Root Cause Analysis of High Magnetic Noise Density Using JMP

TDK Philippines Corporation
A TDK Group Company
BMS Development
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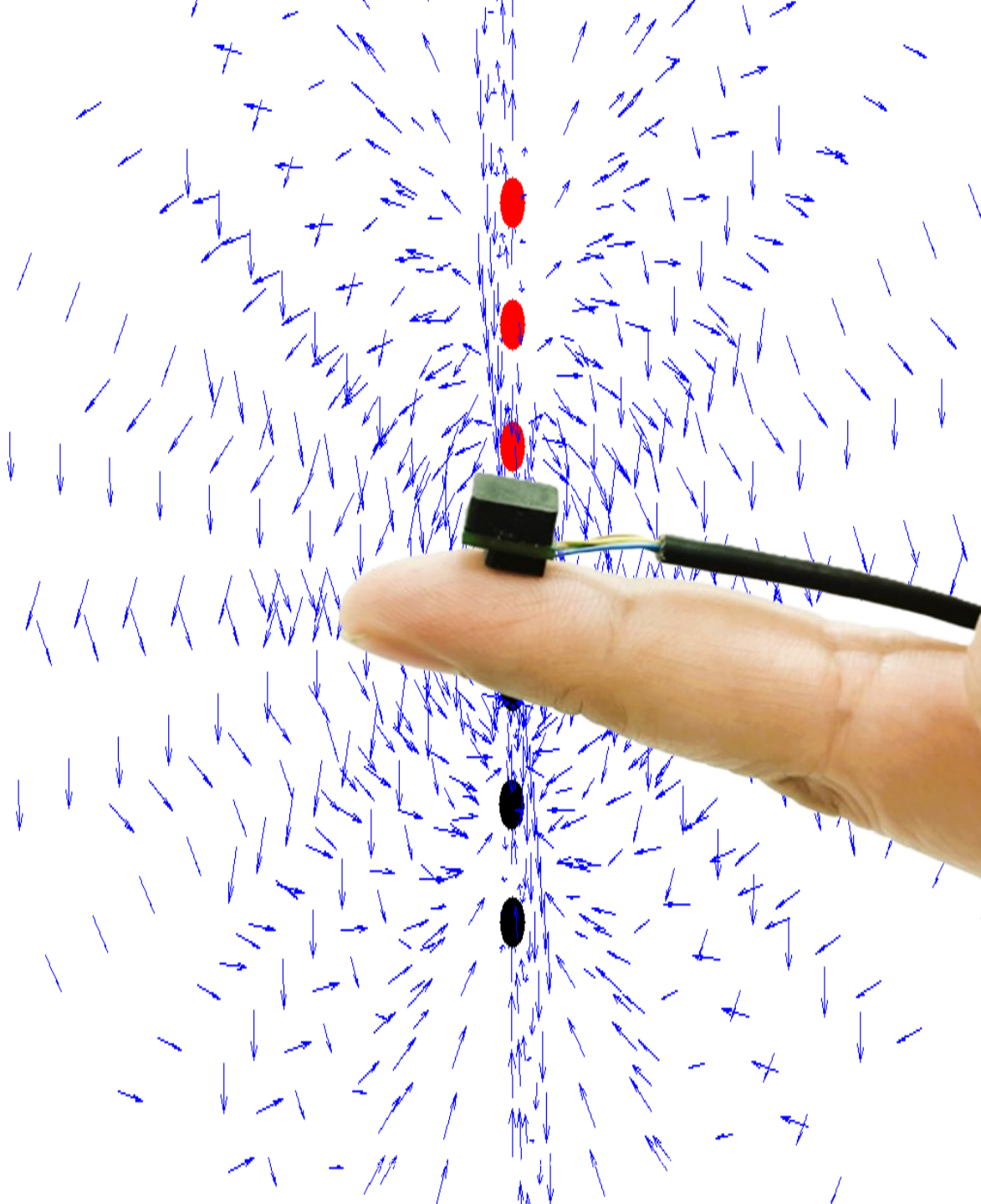
Professional Bio

NEIL PELAYO	
Job Title	Test Engineer
Department	Bio MR Sensor (BMS) Development
Company	TDK Philippines Corporation

- With four years of experience using JMP in new product development, I specialize in quickly and thoroughly evaluating design revisions to drive informed decision-making.
- My work also includes electrostatic discharge (ESD) control and mitigation activities
- JMP has been an essential tool in delivering clear, data-driven product performance analyses that customers can easily understand and trust.

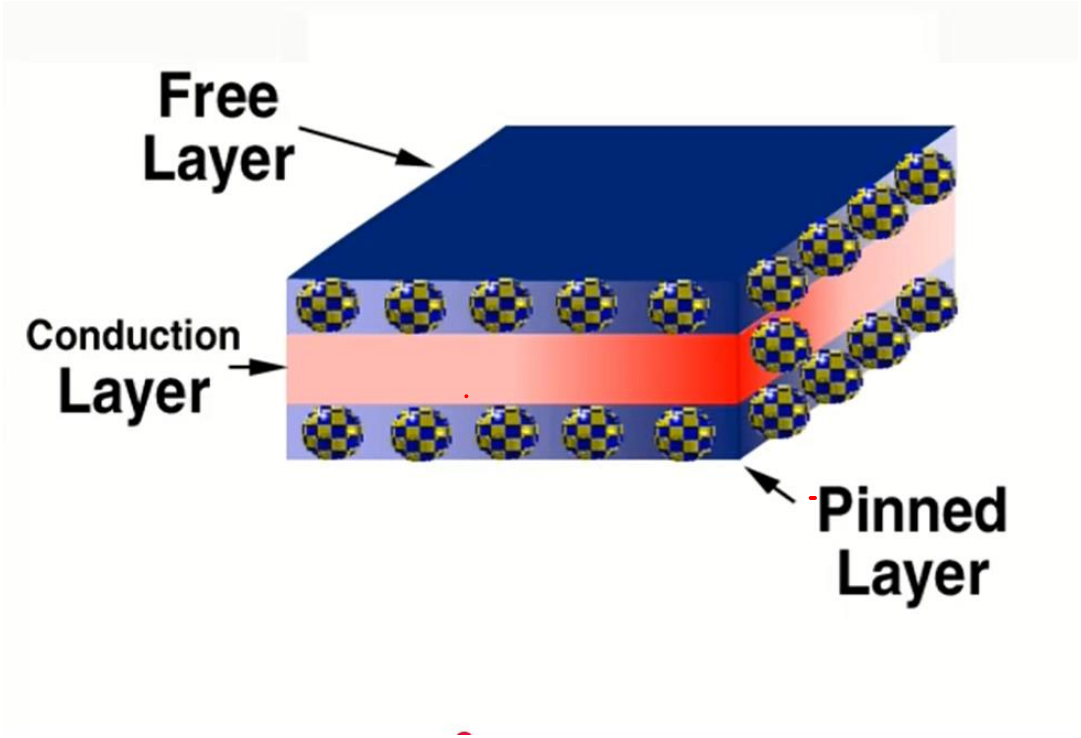
BACKGROUND

- Compact Design
- High Sensitivity
- Low Magnetic Noise Density



Background

- **GMR Sensor is a highly sensitive** magnetic field sensing device composed of multiple and very thin layers of ferro-magnetic and non-magnetic material.
- **Critical Characterization:** Magnetic noise density determines the sensor's ability to detect very small magnetic signals.
- Widely used in electronic industry, industrial applications and bio-medical field.



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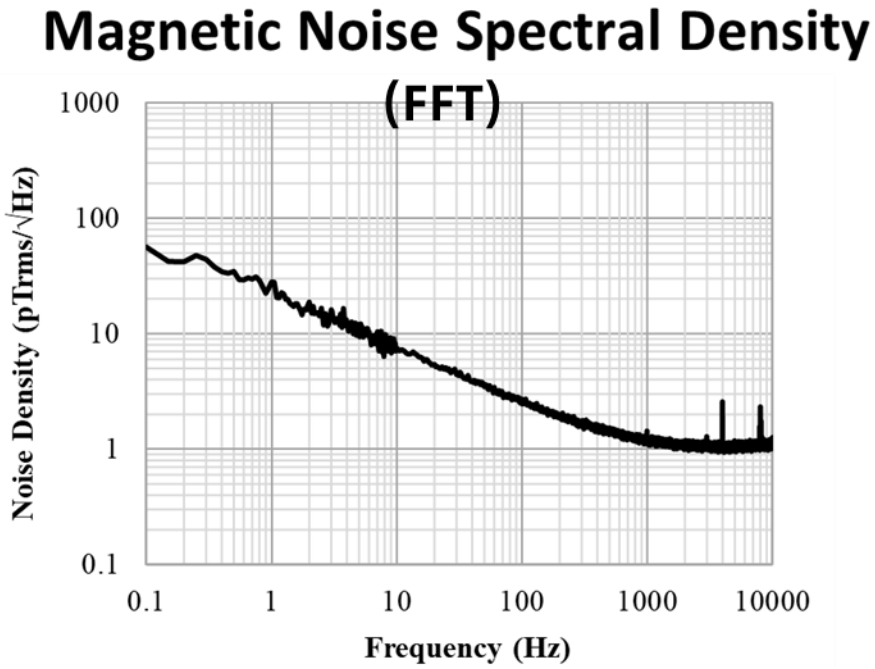

