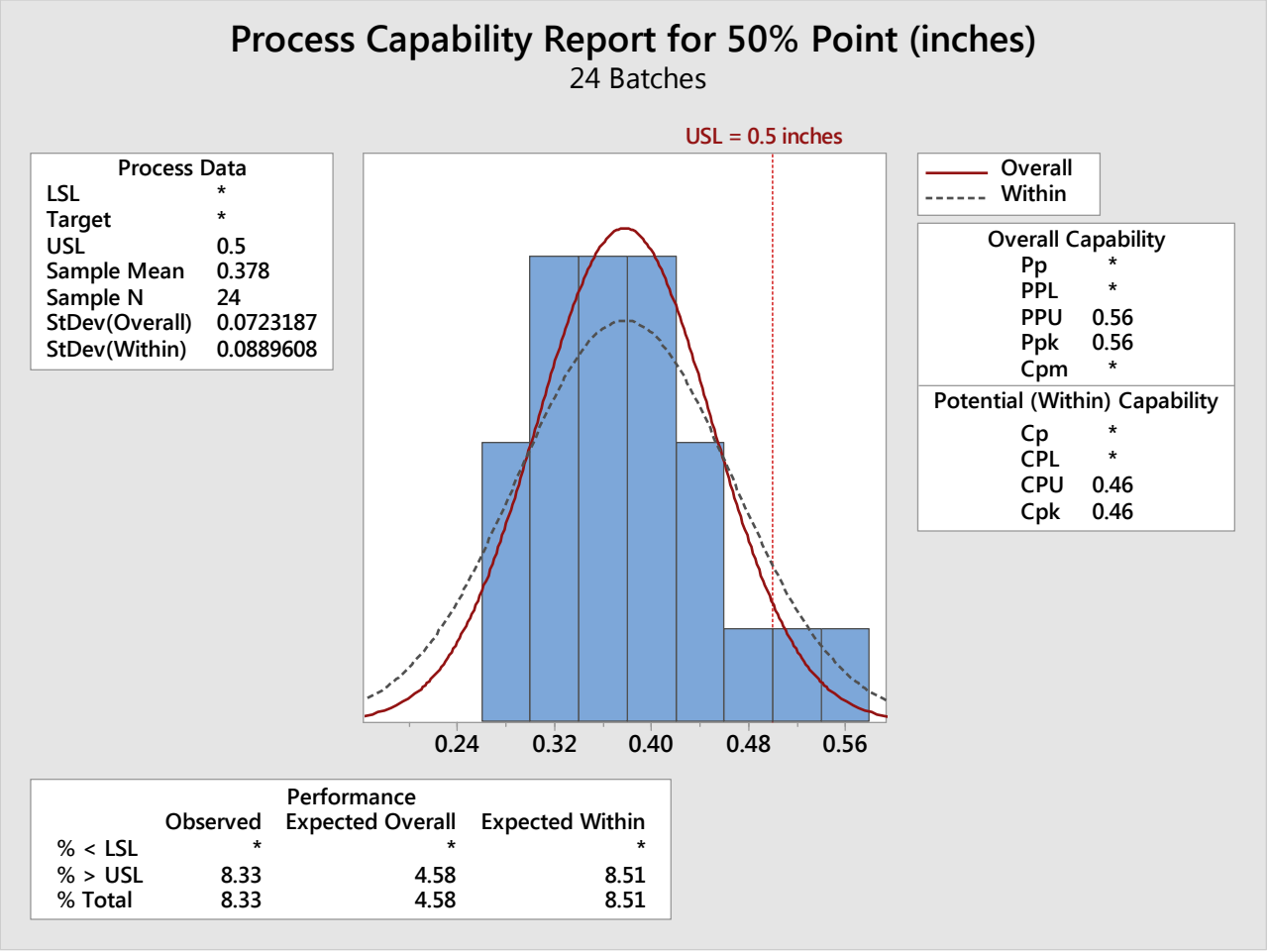
- 19 Batches tested using Modified Energy Output and calculated Bruceton 50% point
- 1 Batch replicated 5 times
- Overall mean = 0.378 inches for the 50% point of all tested batches.





MOD EOF Process Capability (Based on 50% Point)

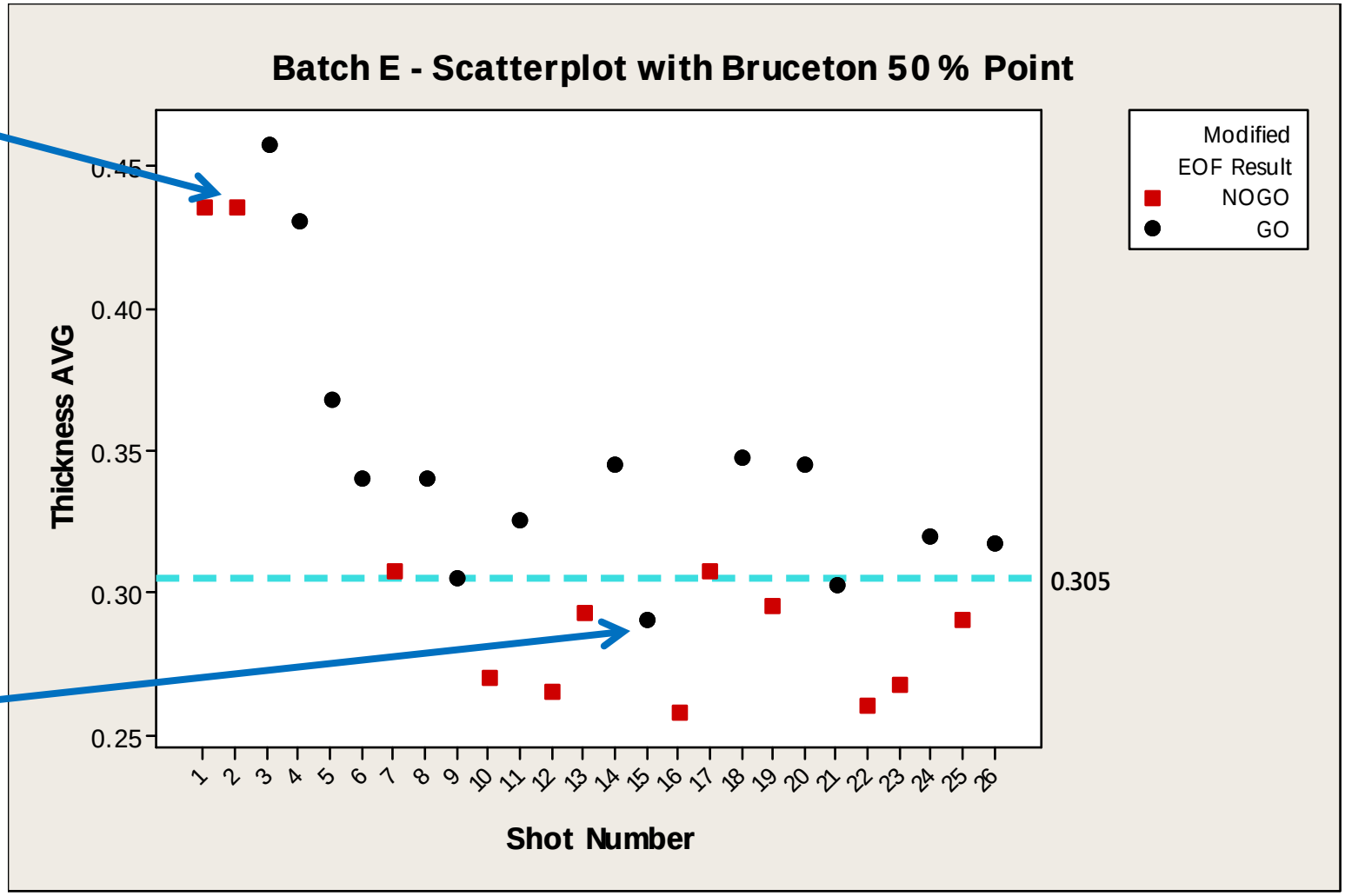
- 4.58 % of tested blocks should fail MIL-DTL-50523A. (Based on 24 batches tested and 50% point values)
- 1.0992 batches out of the 24 should fail.
- Actual results showed that two (2) batches did fail.
  - Batch F and Batch A-4 both had a calculated 50% point above 0.500 inches in height which is indicative of a probable failure.



