

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

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Non-Export Control Information – Releasable to Foreign Persons
(Export Reference)

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)



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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



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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

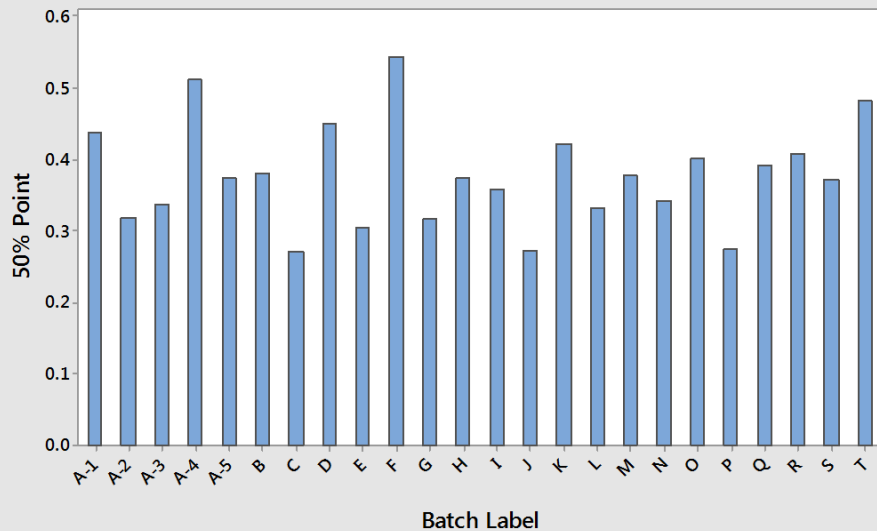


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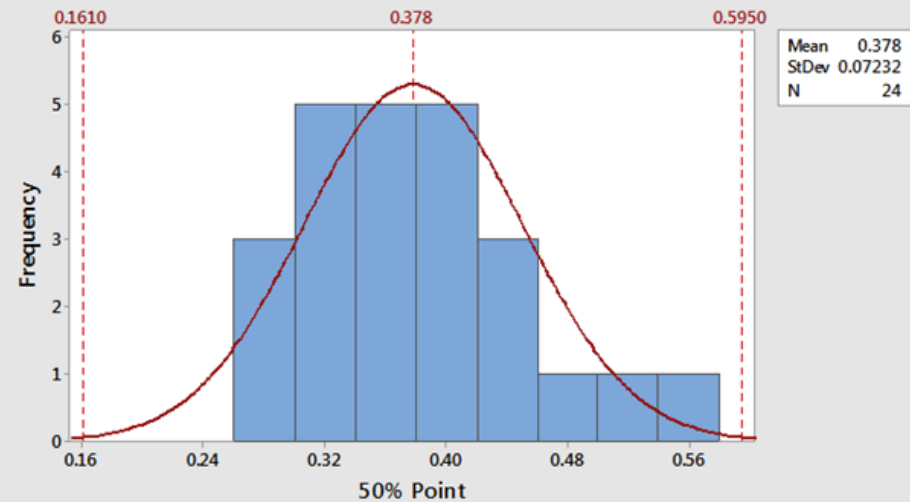
MOD EOF Results

- 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.

Chart of Bruceton 50% Points



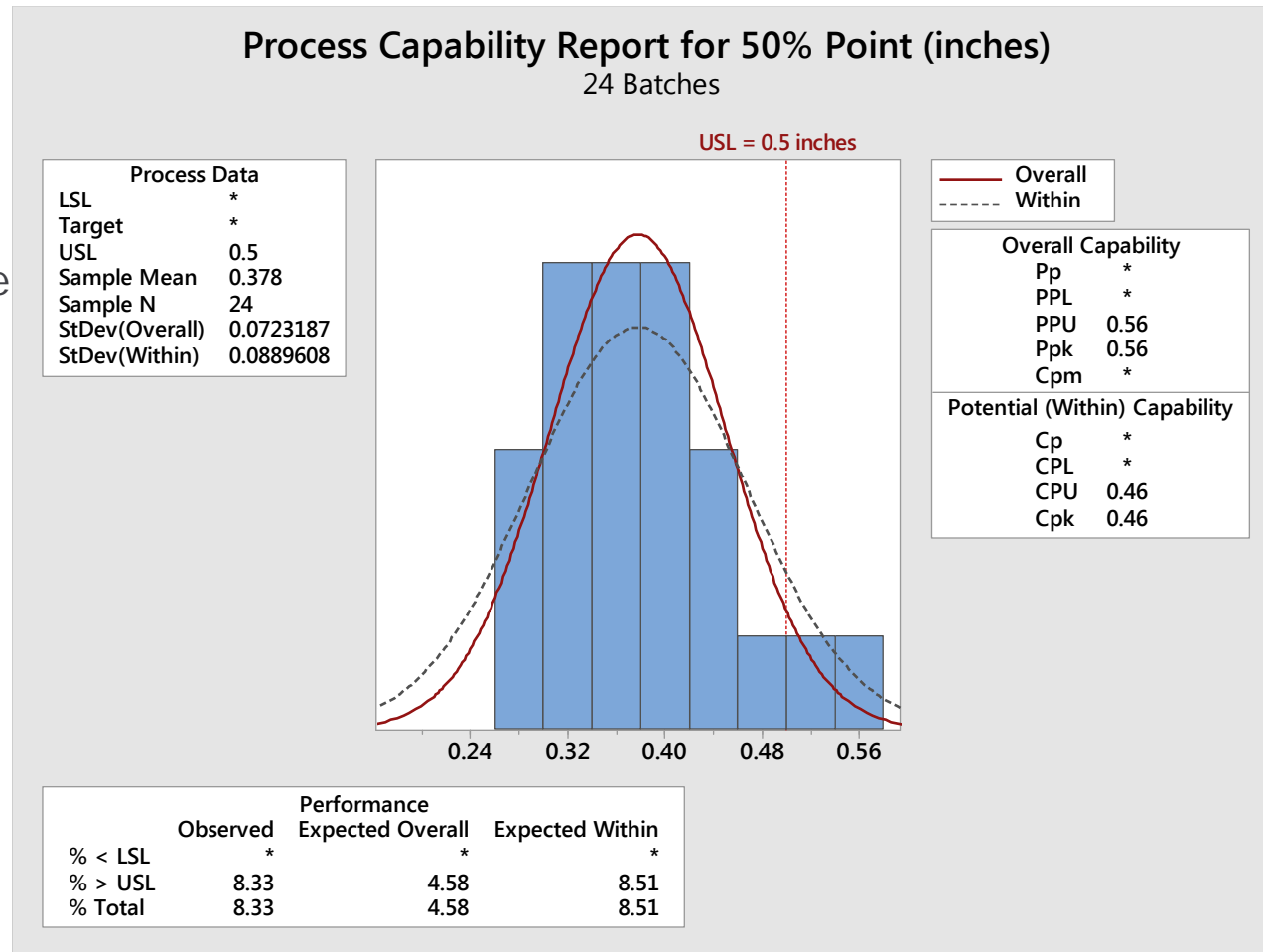
Histogram of 50% Point (inches)
24 Batches Total



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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.