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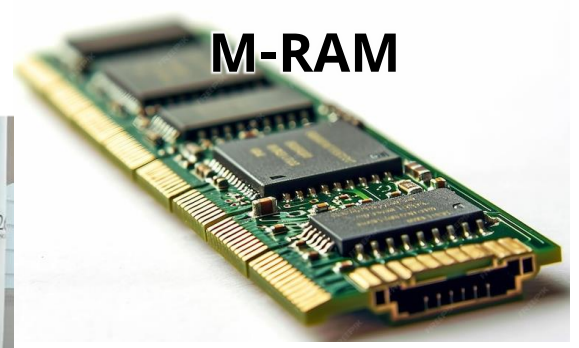
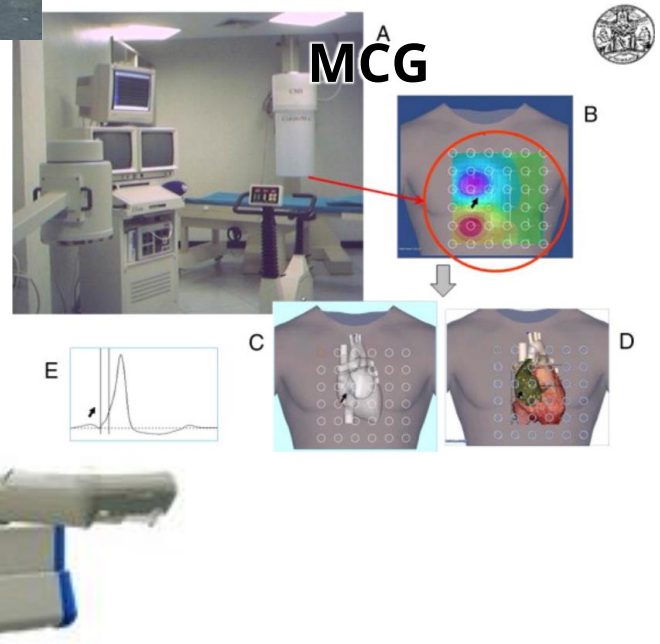
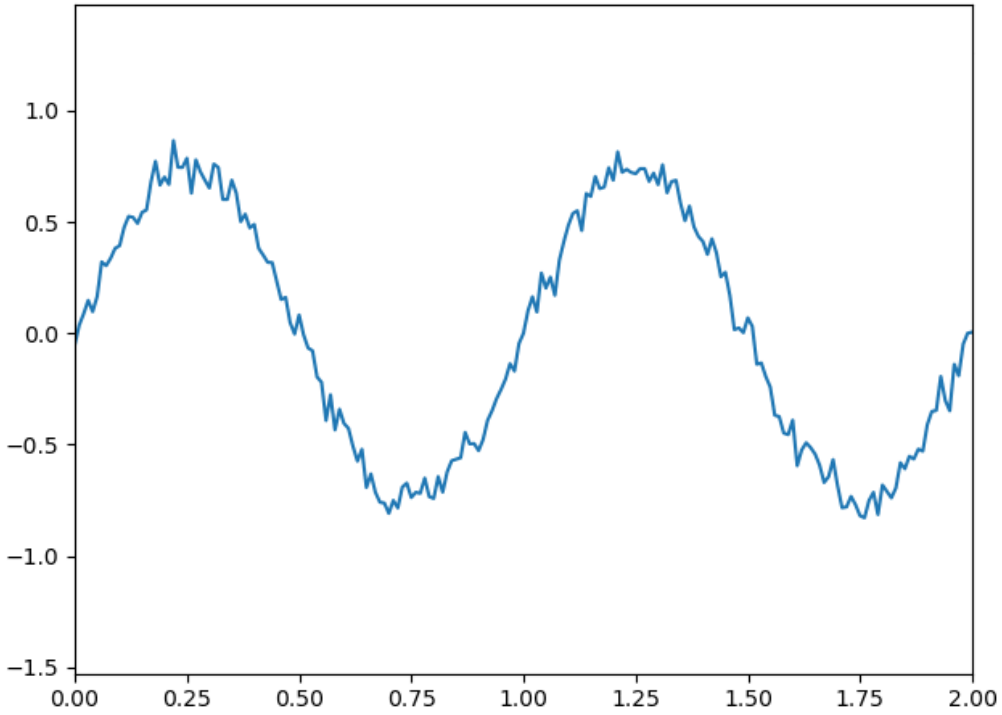




PROBLEM

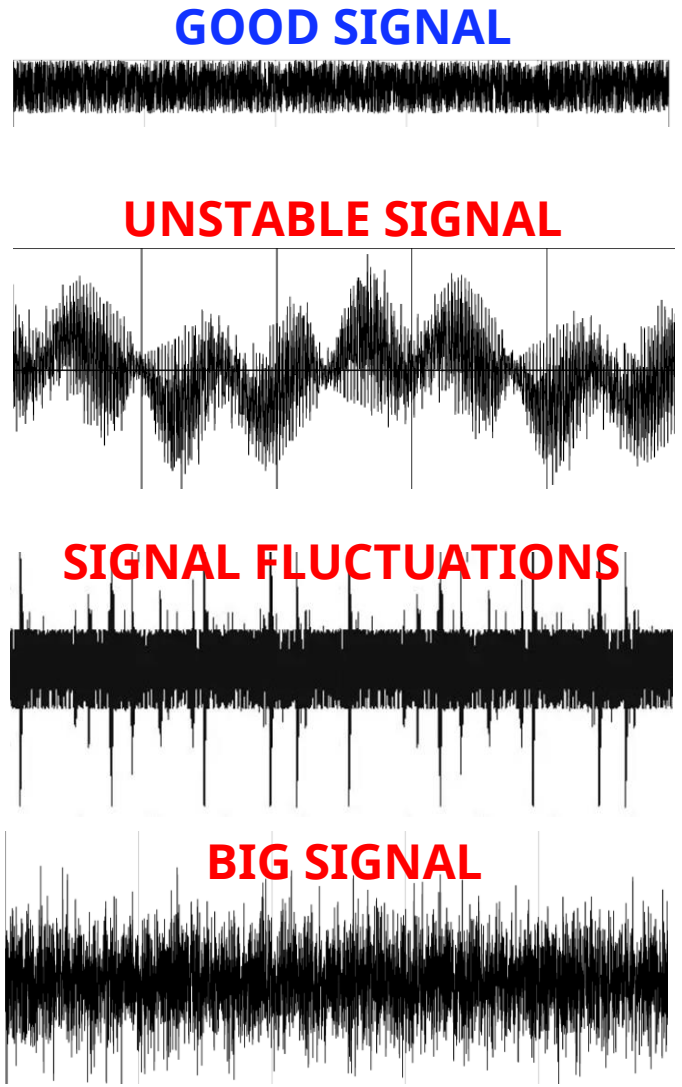
- Spiky/ Noisy Signal
- Unstable Signal



Problem Detection

- Recent performance data shows unstable signals, frequent fluctuations, and elevated noise levels.

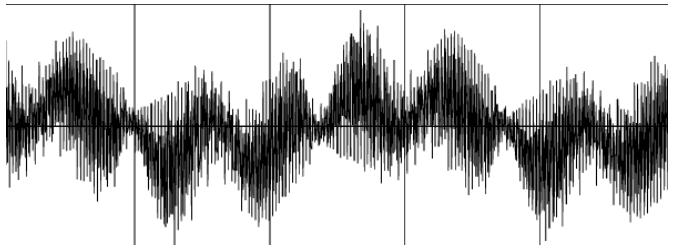
- **Factors:**
  - System configuration
  - Environmental condition
  - Grounding integrity
  - Material properties



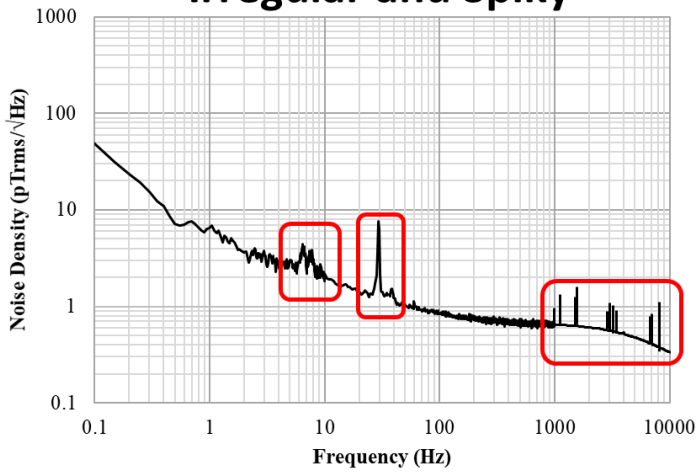
Problem Detection

- Signal irregularities affects the profile of Magnetic Noise Density.