Input Comparison– Batch E & F

Thickest NOGO

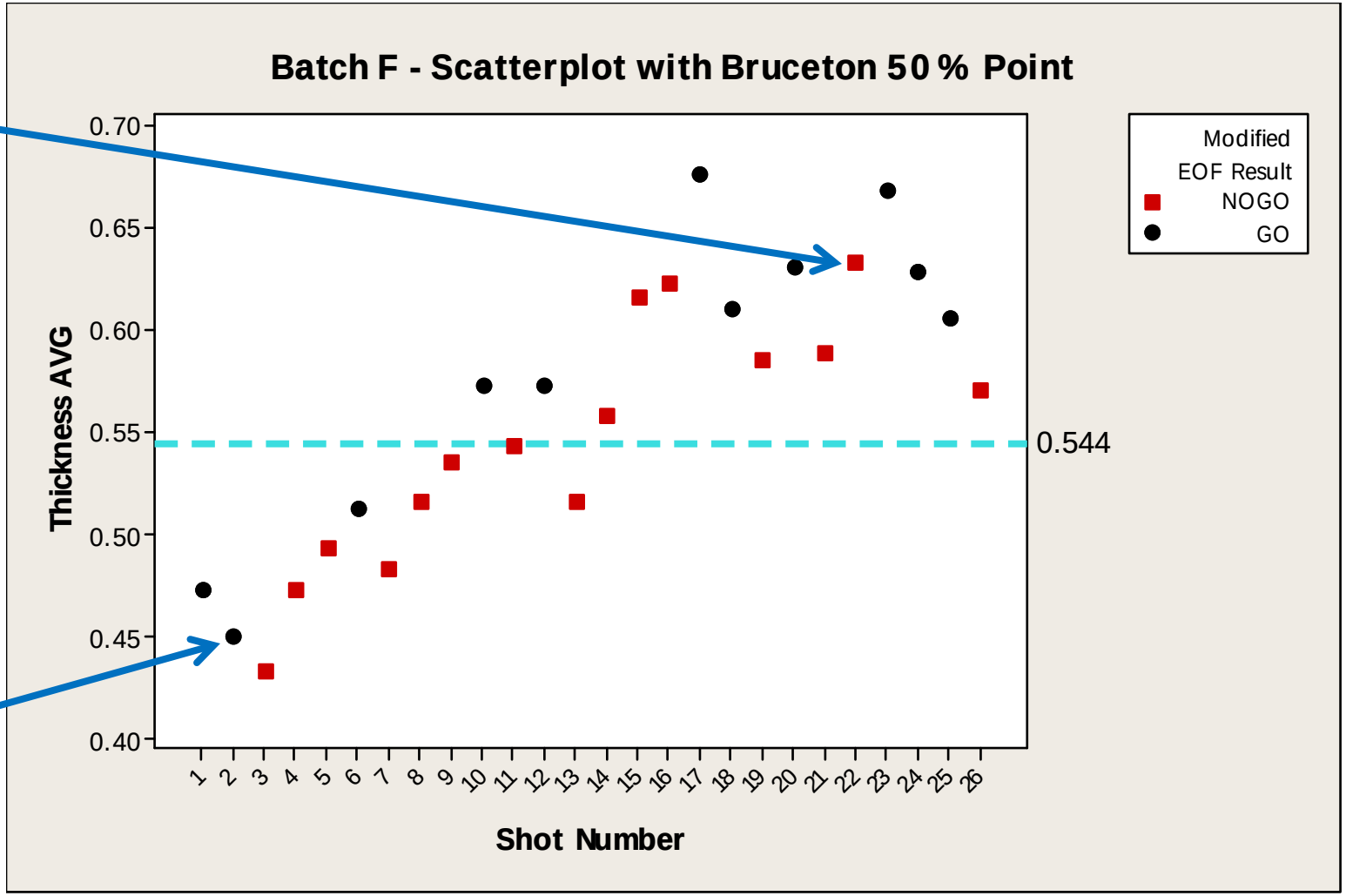
Thinnest GO



Input Comparison– Batch E & F

Thickest NOGO

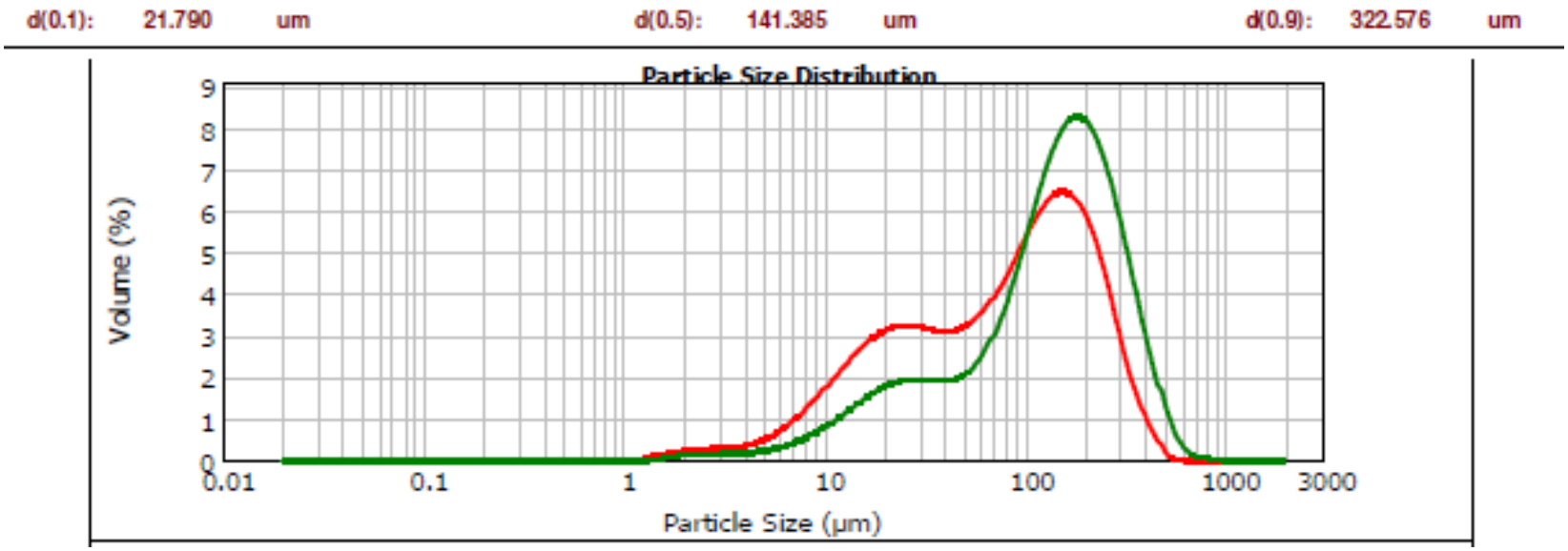
Thinnest GO



Input Comparison– Batch E & F

C-4 M112 Block Compostiton % RDX							
C-4 Batch	Block	1st Third	2nd Third	3rd Third	**AVG**	**STDDEV**	**RANGE**
E	15	89.41	88.94	89.22	**89.08**	**0.20**	**0.28**
E	2	89.45	89.60	89.4	**89.48**	**0.10**	**0.20**
F	22	89.44	89.96	89.75	**89.72**	**0.26**	**0.52**
F	2	89.24	89.27	89.19	**89.23**	**0.04**	**0.08**