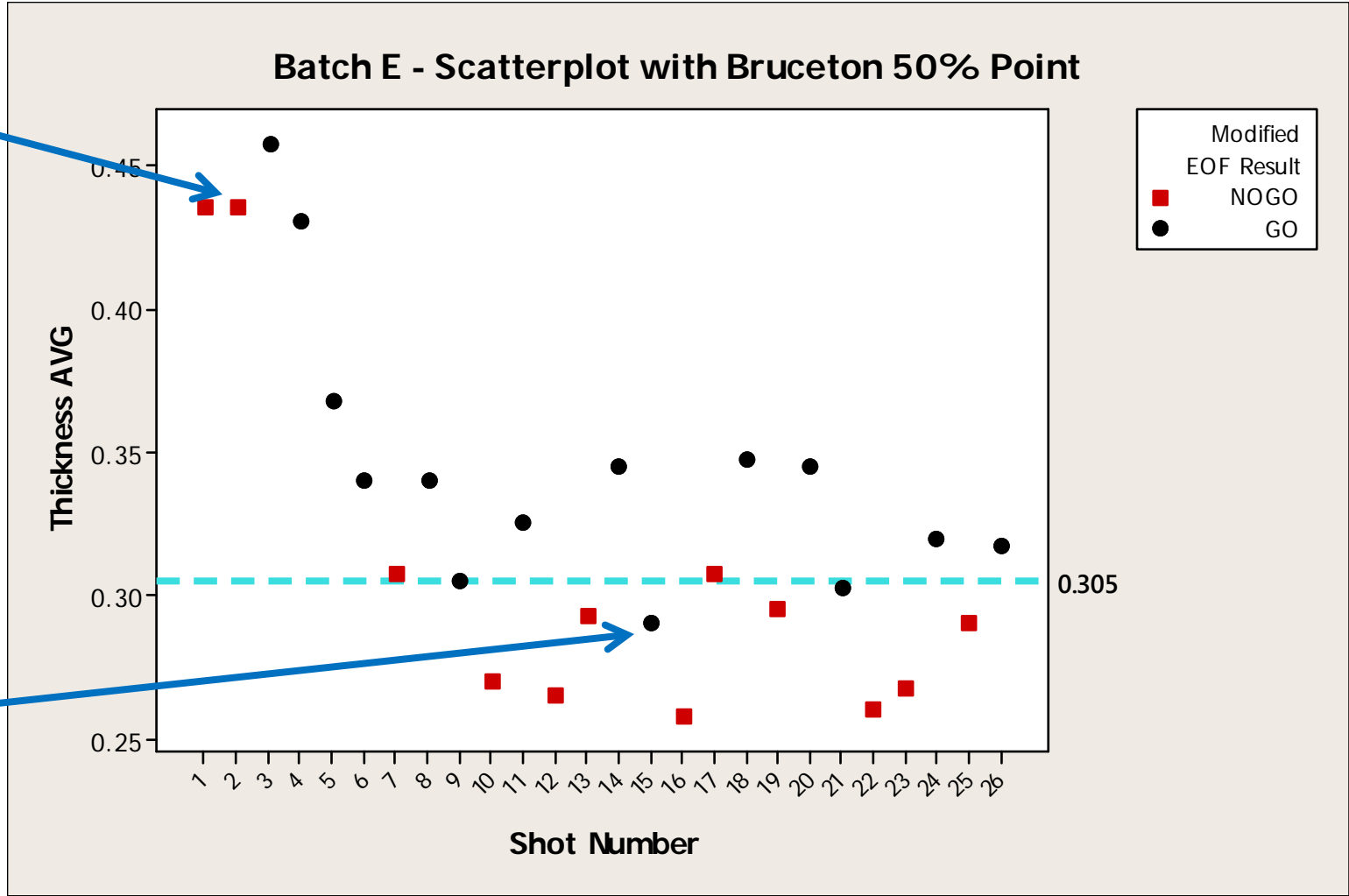


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Input Comparison– Batch E & F

Thickest NOGO

Thinnest GO

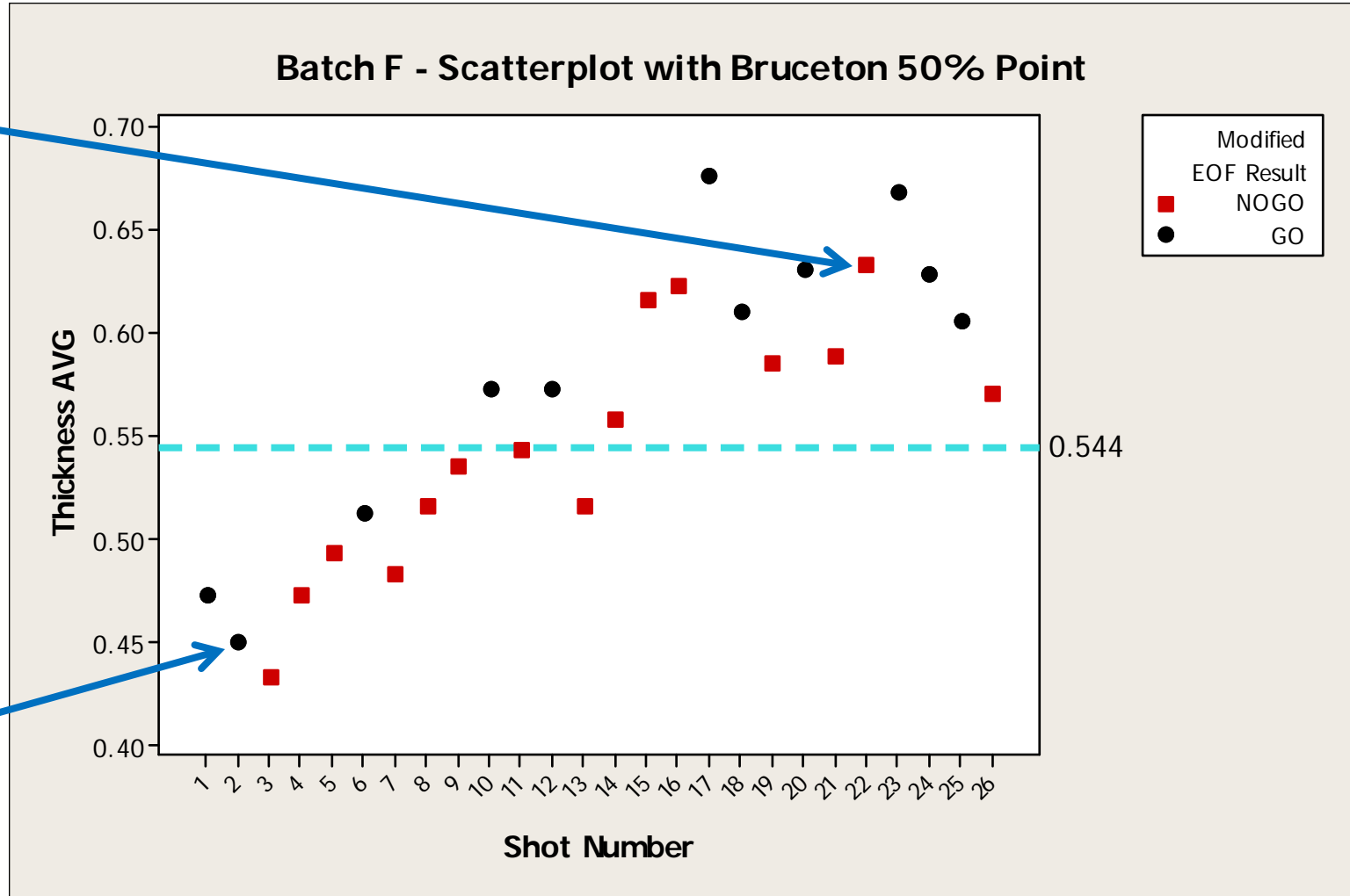


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Input Comparison– Batch E & F