UNSTABLE SIGNAL

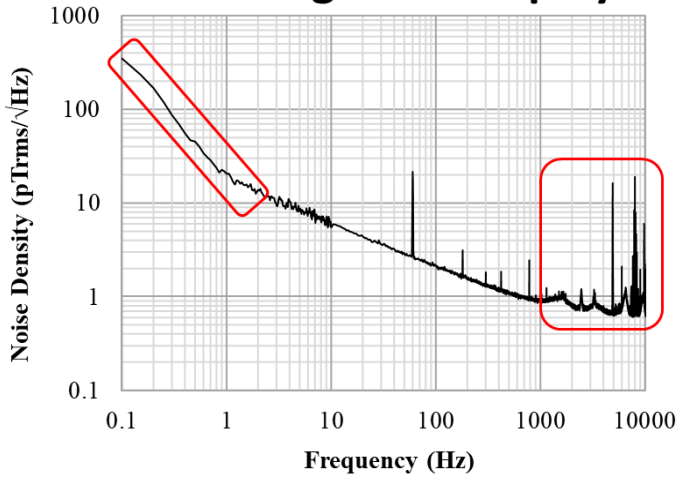


Irregular and Spiky

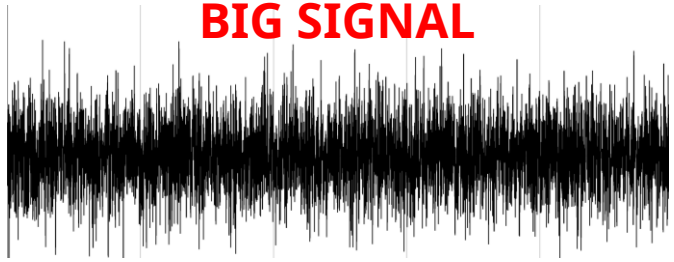


SIGNAL FLUCTUATIONS

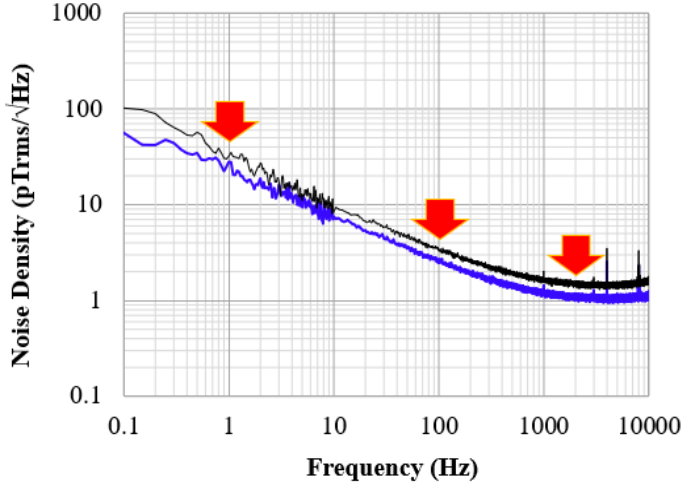
Lifted Signal and Spiky



BIG SIGNAL

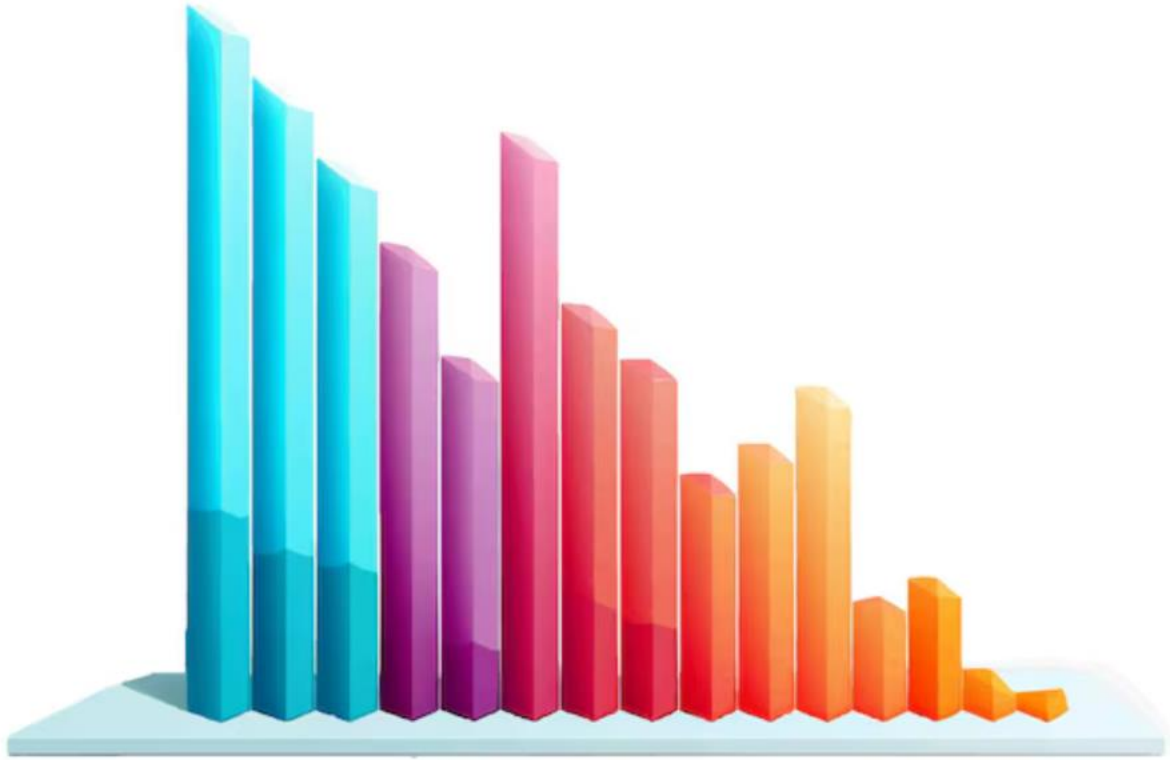


Elevated Level



DEFINE THE PROBLEM

- Is yield hitting the target?



Define - Noise Density Yield is Below Target

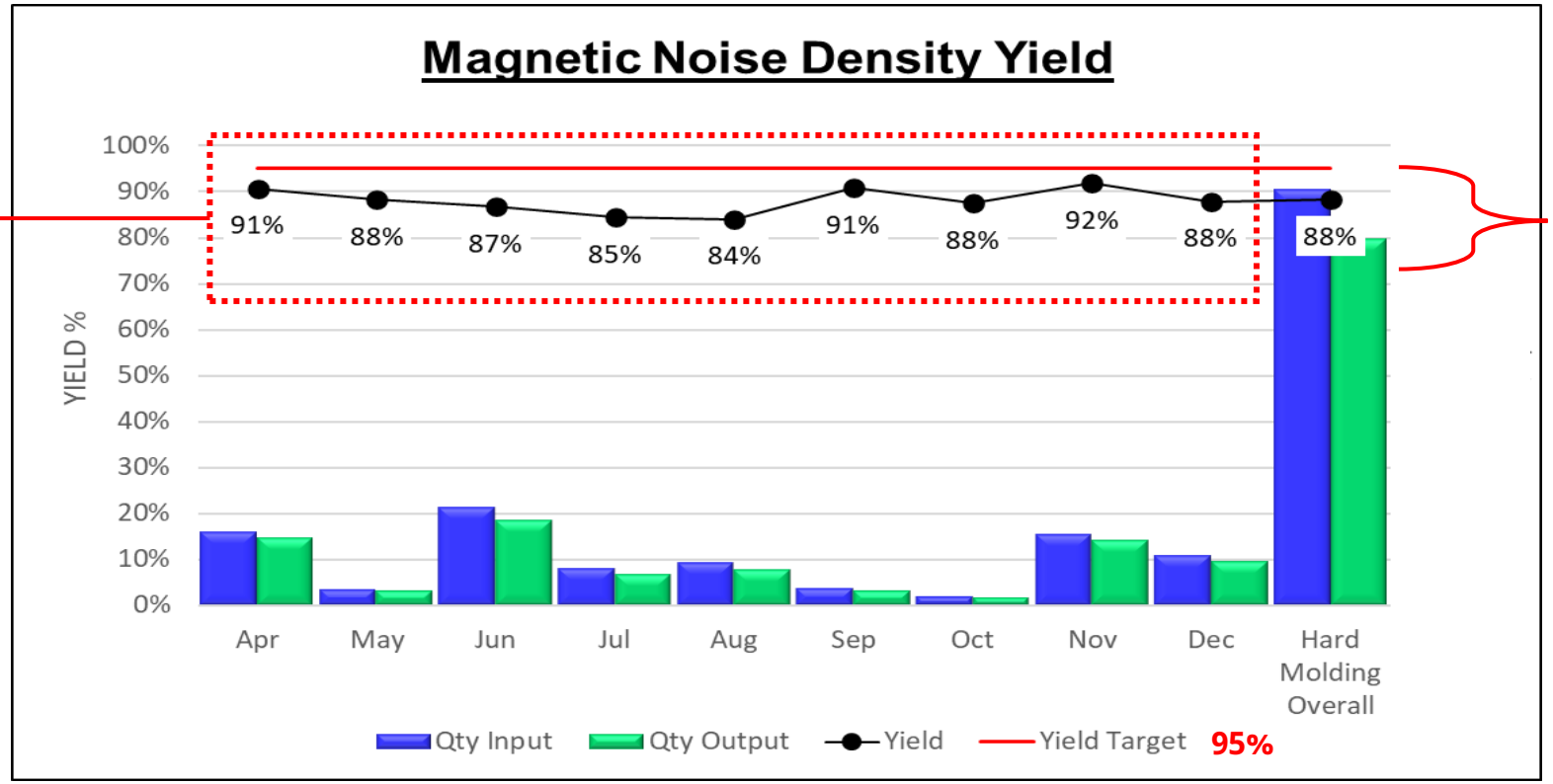


Illustration 1: The monthly yield trend chart of noise density process

- The yield is significantly low by 7%.
- Loss is around Php950k.

- The yield for 9 months did not achieve the target yield of 95%.

Key Question:

What are the contributors to yield loss?

MEASURE the PROBLEM

- Using **JMP platform: Data Distribution**

Measure - Distribution of Noise Density Test Result

- Right-skewed distribution
- Outliers of 46~85 pT (8.9% failure rate)
- Mean shift of +7.8pT from target

- Next Steps:
  - Investigate tester – *Machine*
  - Compare material lots - *Material*

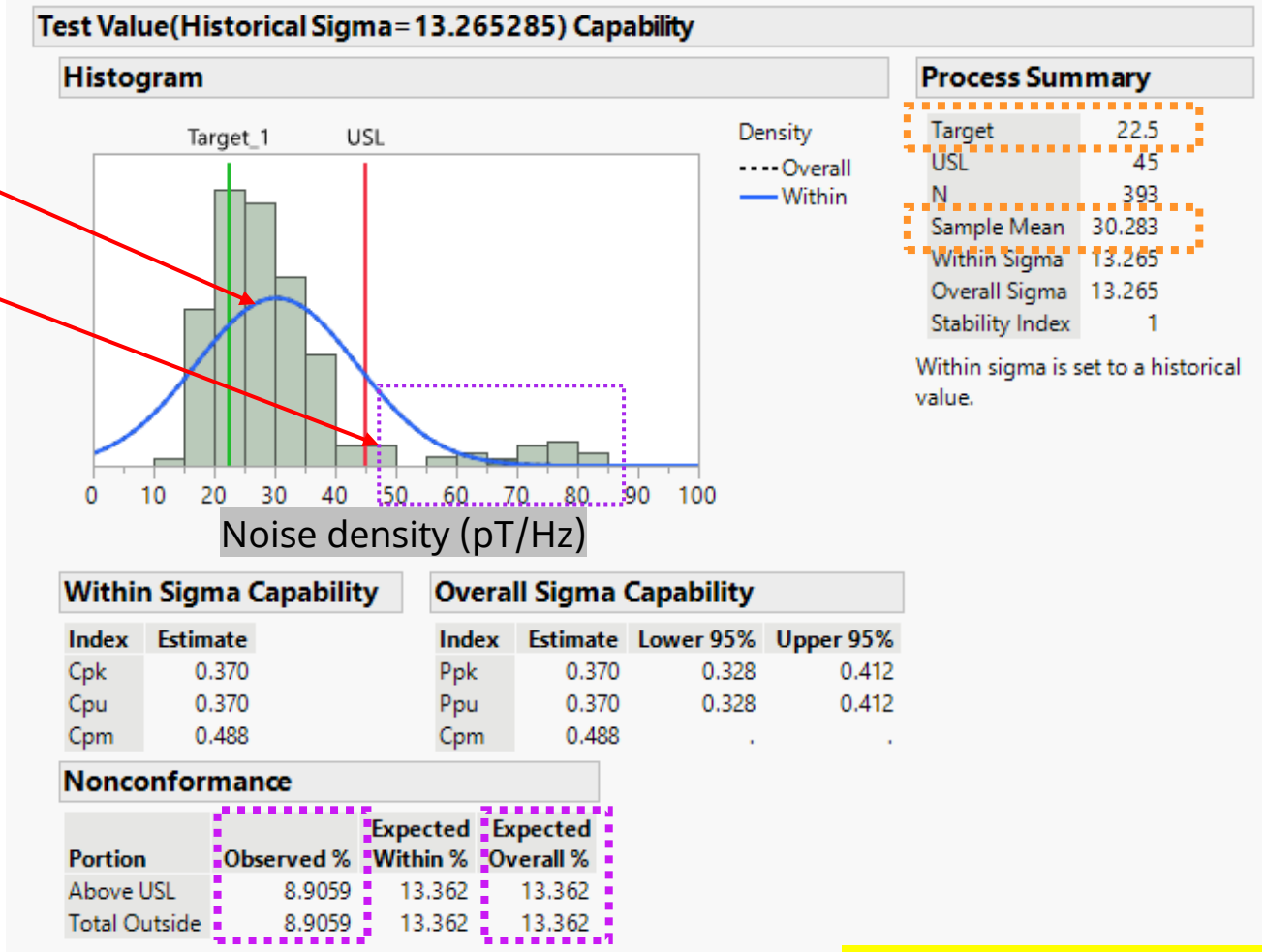
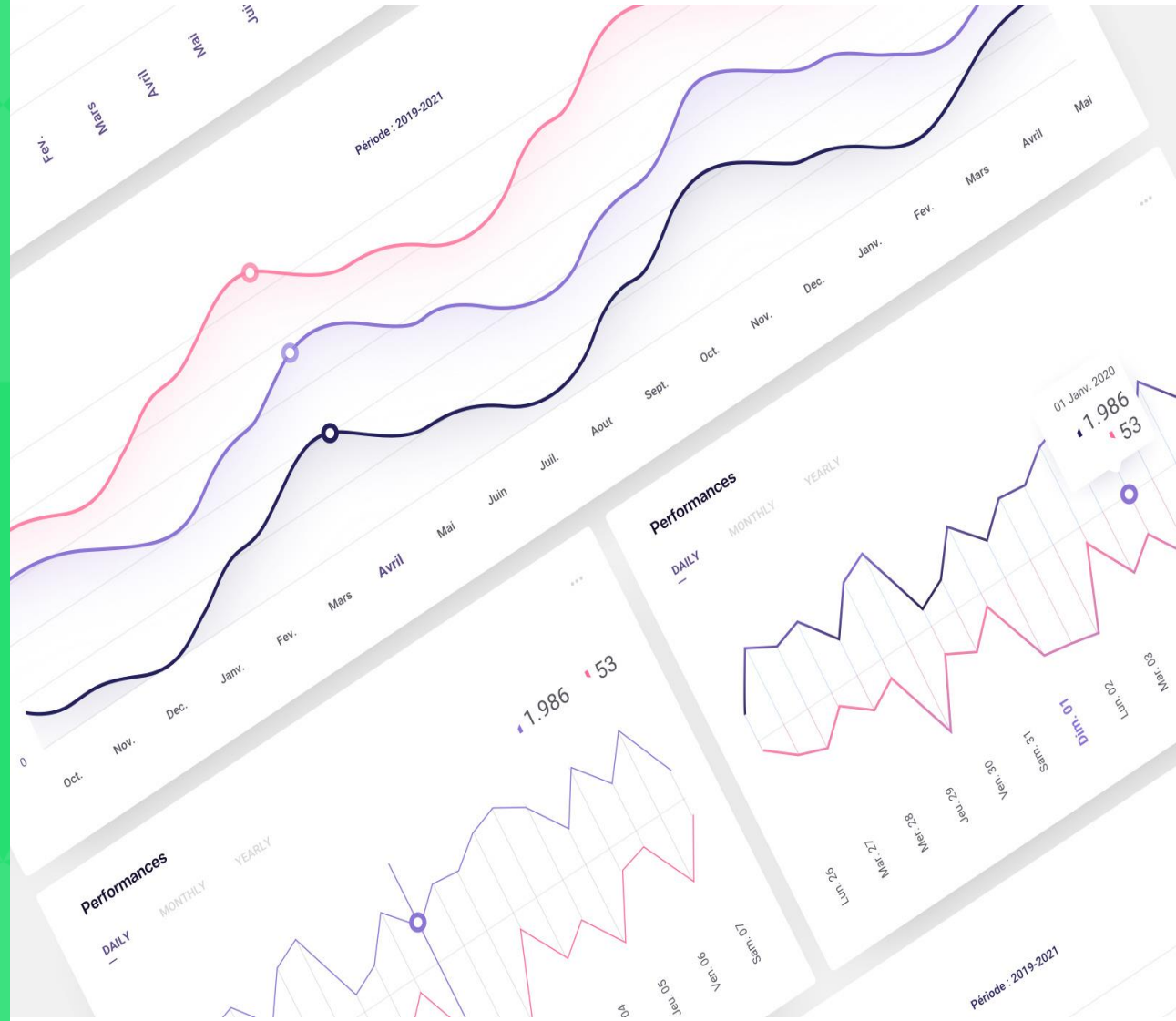