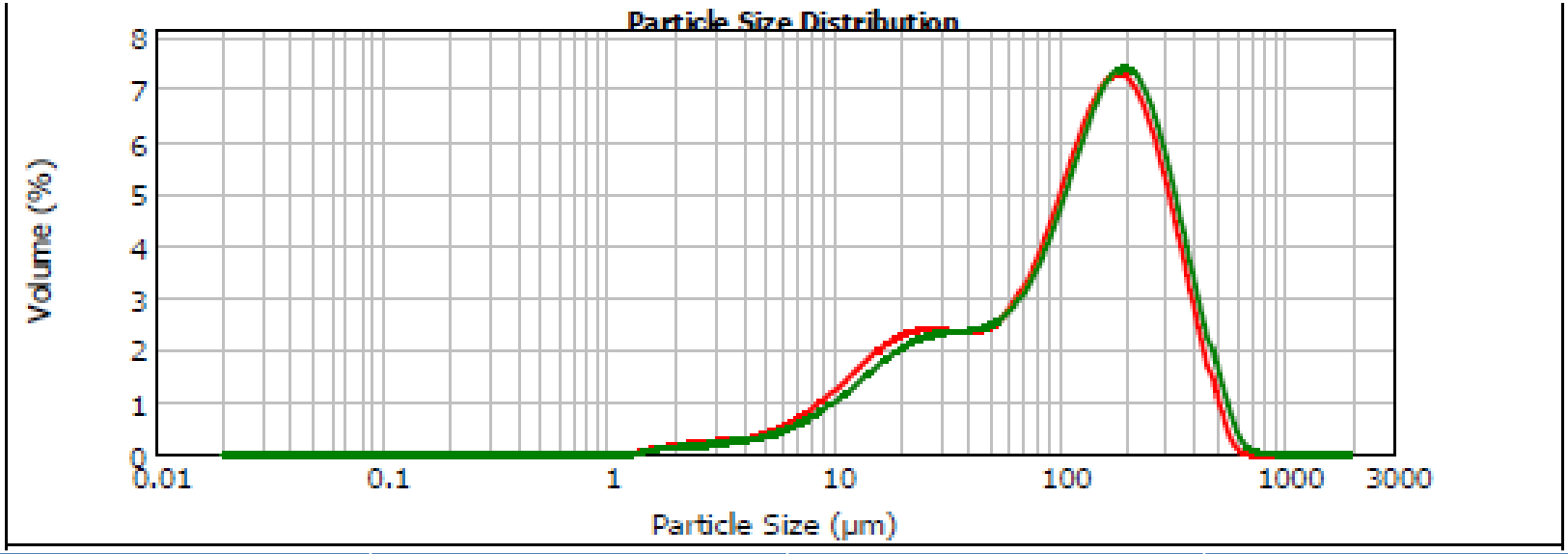
Batch F Overlay



Block 2 (0.45 in)	D(0.1)	D(0.5)	D(0.9)
1st Third	12.811	85.272	226.807
2nd Third	12.549	87.585	236.891
3rd Third	12.865	79.517	263.230
Block 22 (0.63 in)	**D(0.1)**	**D(0.5)**	**D(0.9)**
1st Third	19.371	132.833	304.517
2nd Third	22.801	148.126	329.931
3rd Third	24.130	142.962	334.944

Batch E Overlay

d(0.1): 18.514 um d(0.5): 134.782 um d(0.9): 334.893 um



Block 15 (0.30 in)	D(0.1)	D(0.5)	D(0.9)
1st Third	16.369	117.486	296.263
2nd Third	16.746	131.153	325.246
3rd Third	15.380	122.801	310.173
Block 2 (0.43 in)	**D(0.1)**	**D(0.5)**	**D(0.9)**
1st Third	24.448	143.910	340.795
2nd Third	17.297	131.193	337.362
3rd Third	12.261	127.317	326.390

PSD comparison

F Block 2 (0.45 in)	D(0.1)	D(0.5)	D(0.9)
1st Third	12.811	85.272	226.807
2nd Third	12.549	87.585	236.891
3rd Third	12.865	79.517	263.230
F Block 22 (0.63 in)	**D(0.1)**	**D(0.5)**	**D(0.9)**
1st Third	19.371	132.833	304.517
2nd Third	22.801	148.126	329.931
3rd Third	24.130	142.962	334.944
E Block 15 (0.30 in)	**D(0.1)**	**D(0.5)**	**D(0.9)**
1st Third	16.369	117.486	296.263
2nd Third	16.746	131.153	325.246
3rd Third	15.380	122.801	310.173
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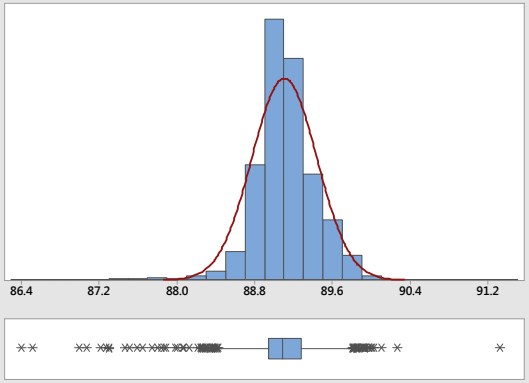
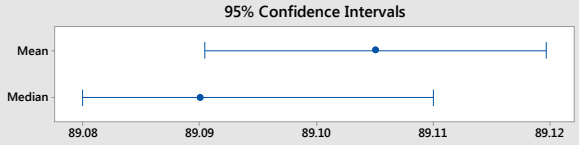
1st Third	24.448	143.910	340.795
2nd Third	17.297	131.193	337.362
3rd Third	12.261	127.317	326.390

M112 Variability – All Means (RDX,% & 10th Percentile)

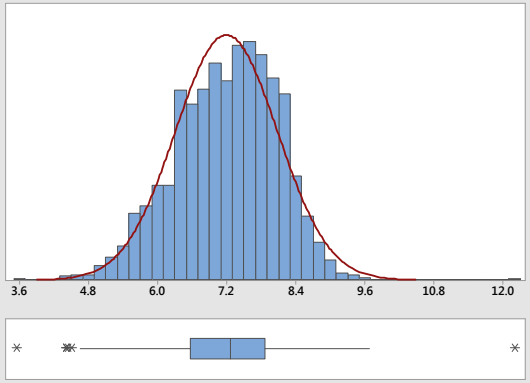
Summary Report for RDX



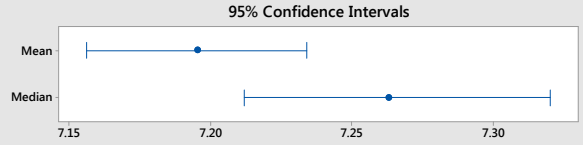
Anderson-Darling Normality Test	
A-Squared	25.53
P-Value	<0.005
Mean	89.105
StDev	0.334
Variance	0.111
Skewness	-1.08148
Kurtosis	8.92675
N	2006
Minimum	86.400
1st Quartile	88.940
Median	89.090
3rd Quartile	89.280
Maximum	91.320
95% Confidence Interval for Mean	
89.090	89.120
95% Confidence Interval for Median	
89.080	89.110
95% Confidence Interval for StDev	
0.324	0.345