Thickest NOGO

Thinnest GO



Non-Export Control Information – Releasable to Foreign Persons
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Input Comparison– Batch E & F

C-4 M112 Block Compositon % RDX

C-4 Batch	Block	1 st Third	2 nd Third	3 rd 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

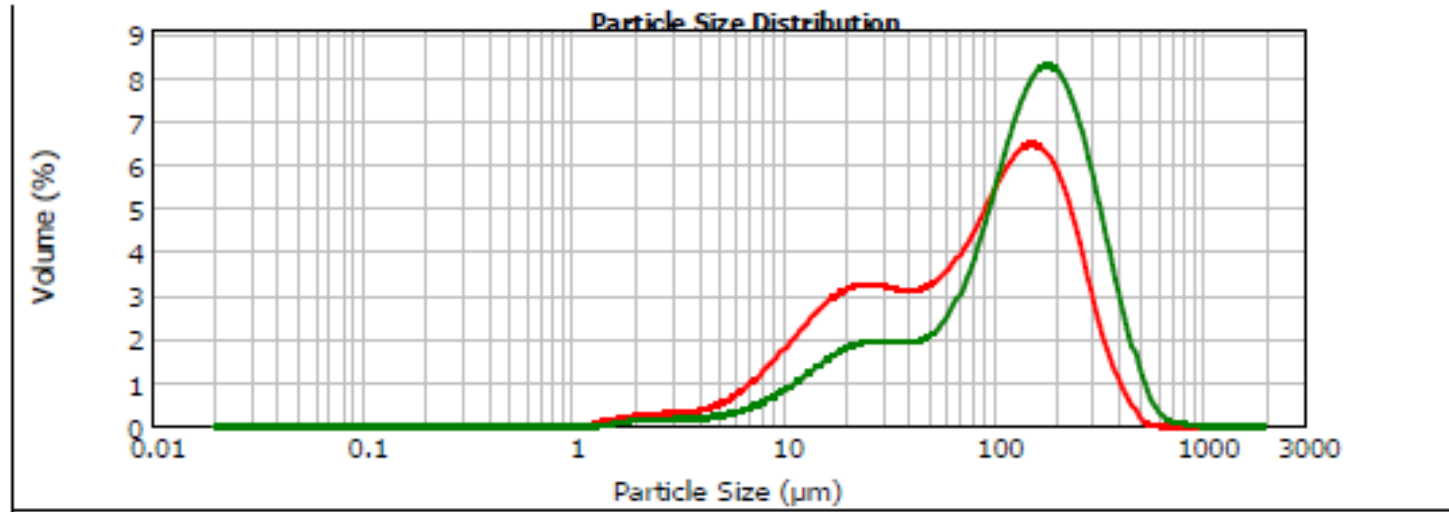
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Batch F Overlay

d(0.1): 21.790 um

d(0.5): 141.385 um

d(0.9): 322.576 um



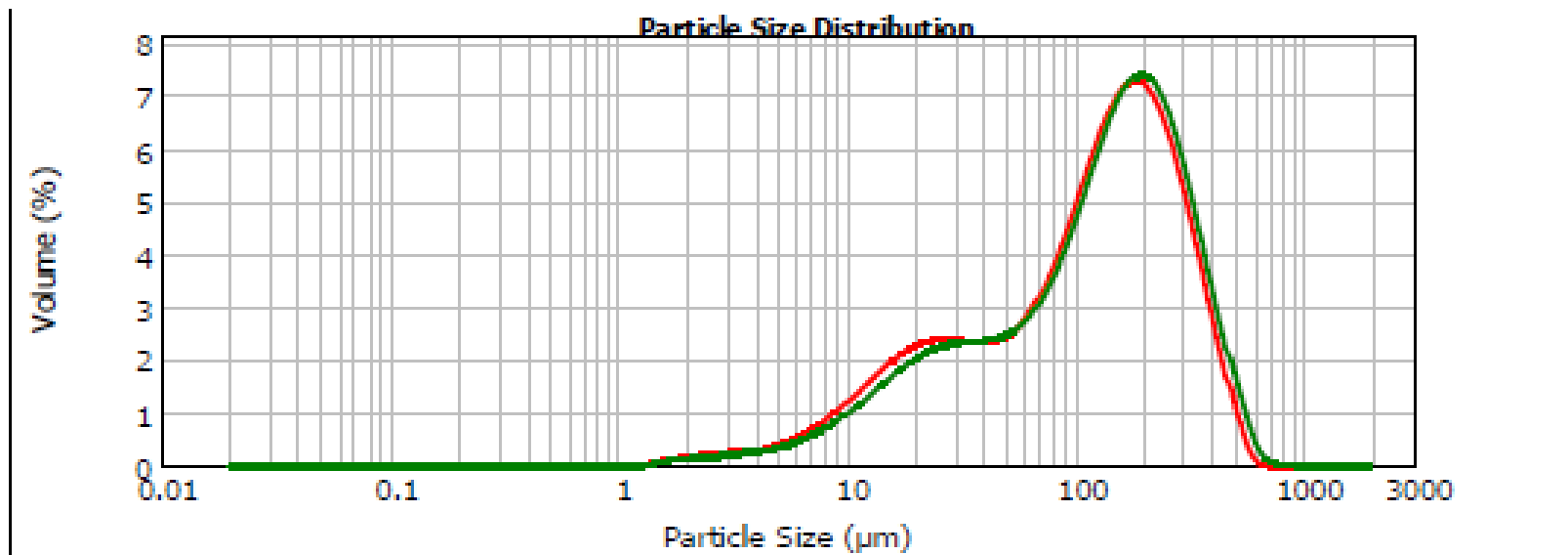
Block 2 (0.45 in)	D(0.1)	D(0.5)	D(0.9)
1 st Third	12.811	85.272	226.807
2 nd Third	12.549	87.585	236.891
3 rd Third	12.865	79.517	263.230
Block 22 (0.63 in)	D(0.1)	D(0.5)	D(0.9)
1 st Third	19.371	132.833	304.517
2 nd Third	22.801	148.126	329.931
3 rd Third	24.130	142.962	334.944