Illustration 2: Noise density distribution

JMP Platform: Distribution

ANALYZE the tester

- Trend monitoring using **JMP platform: Control Chart Builder**



Analyze - Daily Tester Monitoring

- **1.** The mean is stable
- **2.** Low variability with strong stability index of 0.175.
- **3.** The Control is strong

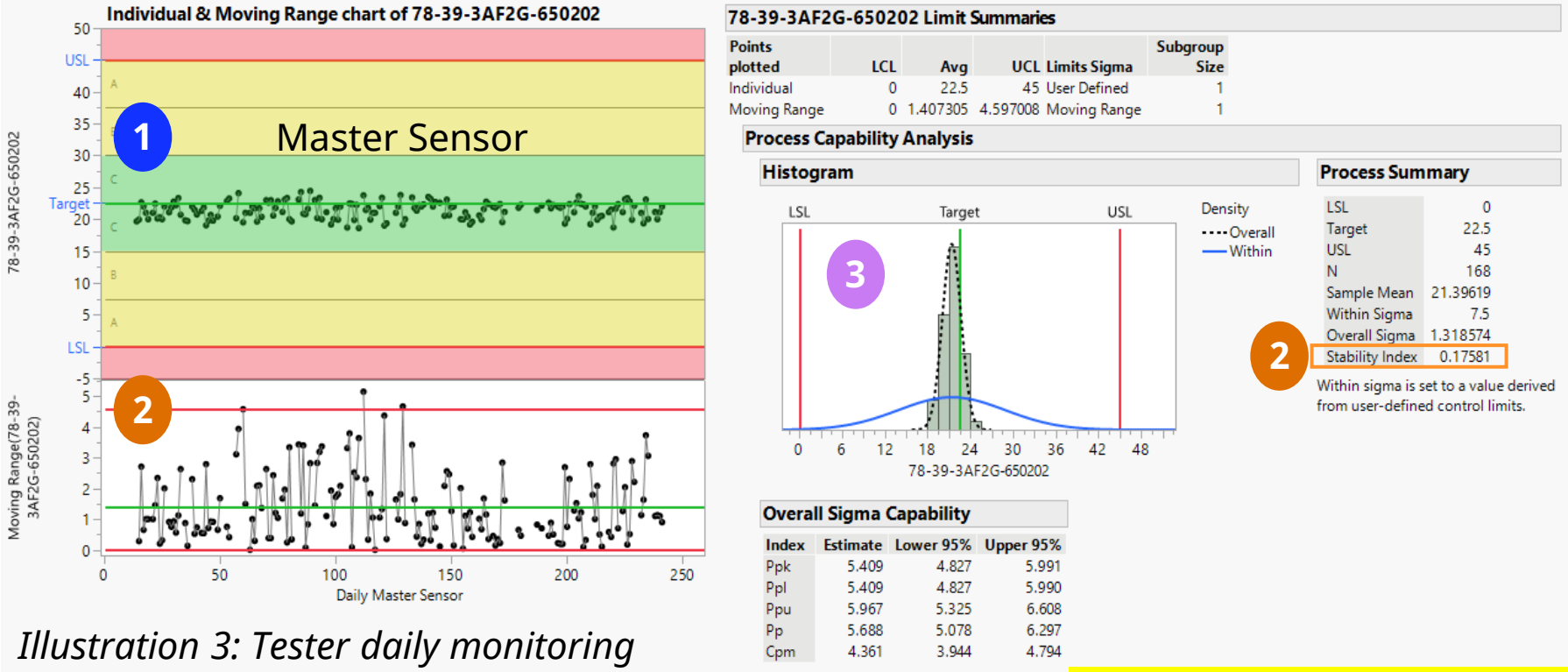


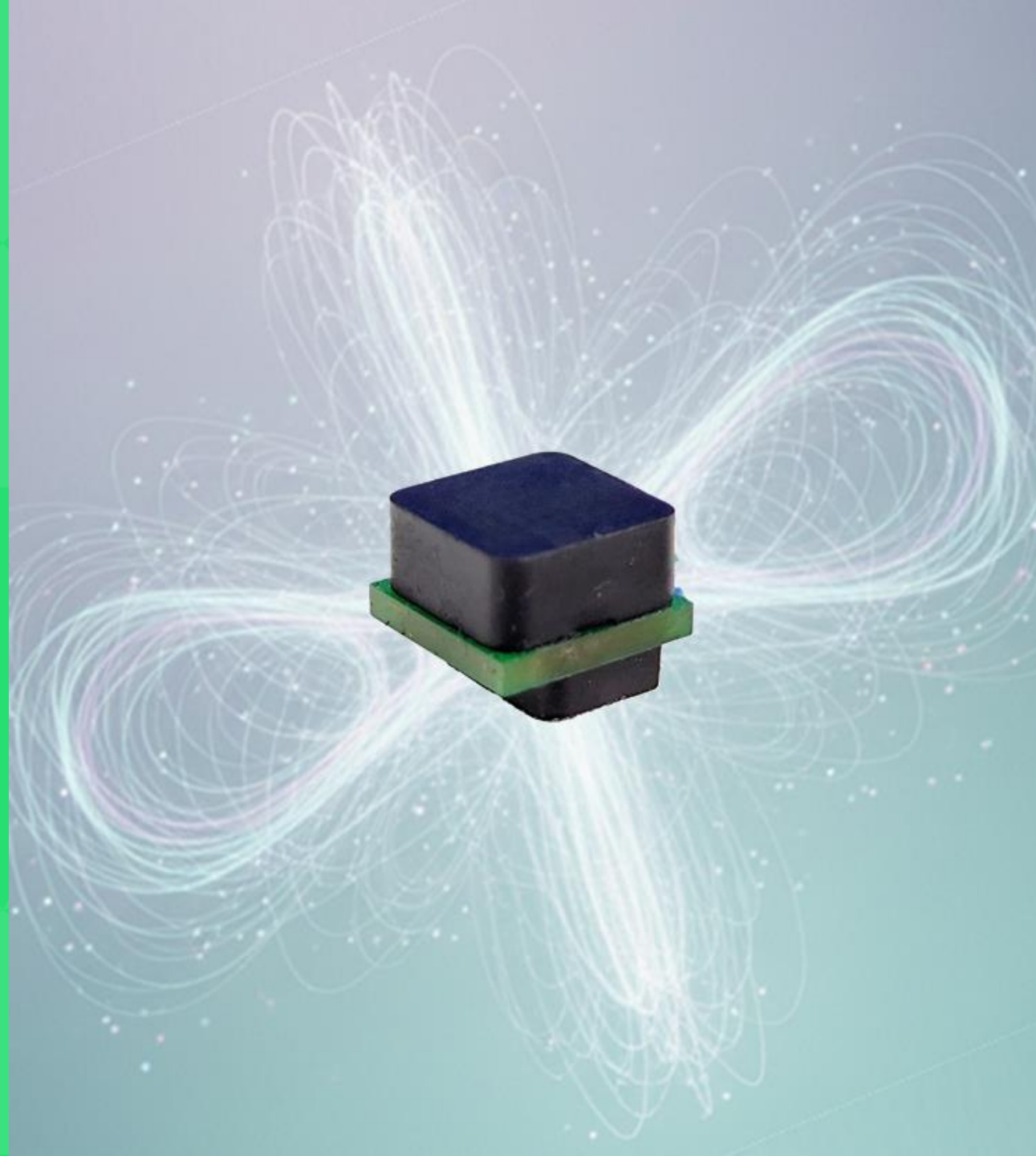
Illustration 3: Tester daily monitoring

JMP Platform: Control Chart Builder

- Remarks: Mean and moving average are stable
- Conclusion: Tester confirmed stable and ruled out as a cause