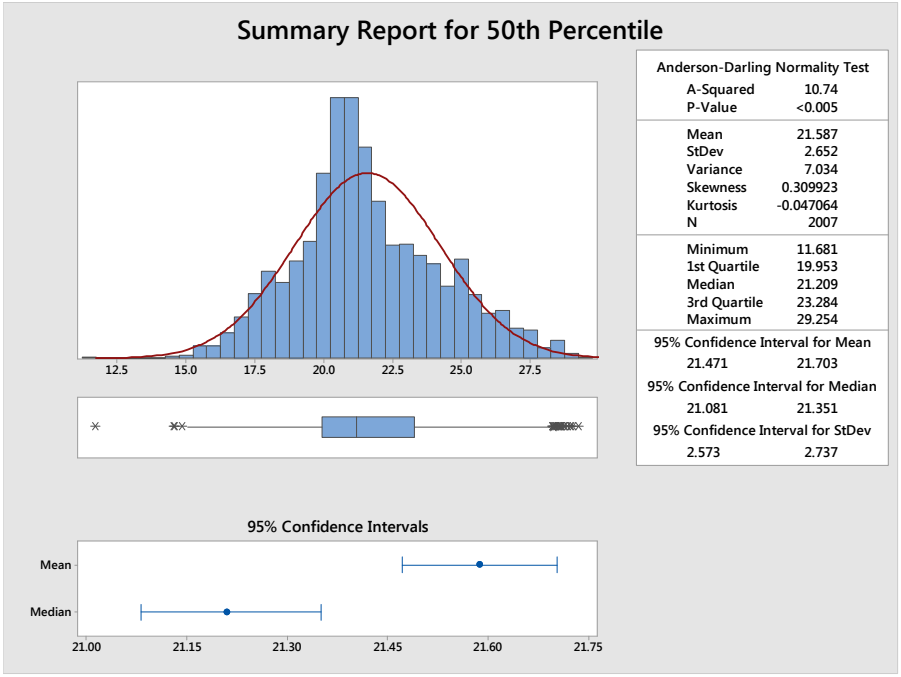
Summary Report for 10th Percentile

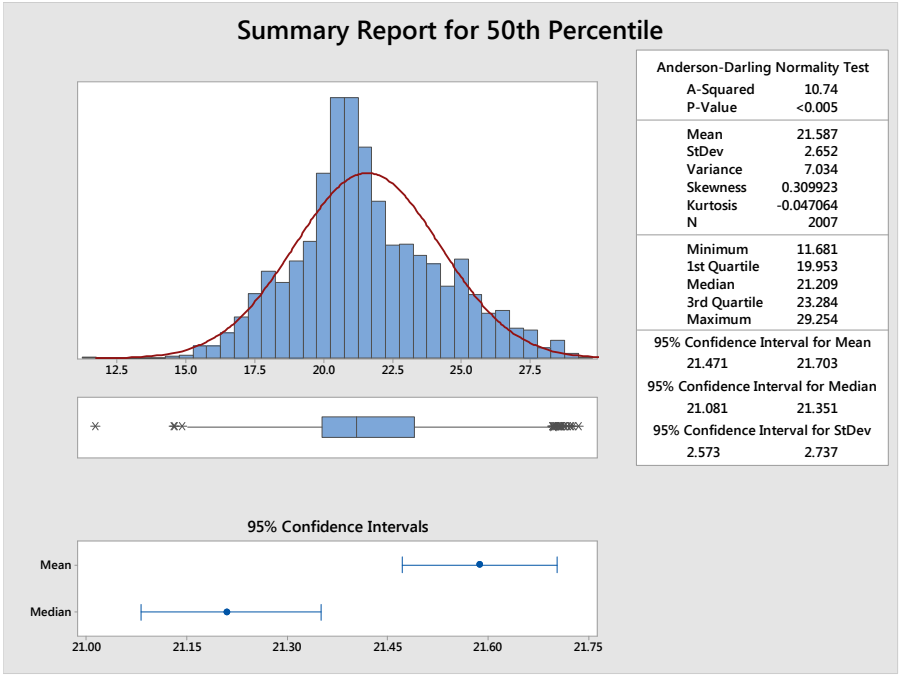


Anderson-Darling Normality Test	
A-Squared	4.85
P-Value	<0.005
Mean	7.1952
StDev	0.8868
Variance	0.7864
Skewness	-0.226682
Kurtosis	0.243980
N	2007
Minimum	3.5430
1st Quartile	6.5720
Median	7.2630
3rd Quartile	7.8620
Maximum	12.2030
95% Confidence Interval for Mean	
7.1564	7.2340
95% Confidence Interval for Median	
7.2120	7.3200
95% Confidence Interval for StDev	
0.8602	0.9151

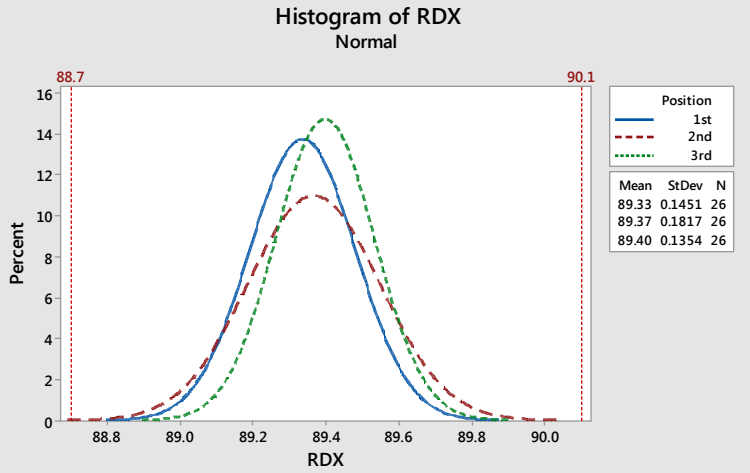


M112 Variability – All Means (50th & 90th Percentile)



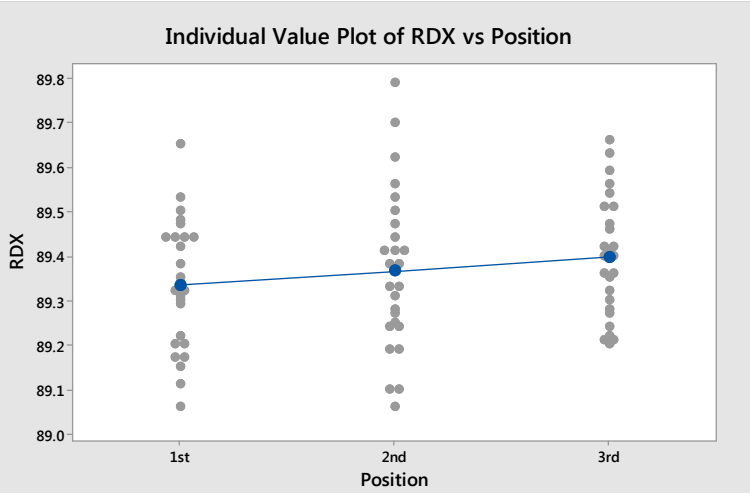


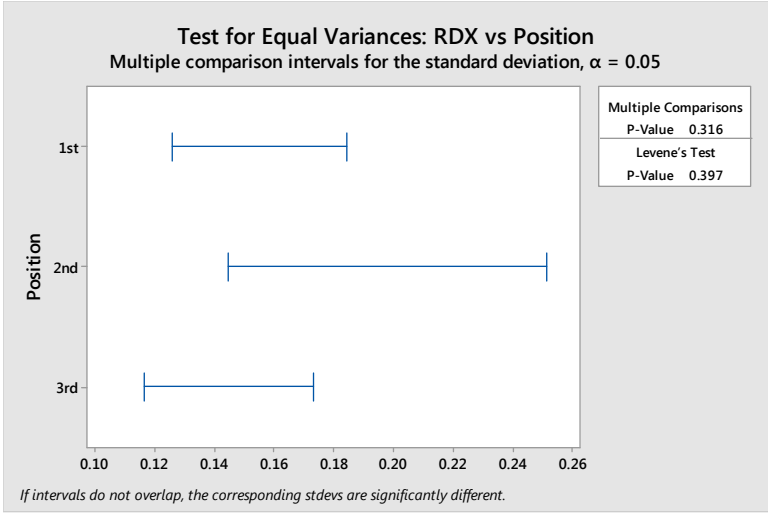
M112 Block Variability (Within Block)