Batch E Overlay

d(0.1): 18.514 um

d(0.5): 134.782 um

d(0.9): 334.893 um



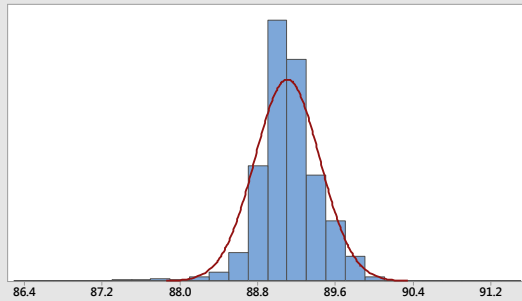
Block 15 (0.30 in)	D(0.1)	D(0.5)	D(0.9)
1 st Third	16.369	117.486	296.263
2 nd Third	16.746	131.153	325.246
3 rd Third	15.380	122.801	310.173
Block 2 (0.43 in)	D(0.1)	D(0.5)	D(0.9)
1 st Third	24.448	143.910	340.795
2 nd Third	17.297	131.193	337.362
3 rd Third	12.261	127.317	326.390

PSD comparison

F Block 2 (0.45 in)	D(0.1)	D(0.5)	D(0.9)
1 st Third	12.811	85.272	226.807
2 nd Third	12.549	87.585	236.891
3 rd Third	12.865	79.517	263.230
F Block 22 (0.63 in)	D(0.1)	D(0.5)	D(0.9)
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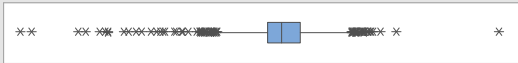
M112 Variability – All Means (RDX,% & 10th Percentile)

Summary Report for RDX



Anderson-Darling Normality Test

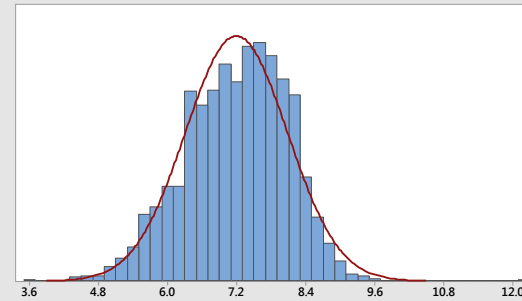
A-Squared	25.53
P-Value	<0.005
Mean	89.105
StDev	0.334
Variance	0.111
Skewness	-1.08148
Kurtosis	8.92675
N	2006
Minimum	86.400
1st Quartile	88.940
Median	89.090
3rd Quartile	89.280
Maximum	91.320
95% Confidence Interval for Mean	89.090 89.120
95% Confidence Interval for Median	89.080 89.110
95% Confidence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



95% Confidence Intervals

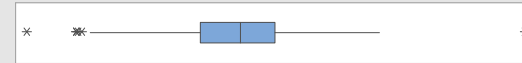


Summary Report for 10th Percentile

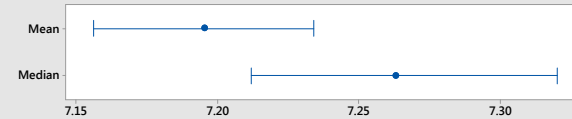


Anderson-Darling Normality Test

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

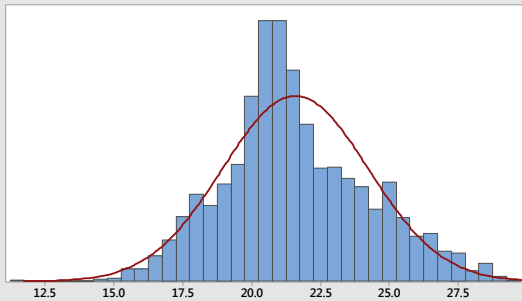


95% Confidence Intervals



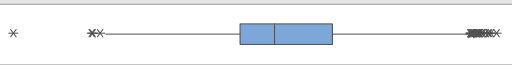
M112 Variability – All Means (50th & 90th Percentile)

Summary Report for 50th Percentile

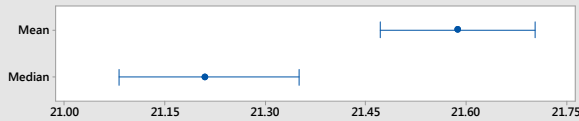


Anderson-Darling Normality Test

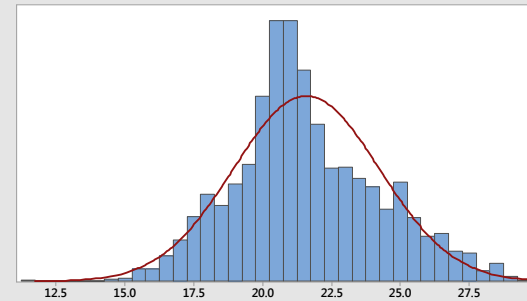
A-Squared	10.74
P-Value	<0.005
Mean	21.587
StDev	2.652
Variance	7.034
Skewness	0.309923
Kurtosis	-0.047064
N	2007
Minimum	11.681
1st Quartile	19.953
Median	21.209
3rd Quartile	23.284
Maximum	29.254
95% Confidence Interval for Mean	21.471 21.703
95% Confidence Interval for Median	21.081 21.351
95% Confidence Interval for StDev	2.573 2.737



95% Confidence Intervals

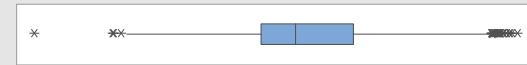


Summary Report for 50th Percentile

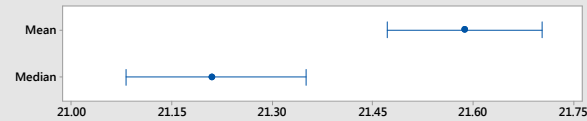


Anderson-Darling Normality Test

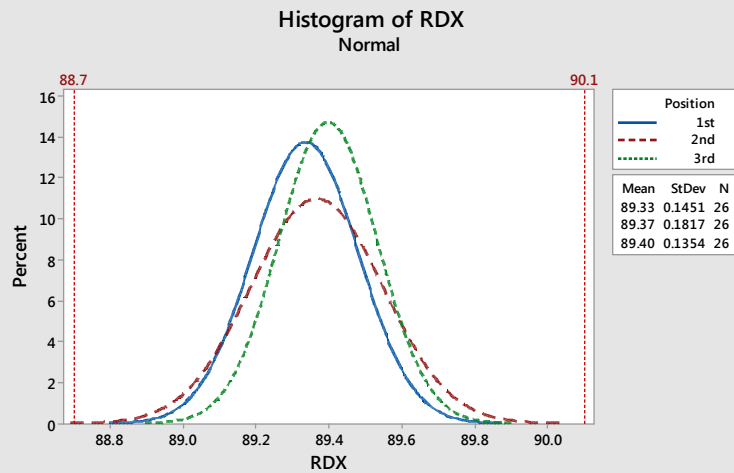
A-Squared	10.74
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95% Confidence Intervals