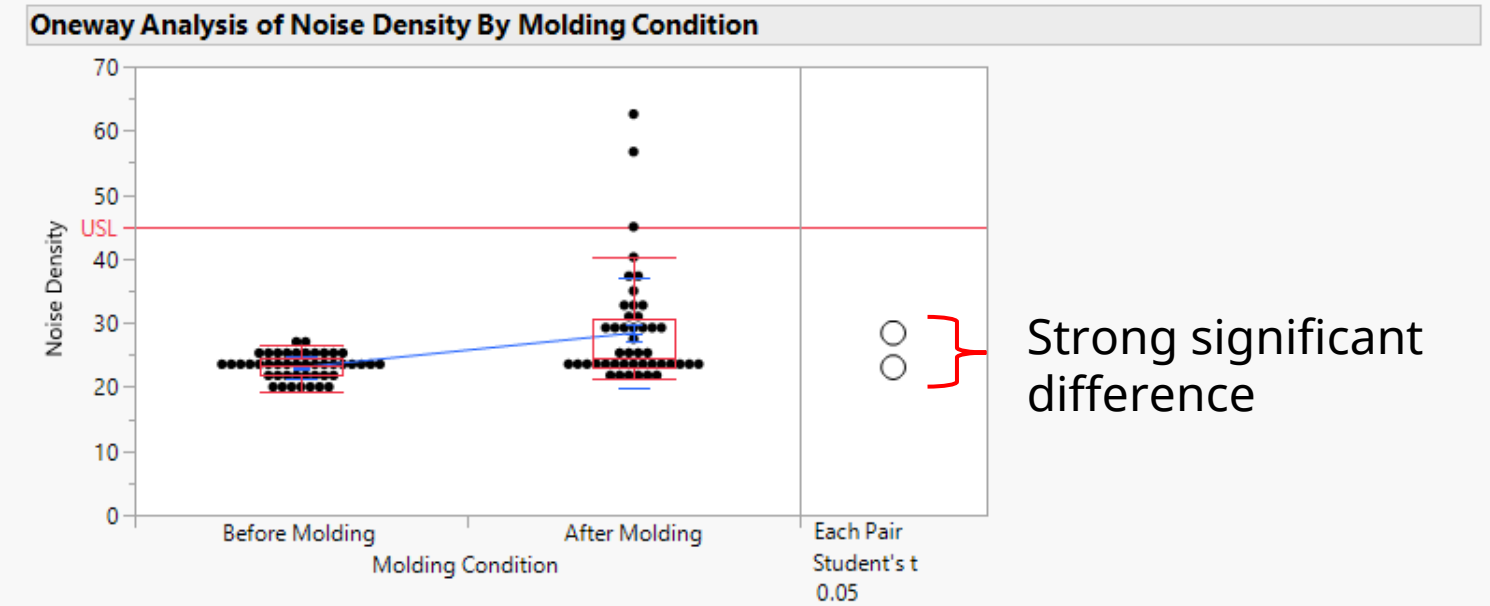
ANALYZE

- Material condition using **JMP platform: Fit Y by X**
- Molding Resin act as protector to GMR



Analyze - Before and After Molding

- Mean shifts from 23.07pT -> 28.42pT (+5.4 shift)
- Variation increases significantly after molding
  - (5x increase in noise variation: 1.81 -> 8.7
- Statistical comparison confirms molding as a major contributing factor
- P-value 0.0001 (0.01%) is a strong significant difference



Strong significant difference

Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean
Before Molding	45	23.07	1.809716	0.27
After Molding	45	28.42	8.709327	1.298

JMP Platform: Fit Y by X

Means Comparisons

Comparisons for each pair using Student's t

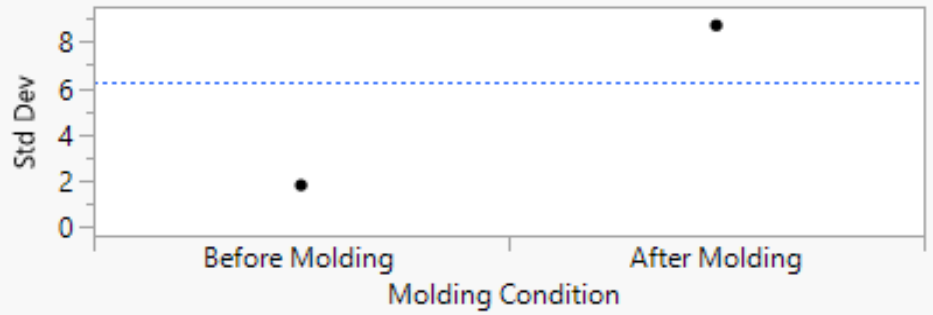
Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
After Molding	Before Molding	5.352074	1.326042	2.716843	7.987304	0.0001*

Analyze - Before and After Molding Variance

- Significant increase in noise density after molding (1.8 -> 8.7)
- Different test for equal variances shows strong significant difference
- P-value is less than 0.05

Tests that the Variances are Equal



Level	Count	Std Dev	MeanAbsDif to Mean	MeanAbsDif to Median
Before Molding	45	1.809716	1.458772	1.453904
After Molding	45	8.709327	5.880525	5.375194

Test	F Ratio	DFNum	DFDen	p-Value
O'Brien[.5]	5.1591	1	88	0.0256*
Brown-Forsythe	11.0075	1	88	0.0013*
Levene	21.1577	1	88	<.0001*
Bartlett	80.0806	1	.	<.0001*
F Test 2-sided	23.1605	44	44	<.0001*

Has Significant difference Across all variance equality check

Welch's Test

Welch Anova testing Means Equal, allowing Std Devs Not Equal

F Ratio	DFNum	DFDen	Prob > F
16.2903	1	47.792	0.0002*

t Test
4.0361

JMP Platform: Fit Y by X

IMPROVE the MATERIAL

- What’s the most suitable molding resin?

Improve – Change the Molding Material

- Remarks: Molding resin B is ideal for stress-sensitive and noise-critical applications.

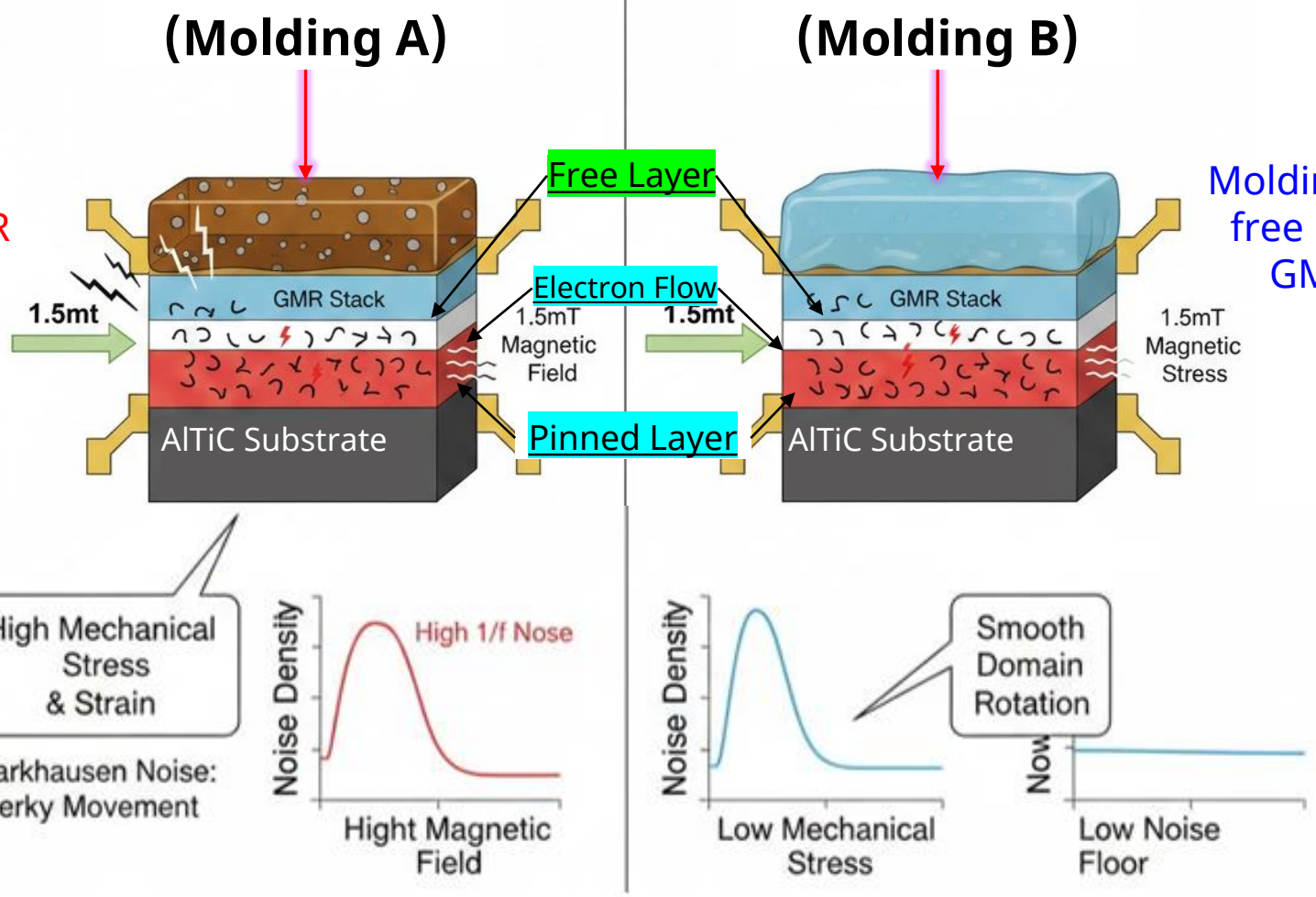
Legend:	Advantage	Slight Disadvantage	Big Disadvantage

Property / Feature	Molding Resin A	Molding Resin B	Advantage
Cure Temperature & Cure Time	100–150°C (120 mins)	100°C (60 mins)	Molding B: Lower temp faster curing time
Coefficient of Thermal Expansion (CTE)	Tg: 43 PPM/°C	Tg: 200–300 PPM/°C	Molding A: Low material expansion in extreme thermal change
Hardness (Shore)	81 D	35 A	Molding A: Easy to mold
Tensile Modulus	High MPa	Low MPa	Molding B: Very low stress applied to GMR
Volume Resistivity	> 1×10^{15} Ω·cm	1.6×10^{15} Ω·cm	Both good electrical insulation, prevents ESD damage

Improve – Change to Molding B Material

Reason: Molding A limits free layer movement, causing abnormal flow of electrons in GMR. Molding B allow movement in free layer resulting to good flow of electrons.