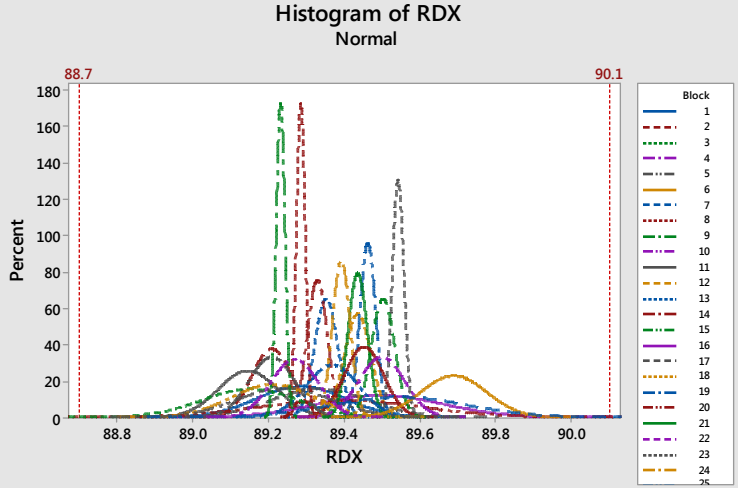
Batches A-1 thru T Within Block

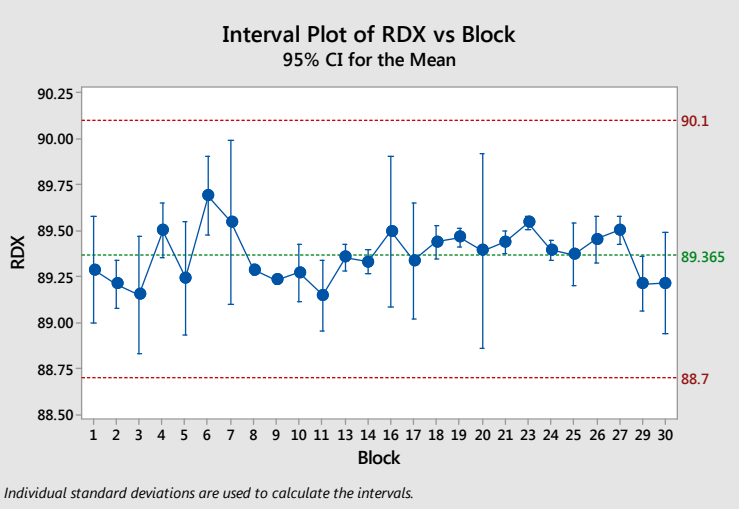
	MAX StDev
RDX, %	0.563
10th	1.405 μ
50th	3.157 μ
90th	18.240 μ





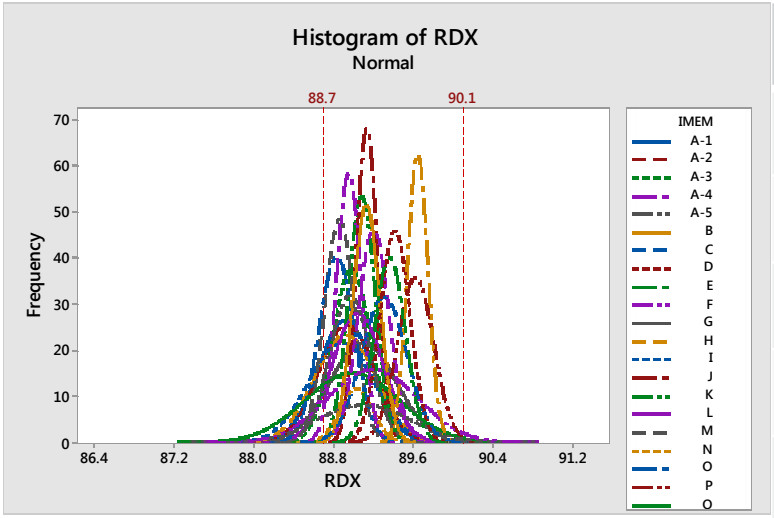
M112 Block Variability (Between Block)



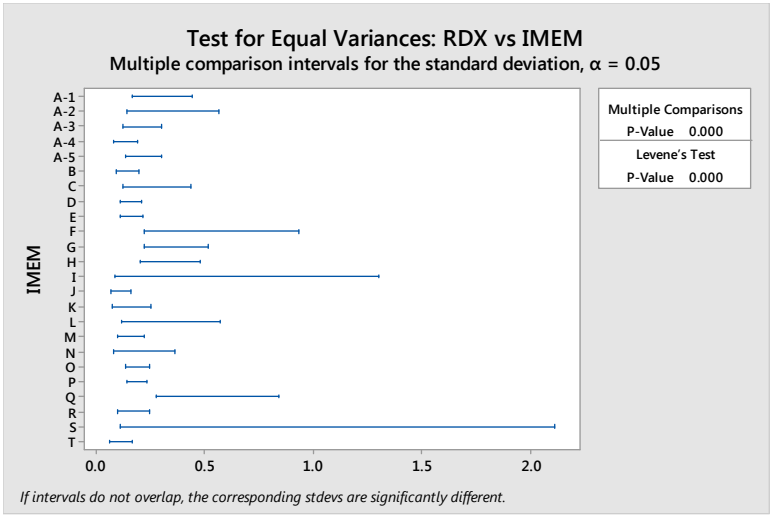


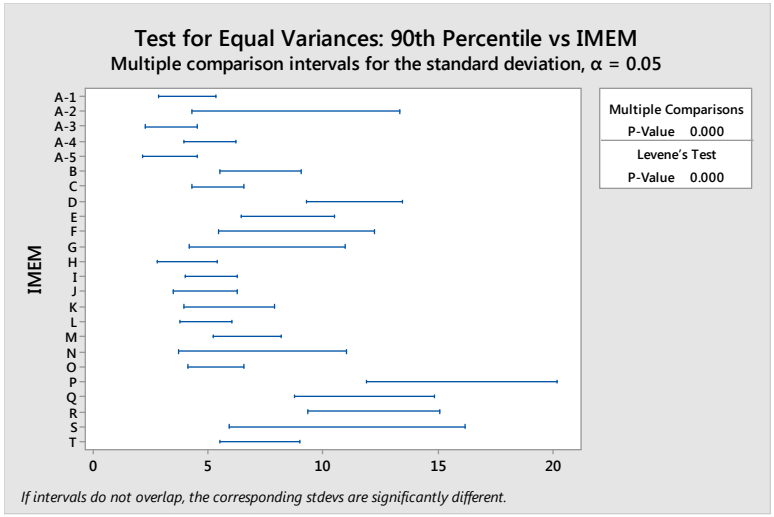
Blocks 1 thru 30 Between Block	
	MAX StDev
RDX, %	0.529
10th	1.122 μ
50th	3.086 μ
90th	11.420 μ

M112 Block Variability (Between Batches)



Batches A-1 thru T	
	MAX StDev
RDX, %	0.473
10th	0.9228 μ
50th	2.213 μ
90th	15.160 μ