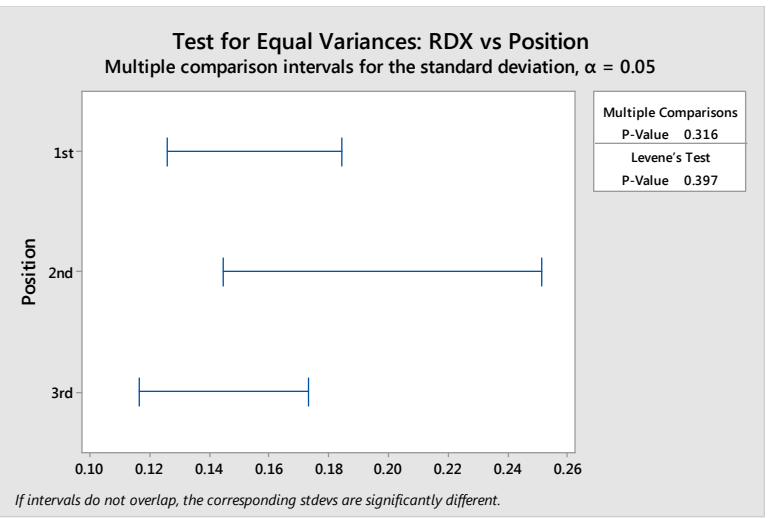
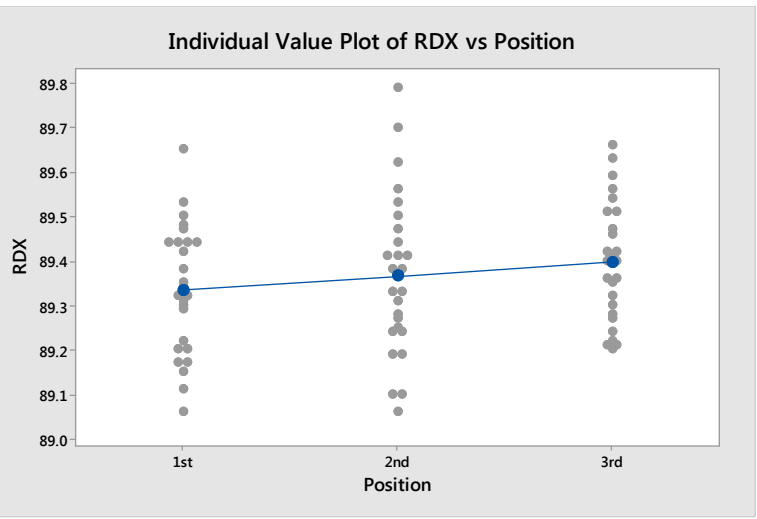


M112 Block Variability (Within Block)



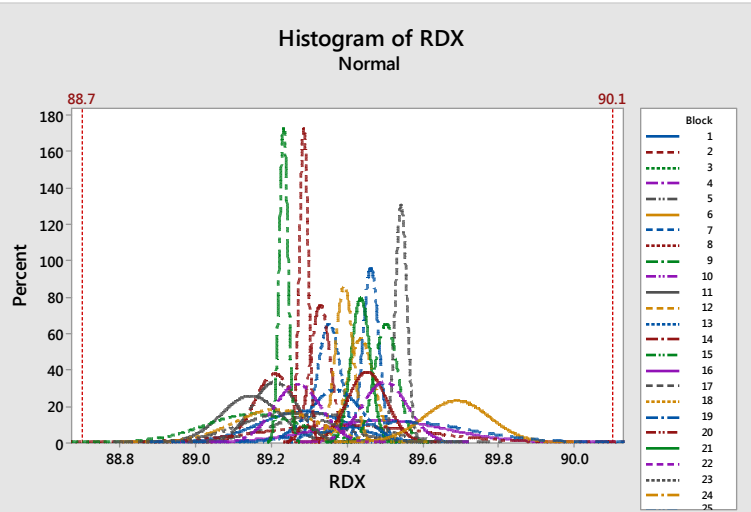
Batches A-1 thru T Within Block

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

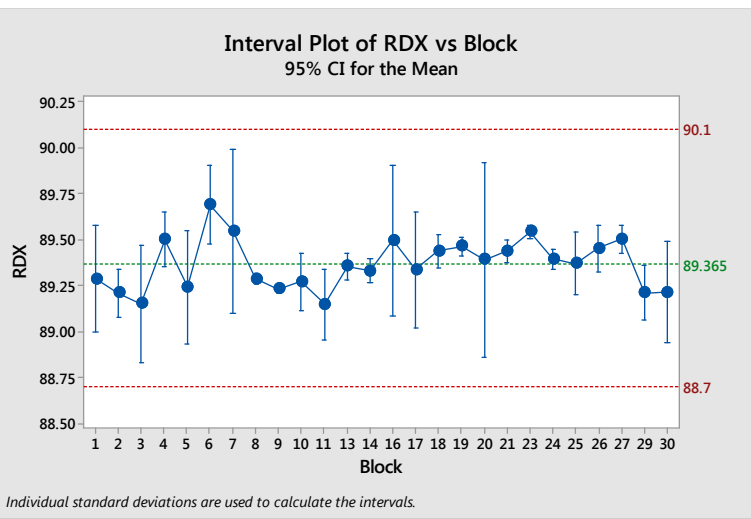


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M112 Block Variability (Between Block)

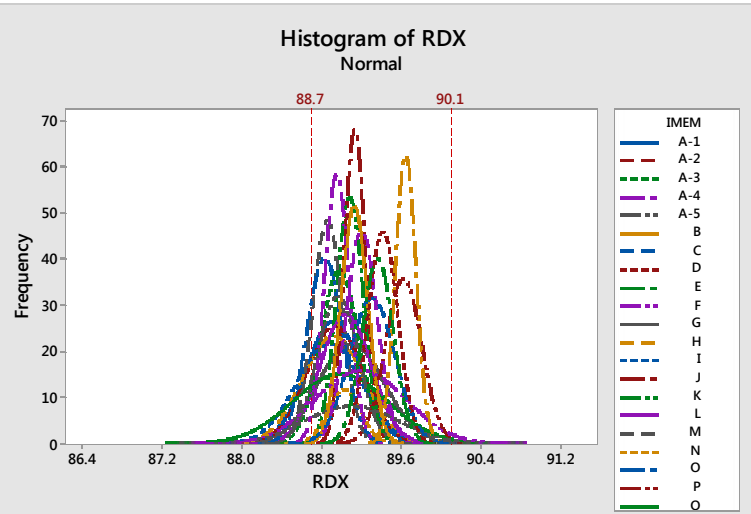


Blocks 1 thru 30 Between Block	
	MAX StDev
RDX, %	0.529
10 th	1.122 μ
50 th	3.086 μ
90 th	11.420 μ