Molding A restrict free moving in GMR layer

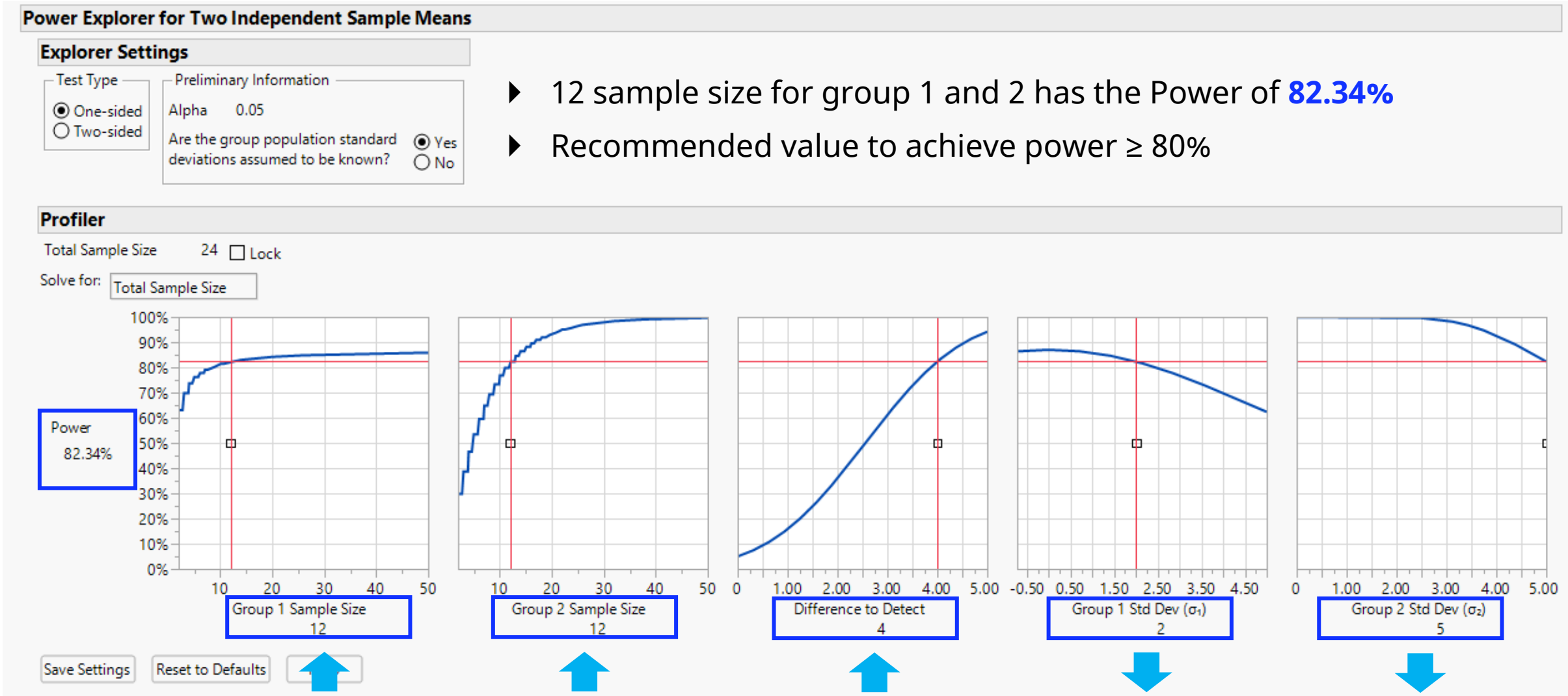


Molding B allows free moving in GMR layer

ANALYZE the QUANTITY

- Maximizing the resources, minimizing the waste using **JMP platform: Sample Size Explorer**
- **The “What If, Probability”**

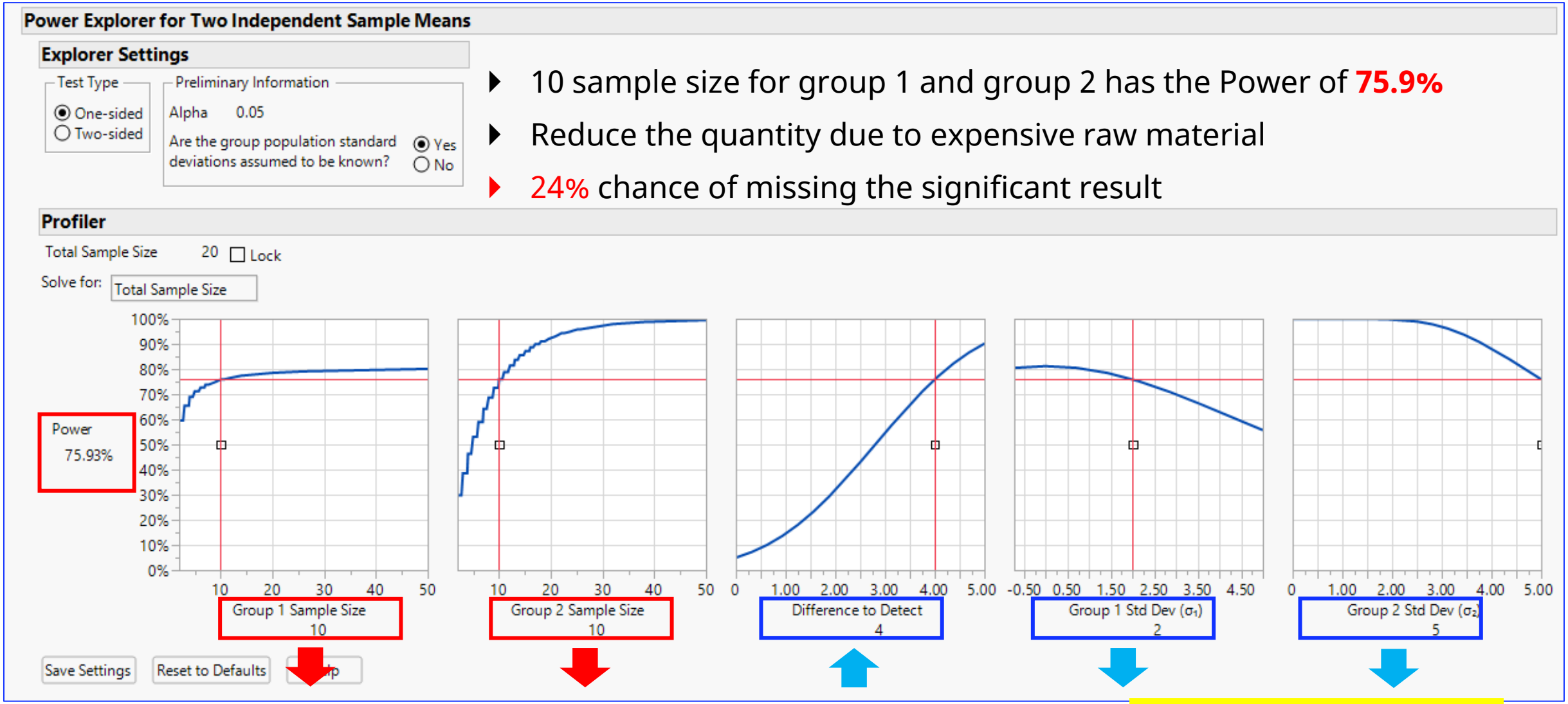
Improve – Identify Sample Quantity



- 12 sample size for group 1 and 2 has the Power of **82.34%**
- Recommended value to achieve power ≥ 80%

JMP Platform: Sample Size Explorer

Improve – Identify Sample Quantity

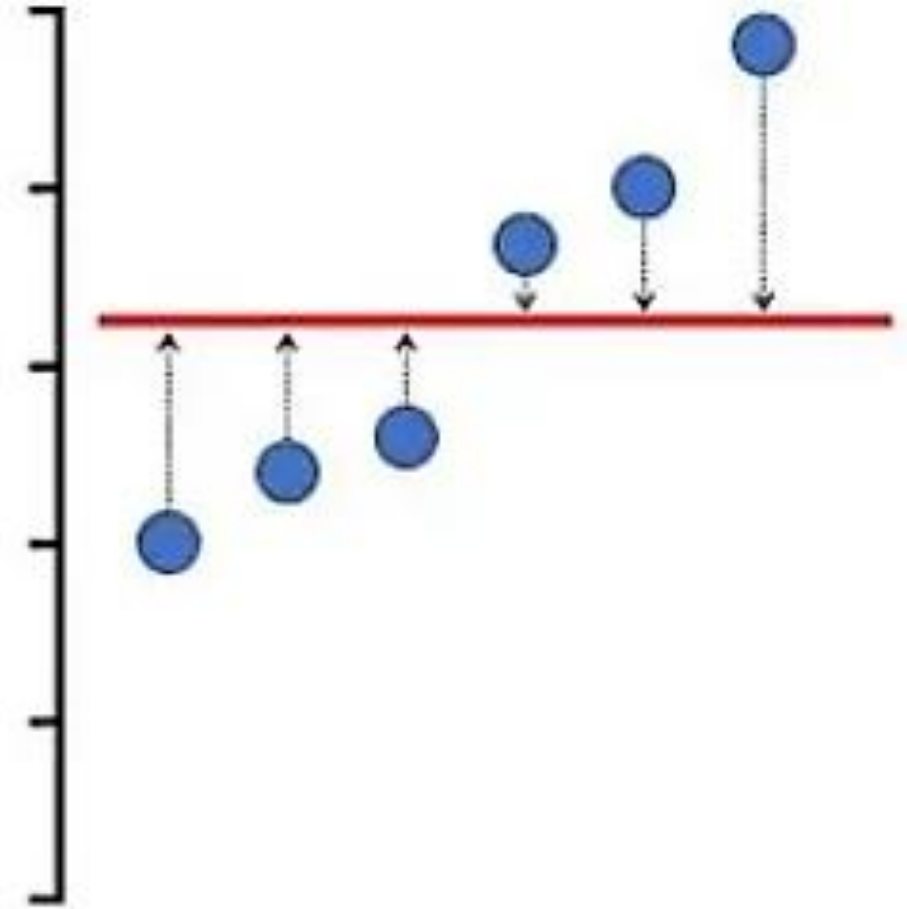


- 10 sample size for group 1 and group 2 has the Power of **75.9%**
- Reduce the quantity due to expensive raw material
- 24% chance of missing the significant result

JMP Platform: Sample Size Explorer

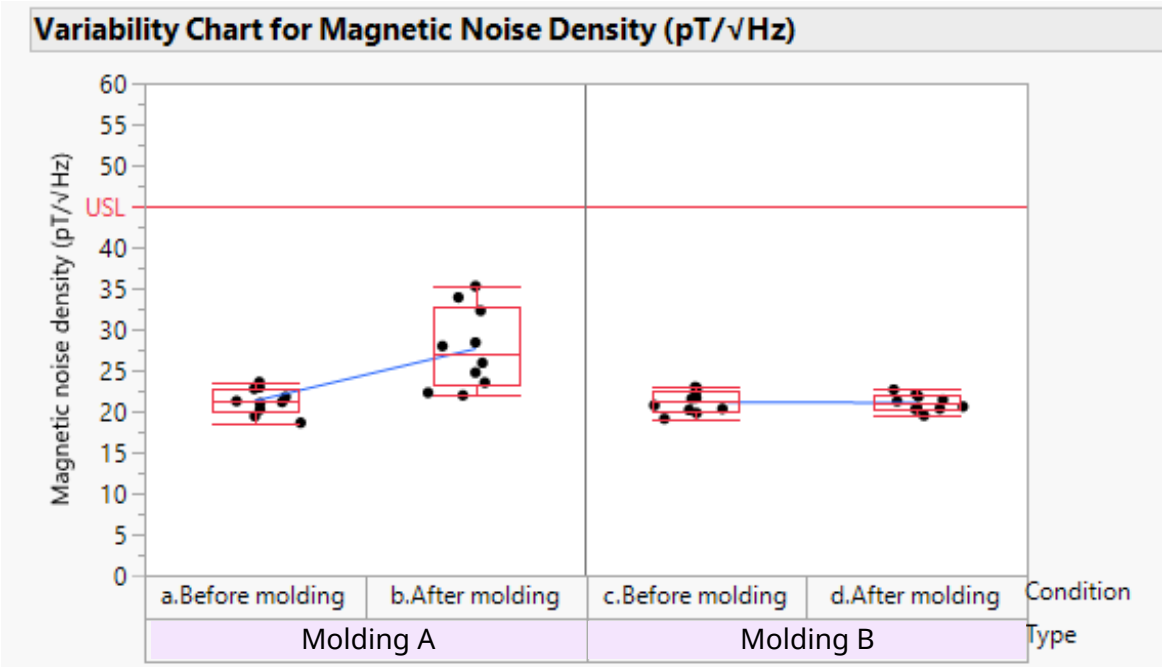
ANALYZE the RESULT

- Compare the molding material and the molding condition using JMP platform: Variability Chart