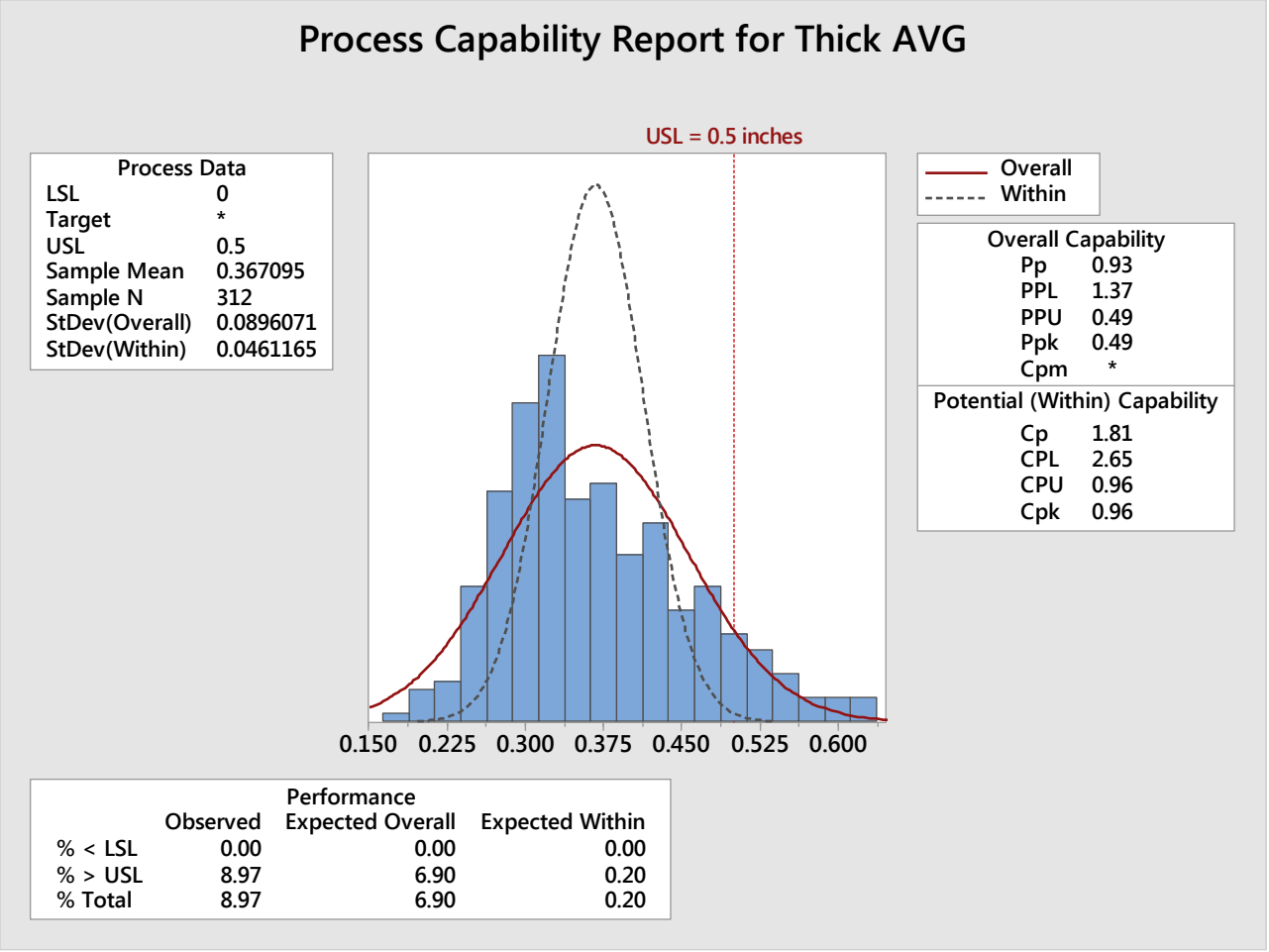


M112 Block Variability (Within & Between Summary)

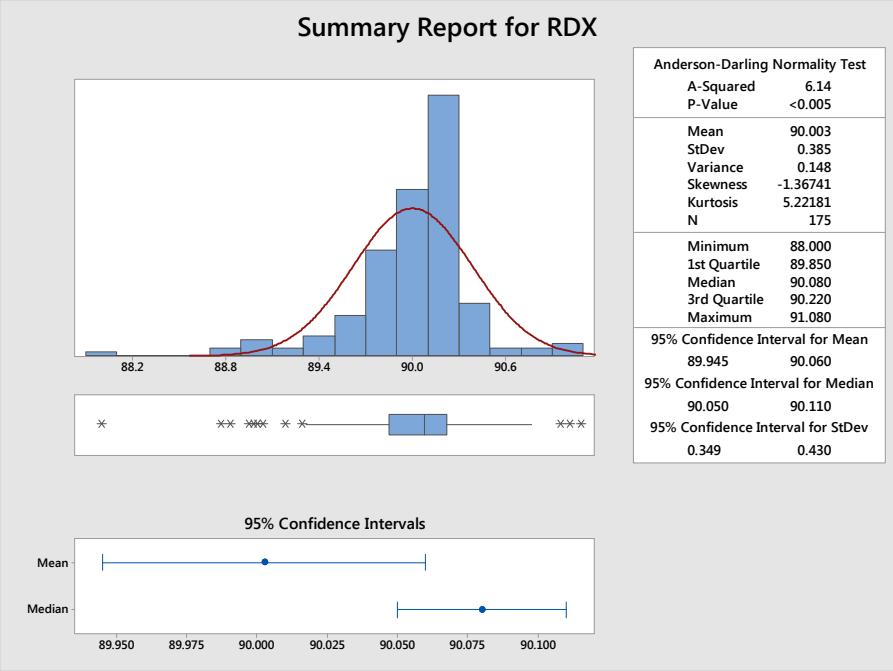
All Batches			
	Within Block	**Between Block**	**Between Batch**
	MAX StDev	**MAX StDev**	**MAX StDev**
RDX, %	0.563	0.529	0.473
10th	1.405 μ	1.122 μ	0.9228 μ
50th	3.157 μ	3.086 μ	2.213 μ
90th	18.240 μ	11.420 μ	15.160 μ

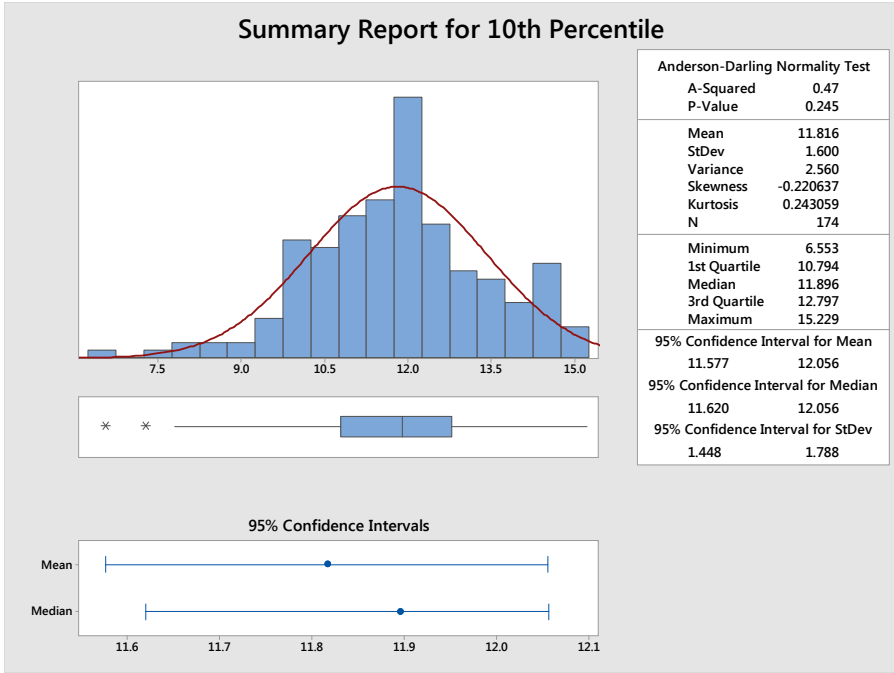
M112 Modified EOF – Process Capability

- 6.90 % of tested blocks should fail MIL-DTL-50523A. (Based on 720 blocks tested)
- 1.656 batches out of the 24 should fail.
- Actual results showed that two (2) batches did fail.
  - Batch F and Batch A-4 both had a calculated 50% point above 0.500 inches in height which is indicative of a probable failure.