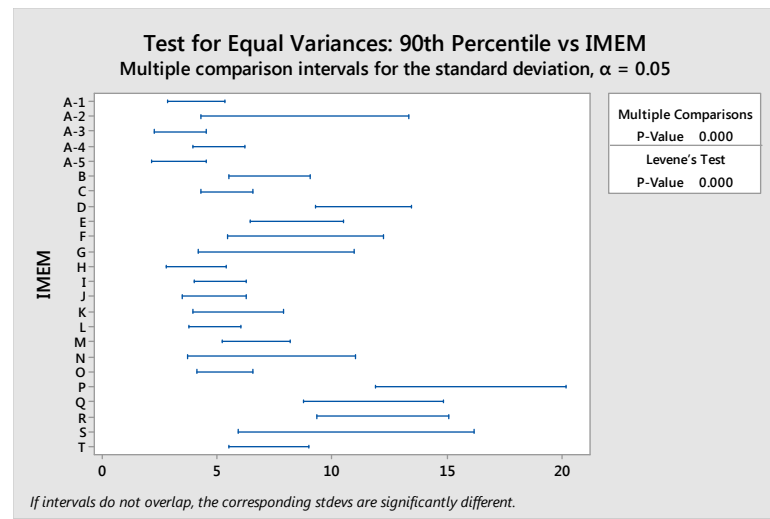
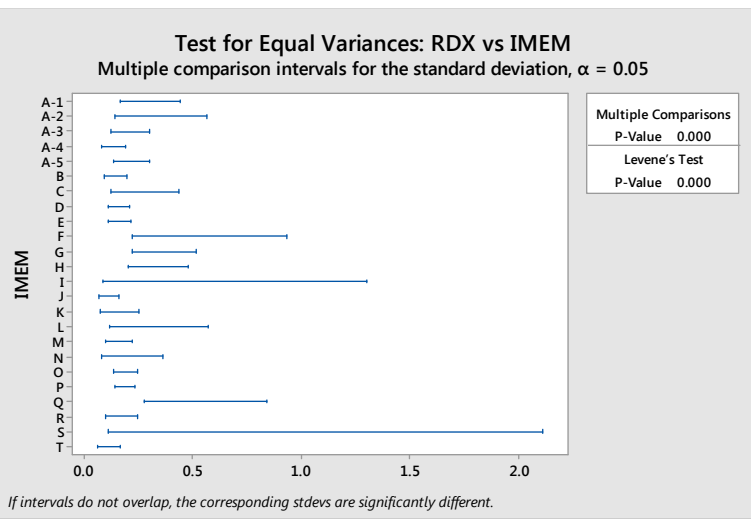


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M112 Block Variability (Between Batches)



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



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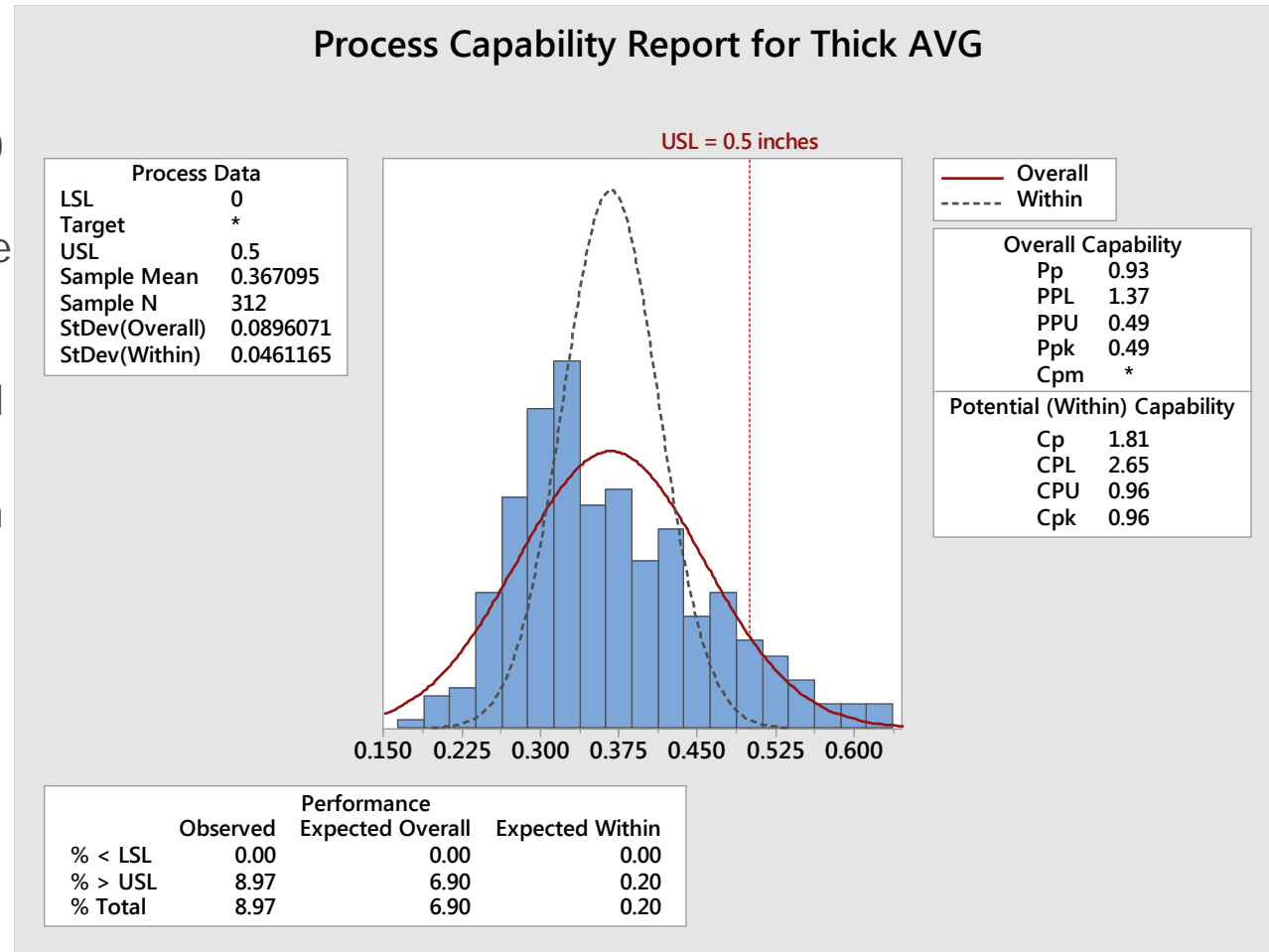
M112 Block Variability (Within & Between Summary)

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

Non-Export Control Information – Releasable to Foreign Persons
(Export Reference)

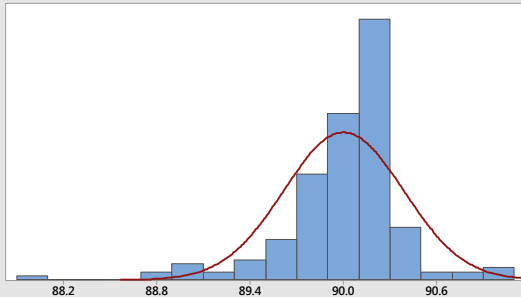
M112 Modified EOF – Process Capability

- 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)

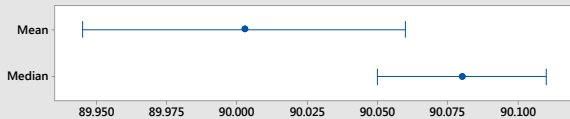
Summary Report for RDX



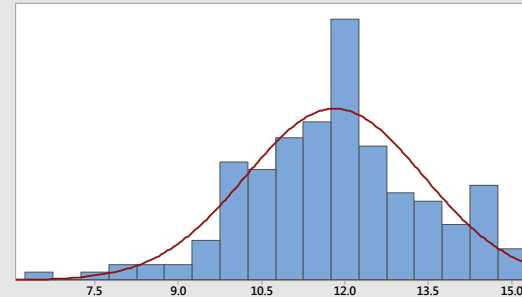
Anderson-Darling Normality Test	
A-Squared	6.14
P-Value	<0.005
Mean	90.003
StDev	0.385
Variance	0.148
Skewness	-1.36741
Kurtosis	5.22181
N	175
Minimum	88.000
1st Quartile	89.850
Median	90.080
3rd Quartile	90.220
Maximum	91.080
95% Confidence Interval for Mean	
	89.945 90.060
95% Confidence Interval for Median	
	90.050 90.110
95% Confidence Interval for StDev	
	0.349 0.430