Analyze –Molding A and Molding B

- Molding A: Mean shift after molding process
  - Mean 21.27pT -> 27.62pT (+6.35 change)
- Molding B: Remains stable after molding process
  - Mean 21.14pT ->21.04pT (-0.10 change)



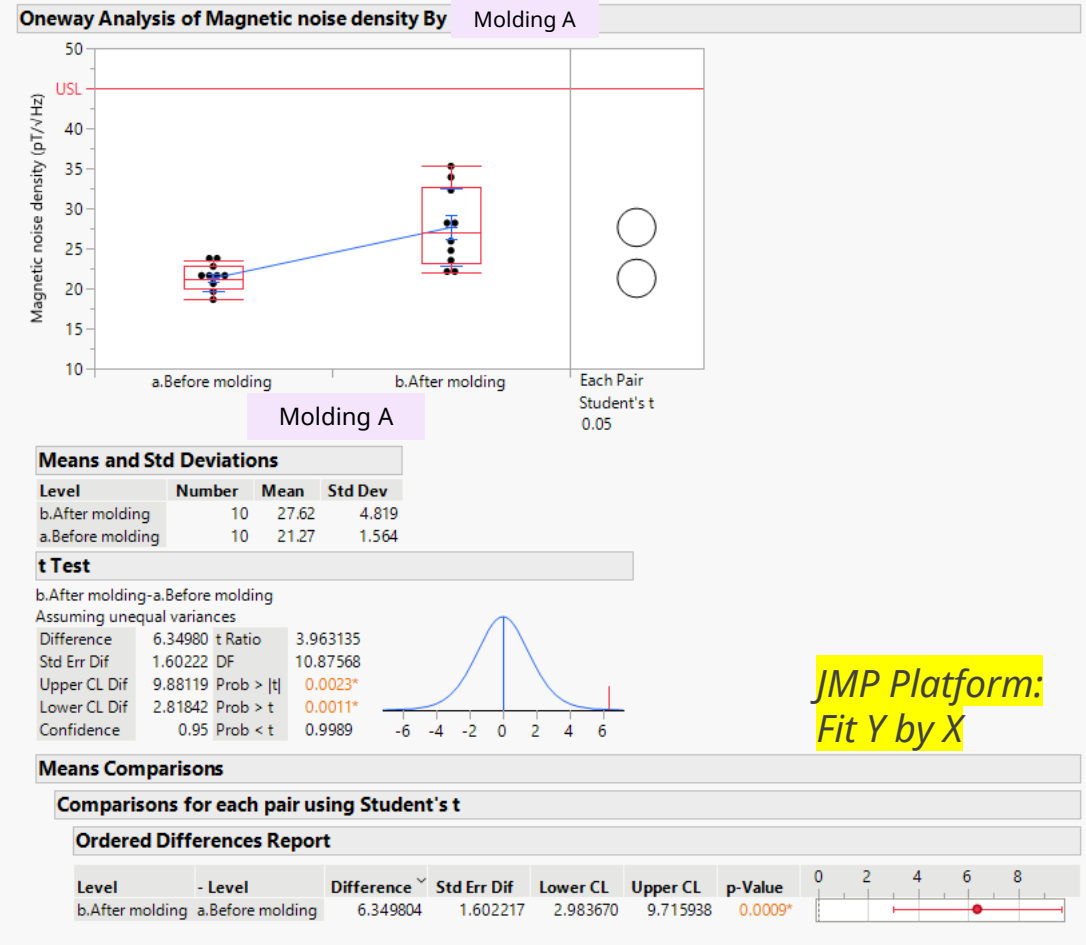
Variability Summary for Magnetic noise density at 1Hz (pT/√Hz)

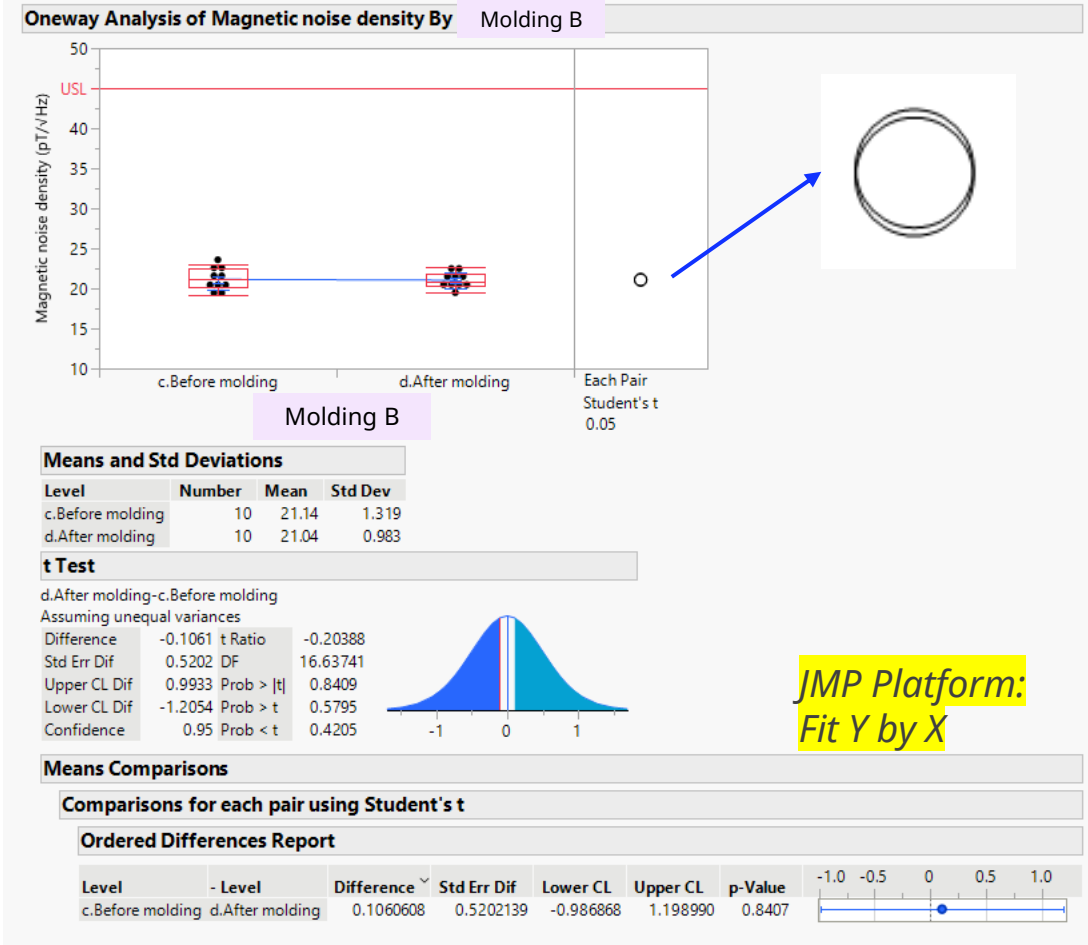
	Mean	Std Dev	CV	Std Err Mean
Magnetic noise density at 1Hz (pT/√Hz)	22.77	3.82	16.79	0.604
Type[Hard Molding]	24.45	4.77	19.52	1.067
Type[Soft Molding]	21.09	1.13	5.374	0.253
Type[Hard Molding] Condition[a.Before molding]	21.27	1.56	7.353	0.495
Type[Hard Molding] Condition[b.After molding]	27.62	4.82	17.45	1.524
Type[Soft Molding] Condition[c.Before molding]	21.14	1.32	6.239	0.417
Type[Soft Molding] Condition[d.After molding]	21.04	0.98	4.671	0.311

JMP Platform: Variability Chart

Analyze – Molding A and Molding B

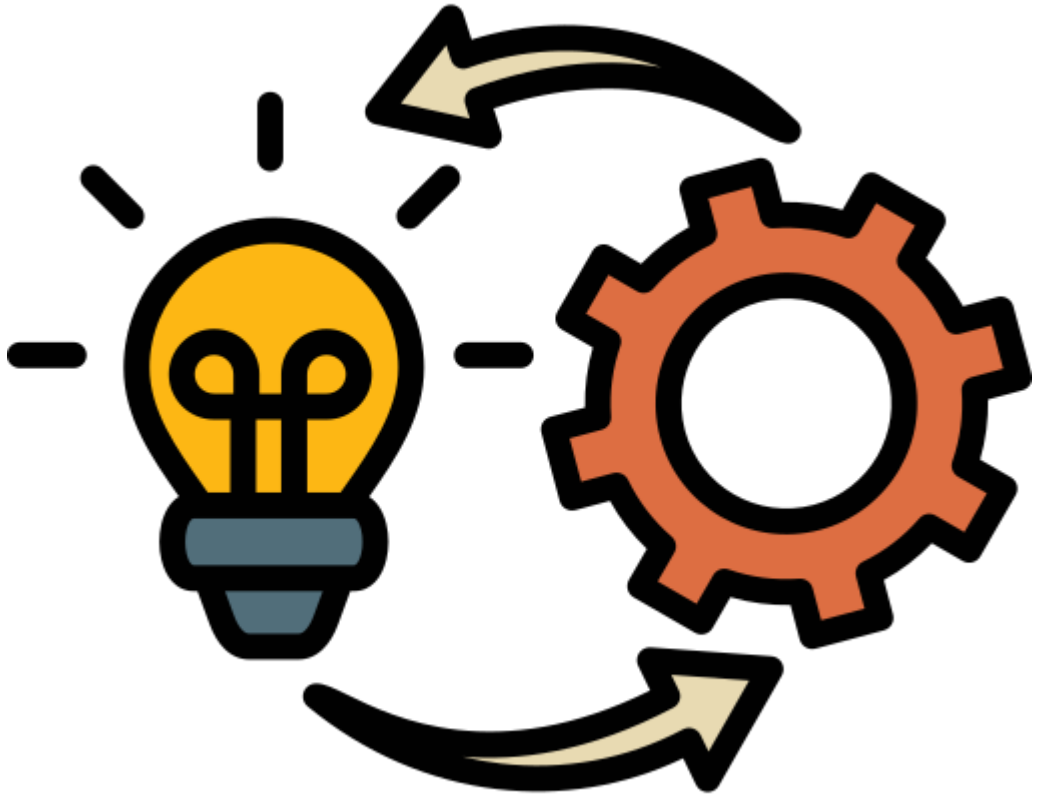
- Molding A has strong significant difference; Molding B almost no variation.