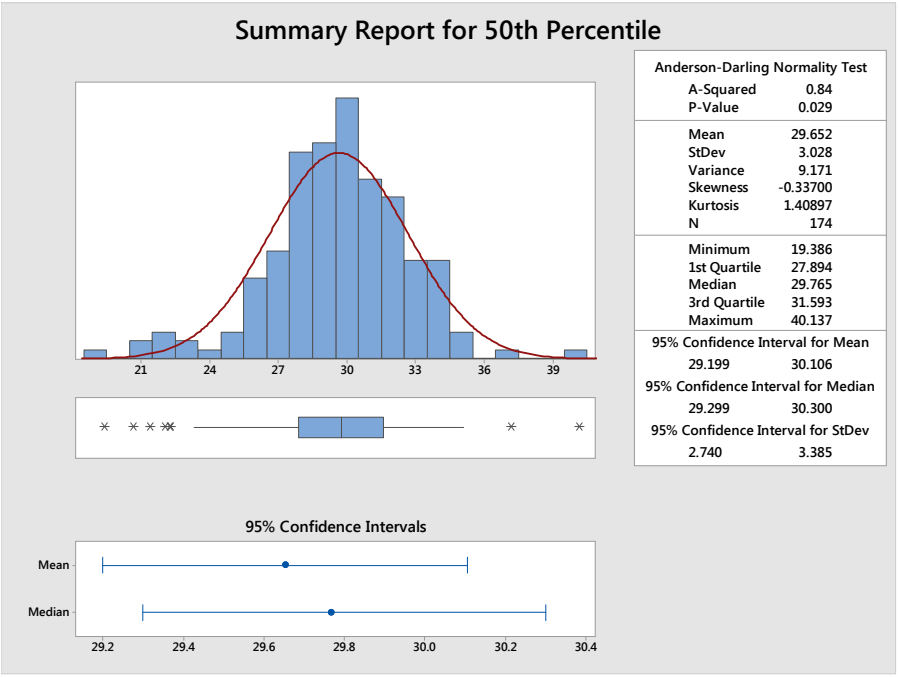


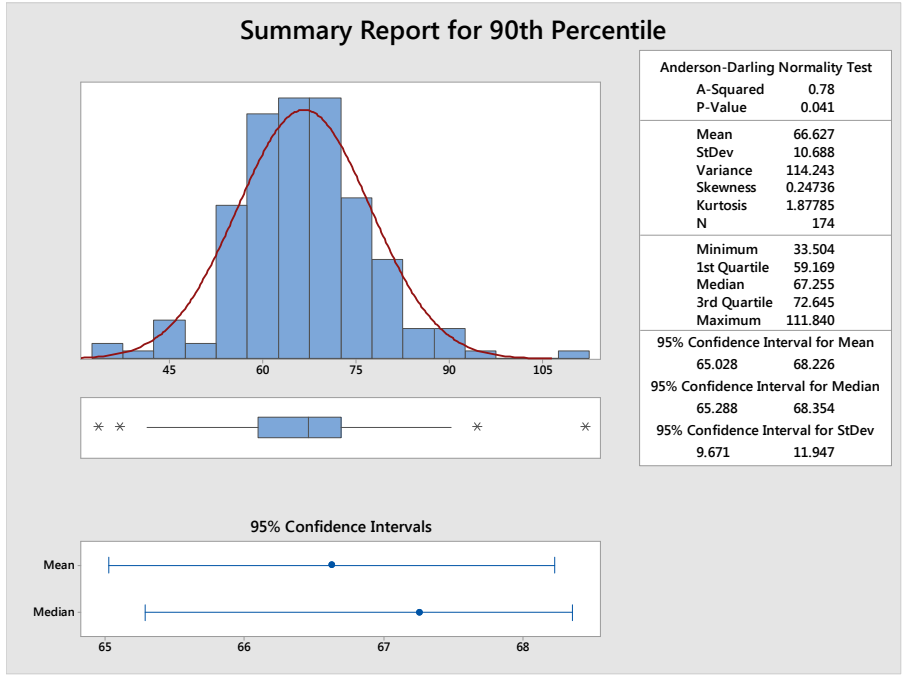
Production Variability – All Means (RDX,% & 10th Percentile)



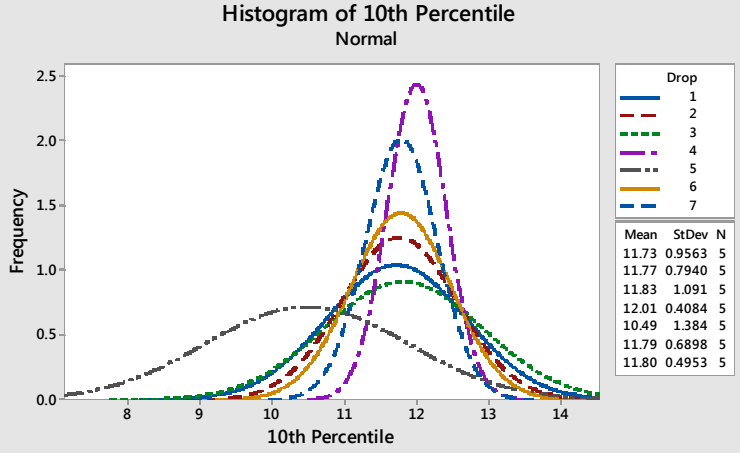


Production Variability – All Means (50th & 90th Percentile)



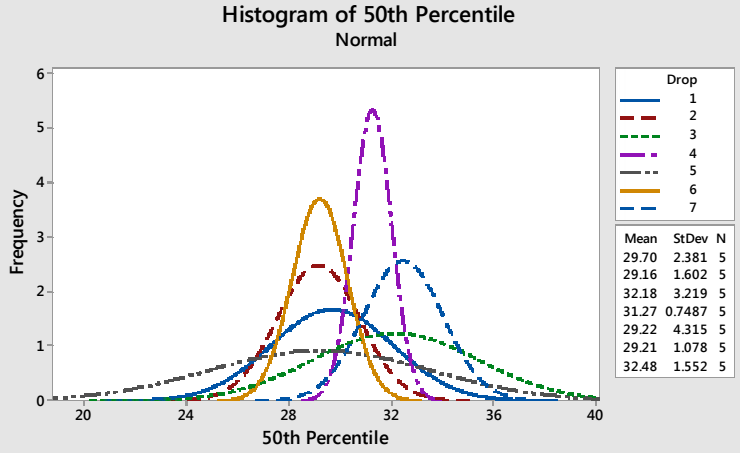


Production Variability (Within Nutsches)

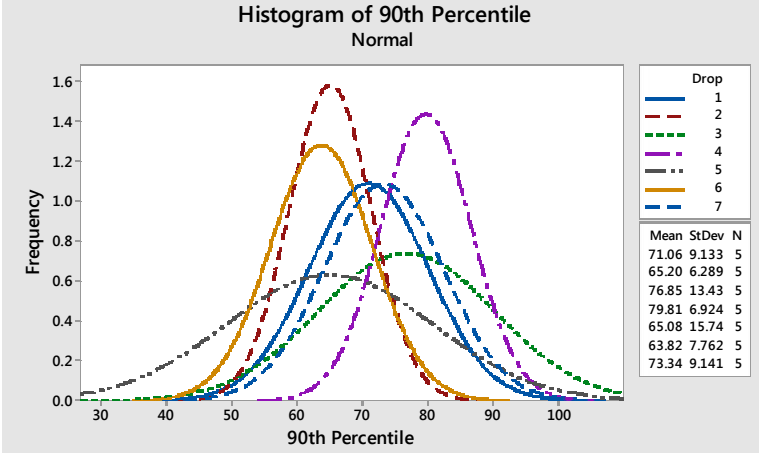


Results include rows where IMEM = 1.

Batch 1	
	MAX StDev
RDX, %	0.5268 g
10th	1.384 µ
50th	4.315 µ
90th	15.74 µ

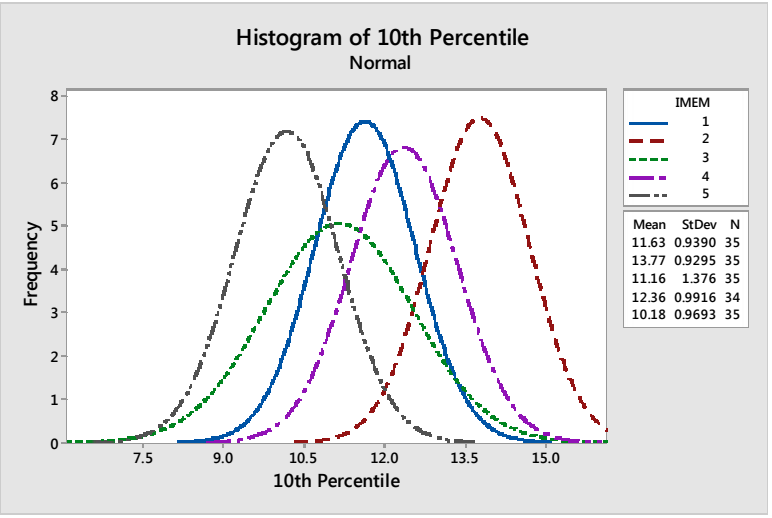


Results include rows where IMEM = 1.