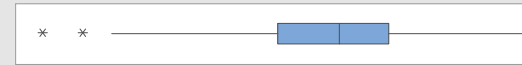
95% Confidence Intervals



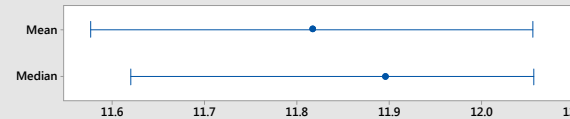
Summary Report for 10th Percentile



Anderson-Darling Normality Test	
A-Squared	0.47
P-Value	0.245
Mean	11.816
StDev	1.600
Variance	2.560
Skewness	-0.220637
Kurtosis	0.243059
N	174
Minimum	6.553
1st Quartile	10.794
Median	11.896
3rd Quartile	12.797
Maximum	15.229
95% Confidence Interval for Mean	
	11.577 12.056
95% Confidence Interval for Median	
	11.620 12.056
95% Confidence Interval for StDev	
	1.448 1.788

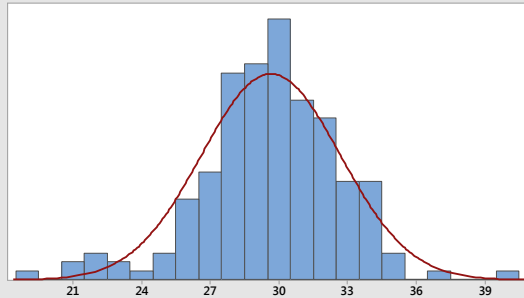


95% Confidence Intervals

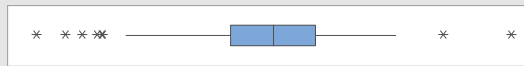


Production Variability – All Means (50th & 90th Percentile)

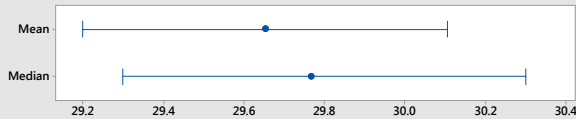
Summary Report for 50th Percentile



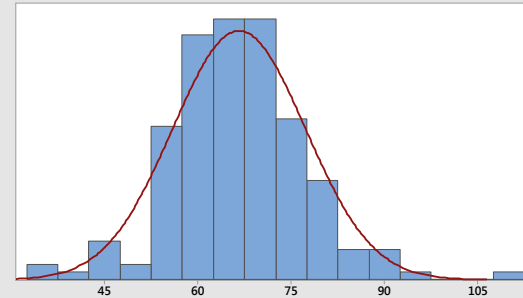
Anderson-Darling Normality Test	
A-Squared	0.84
P-Value	0.029
Mean	29.652
StDev	3.028
Variance	9.171
Skewness	-0.33700
Kurtosis	1.40897
N	174
Minimum	19.386
1st Quartile	27.894
Median	29.765
3rd Quartile	31.593
Maximum	40.137
95% Confidence Interval for Mean	
	29.199 30.106
95% Confidence Interval for Median	
	29.299 30.300
95% Confidence Interval for StDev	
	2.740 3.385



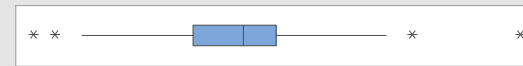
95% Confidence Intervals



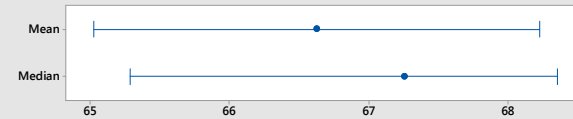
Summary Report for 90th Percentile



Anderson-Darling Normality Test	
A-Squared	0.78
P-Value	0.041
Mean	66.627
StDev	10.688
Variance	114.243
Skewness	0.24736
Kurtosis	1.87785
N	174
Minimum	33.504
1st Quartile	59.169
Median	67.255
3rd Quartile	72.645
Maximum	111.840
95% Confidence Interval for Mean	
	65.028 68.226
95% Confidence Interval for Median	
	65.288 68.354
95% Confidence Interval for StDev	
	9.671 11.947

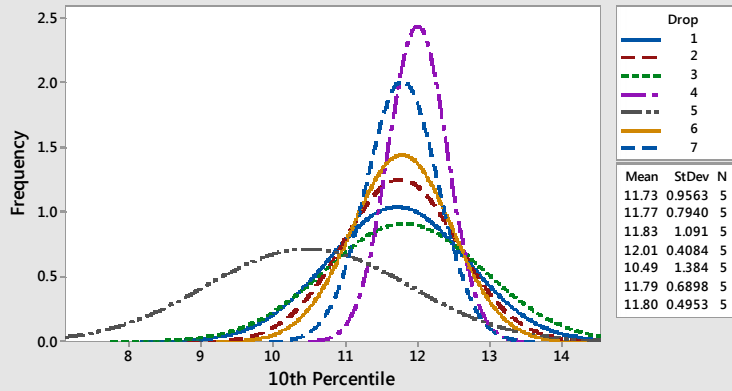


95% Confidence Intervals



Production Variability (Within Nutsches)

Histogram of 10th Percentile
Normal



Results include rows where IMEM = 1.

Batch 1

MAX StDev

RDX, %

0.5268 g

10th

1.384 μ

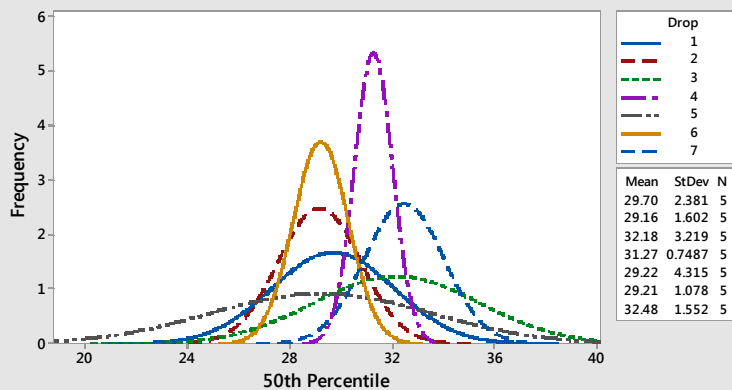
50th

4.315 μ

90th

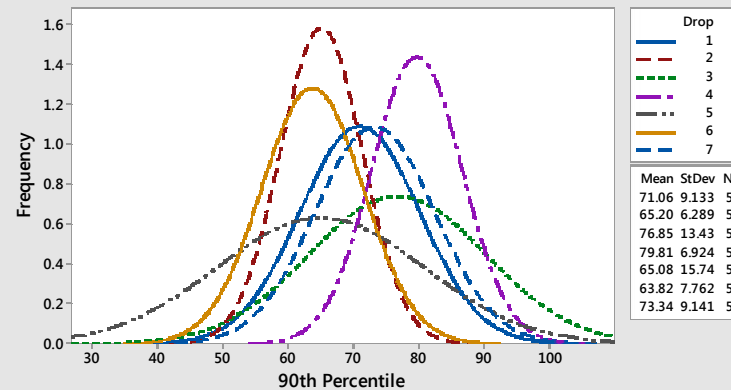
15.74 μ

Histogram of 50th Percentile
Normal



Results include rows where IMEM = 1.