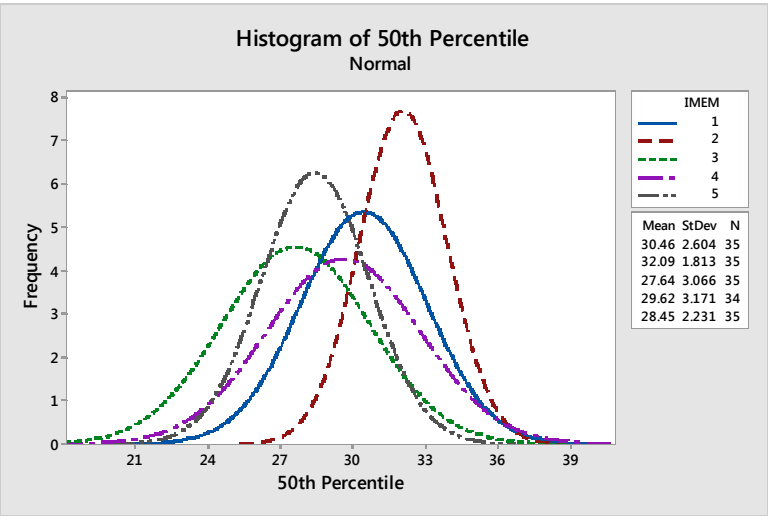


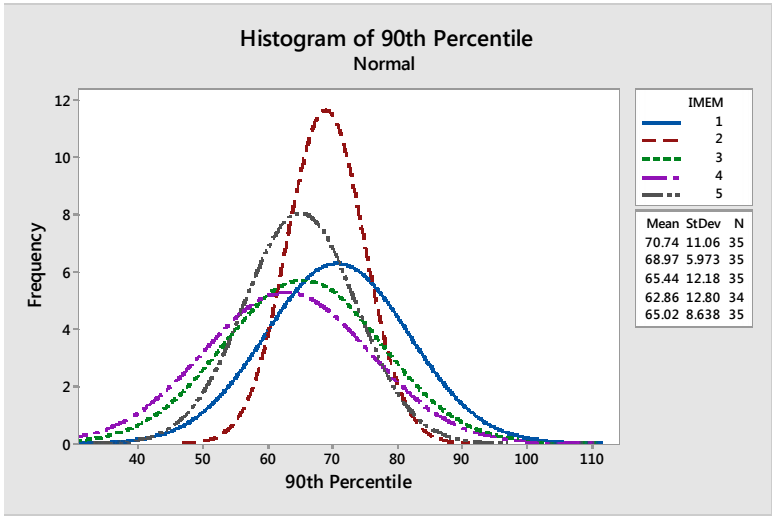
Results include rows where IMEM = 1.

Production Variability (Within Batch or Between Nutsches)

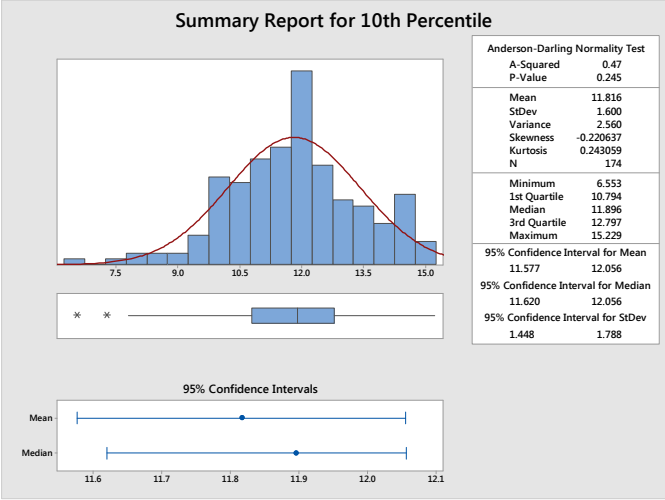


Batch 1	
	MAX StDev
RDX, %	0.4980 g
10th	1.376 μ
50th	3.171 μ
90th	12.800 μ

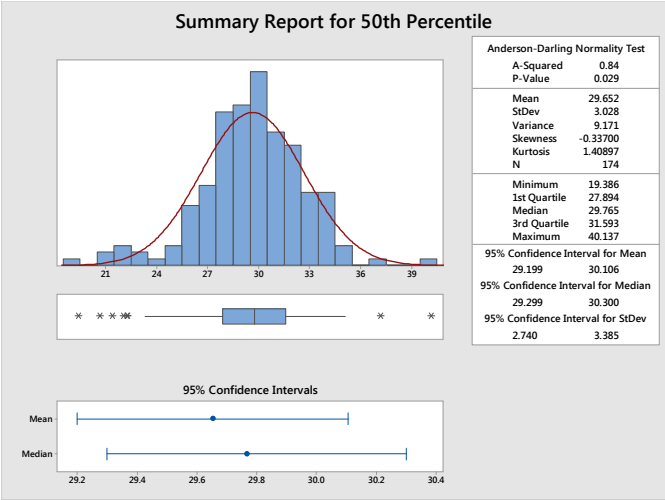


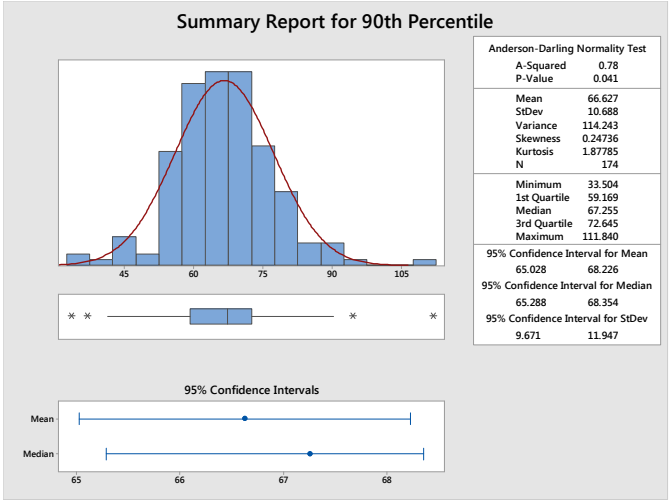


Production Variability (Between Batches)



All Batches (Between)	
	MAX StDev
RDX, %	0.3550 g
10th	1.600 μ
50th	3.028 μ
90th	10.688 μ





Process Variability (Within & Between Summary)

All Batches			
	Within Nutsche	**Between Nutsche**	**Between Batch**
	MAX StDev	**MAX StDev**	**MAX StDev**
RDX, %	0.5268 g	0.4980 g	0.3550 g
10^{th}	2.041 μ	1.376 μ	1.600 μ
50^{th}	4.853 μ	3.171 μ	3.028 μ
90^{th}	19.650 μ	12.800 μ	10.688 μ

Variability Comparison (Within & Between Summary)

	Within Nutsche	Within Block		Between Nutsche	Between Block		Between Batch	Between Batch	
	MAX StDev	**MAX StDev**	**Absolute Diff.**	**MAX StDev**	**MAX StDev**	**Absolute Diff.**	**MAX StDev**	**MAX StDev**	**Absolute Diff.**
RDX, %	0.5268 g	0.5630 g	0.0362 g	0.4980 g	0.5290 g	0.0310 g	0.3550 g	0.4730 g	0.118 g
10^{th}	2.041 µ	1.405 µ	0.636 µ	1.376 µ	1.122 µ	0.254 µ	1.600 µ	0.9228 µ	0.6772 µ
50^{th}	4.853 µ	3.157 µ	1.696 µ	3.171 µ	3.086 µ	0.085 µ	3.028 µ	2.213 µ	0.815 µ
90^{th}	19.650 µ	18.240 µ	1.410 µ	12.800 µ	11.420 µ	1.380 µ	10.688 µ	15.160 µ	4.472 µ

Conclusion / Recommendations / Summary

- Within Nutsche and Block variability is negligible
- Between Nutsche and Block variability is negligible
- Between Batch variability is where the majority of the error is coming from
- Modified EOF test should have been conducted on a 100% pass/fail test instead of Bruceton 50% point (Better matching the Energy Output Test in the specification)
- Better control of input materials will improve consistency of the Composition C-4, within and between batches

Acknowledgements

Dr. Tess Kirchner
Mr. Matt Hathaway
Mr. Chris Long
Mr. Gary Sizemore
Mrs. Sara Lowry
Mrs. Kelly Smith
Mr. Brian Alexander
Mr. Todd Dye
Mr. Tracy Kelly