Histogram of 90th Percentile
Normal

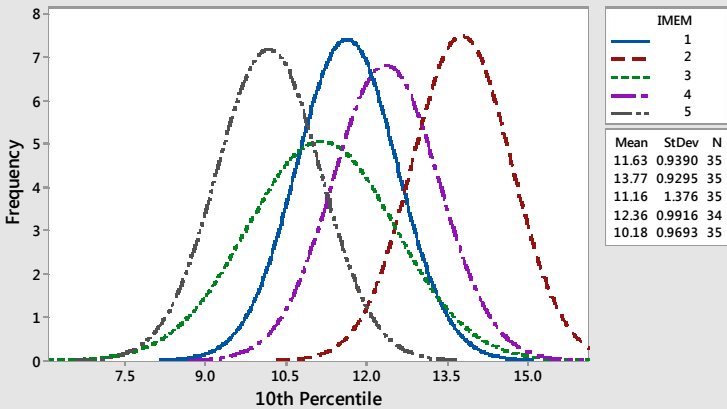


Results include rows where IMEM = 1.

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Production Variability (Within Batch or Between Nutsches)

Histogram of 10th Percentile
Normal



Batch 1

MAX StDev

RDX, %

0.4980 g

10th

1.376 μ

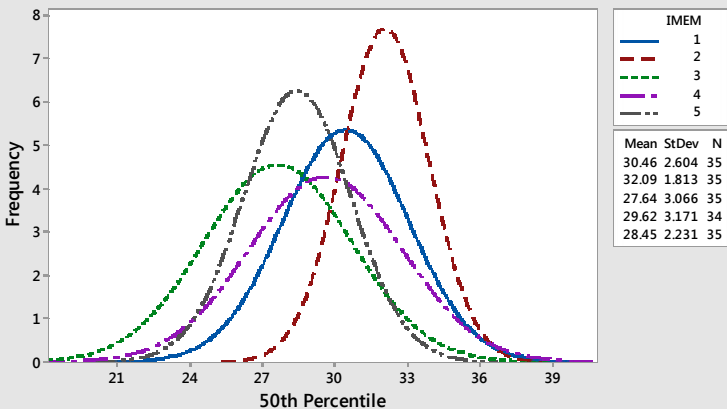
50th

3.171 μ

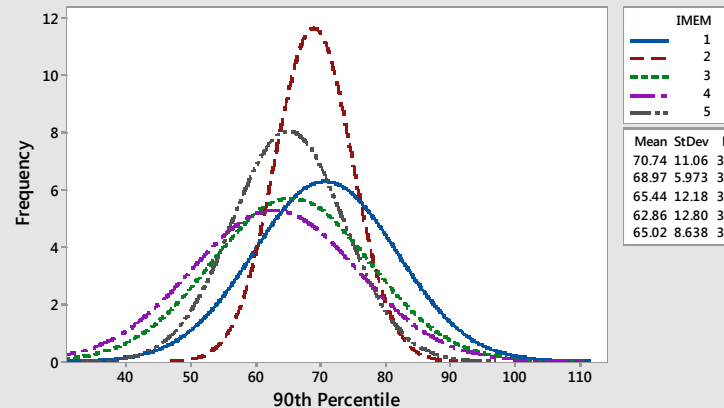
90th

12.800 μ

Histogram of 50th Percentile
Normal

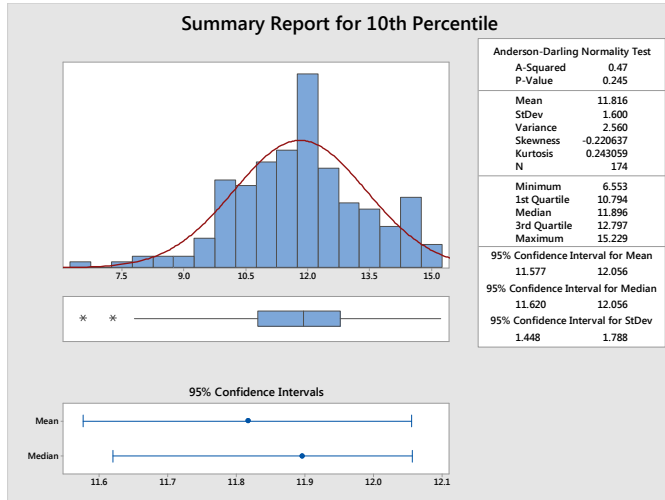


Histogram of 90th Percentile
Normal

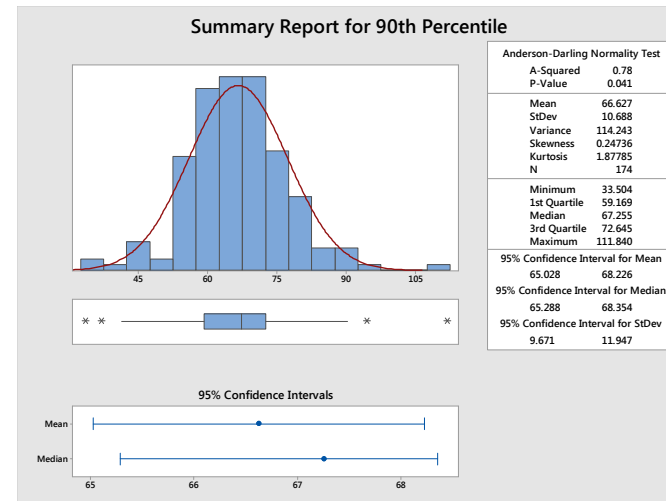
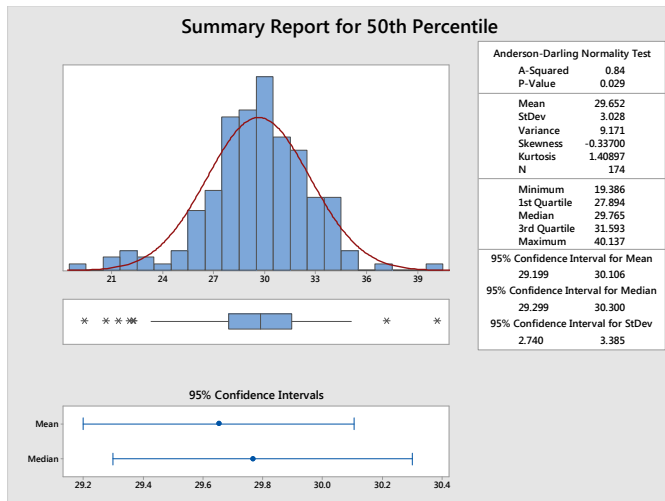


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Production Variability (Between Batches)



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



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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

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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

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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

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