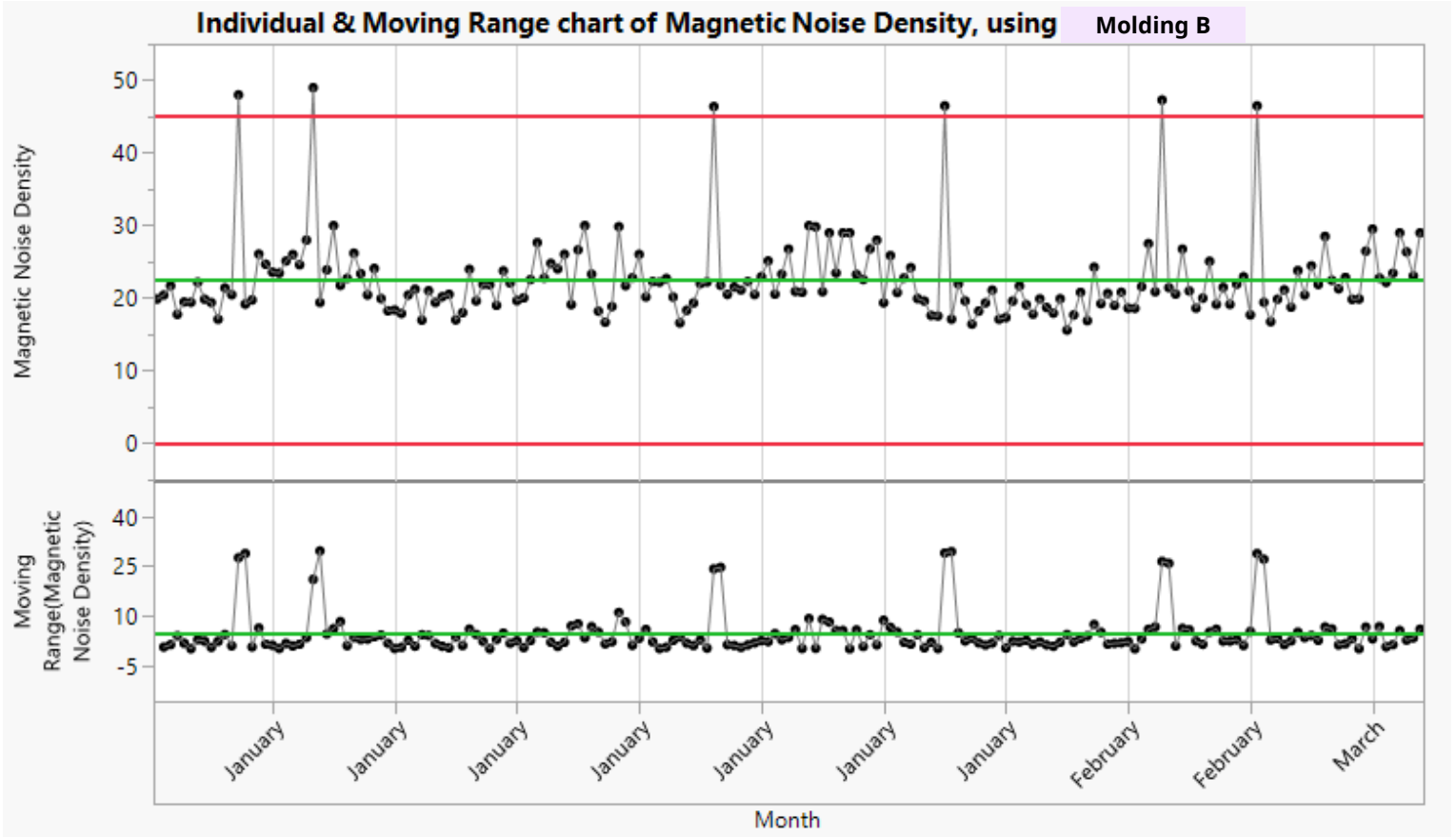
CONTROL

- Implementing Molding B Resin



Control – Implementation of Molding B Resin

- 96.7% of data points are within the specified range.
  - Mean 22.5 pT (excellent mean and in target)
- Defect rate lowered
  - 12% → 3.2%
- Molding B resin is **effective**



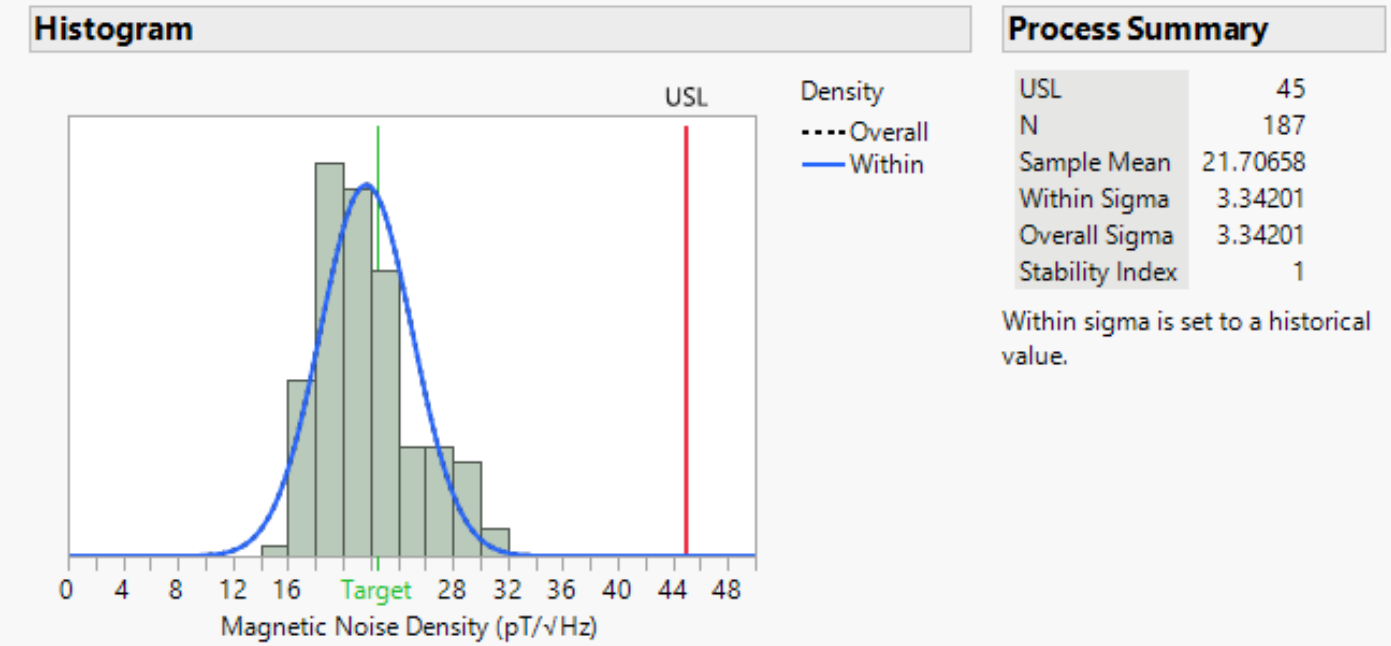
Magnetic Noise Density Limit Summaries

Points plotted	LCL	Avg	UCL	Limits Sigma	Subgroup Size
Individual	0	22.5	45	User Defined	1
Moving Range	.	4.546828	.	Moving Range	1

JMP Platform: Control Chart Builder

Control – Implementation of Molding B Resin

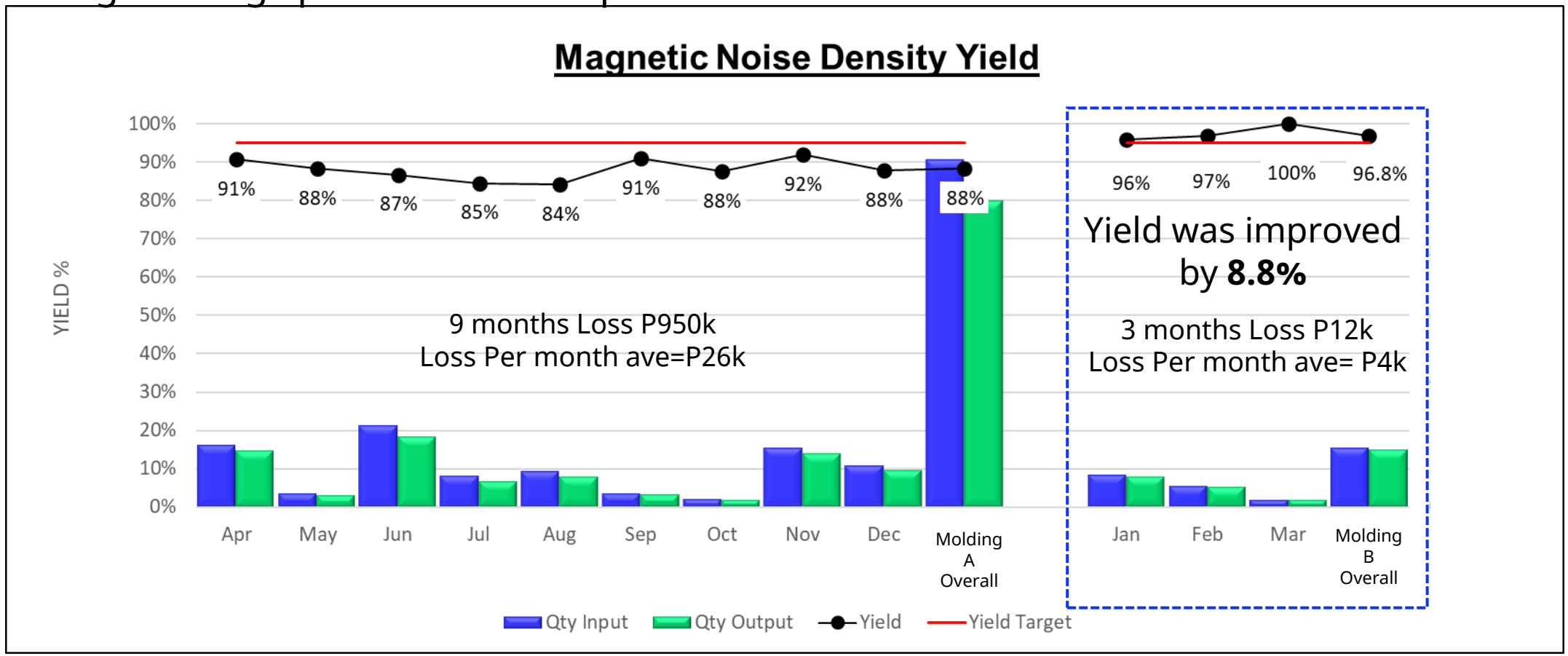
- Mean is close target
  - -0.8 difference
- Bell curve is balance and narrow
- Great process capability
  - 2.32 Cpk



JMP Platform: Distribution

Yield – After Implementation of Molding B Resin

- Yield: From 88% → 96.8%, improved by 8.8%
- Average savings per month → Php22k



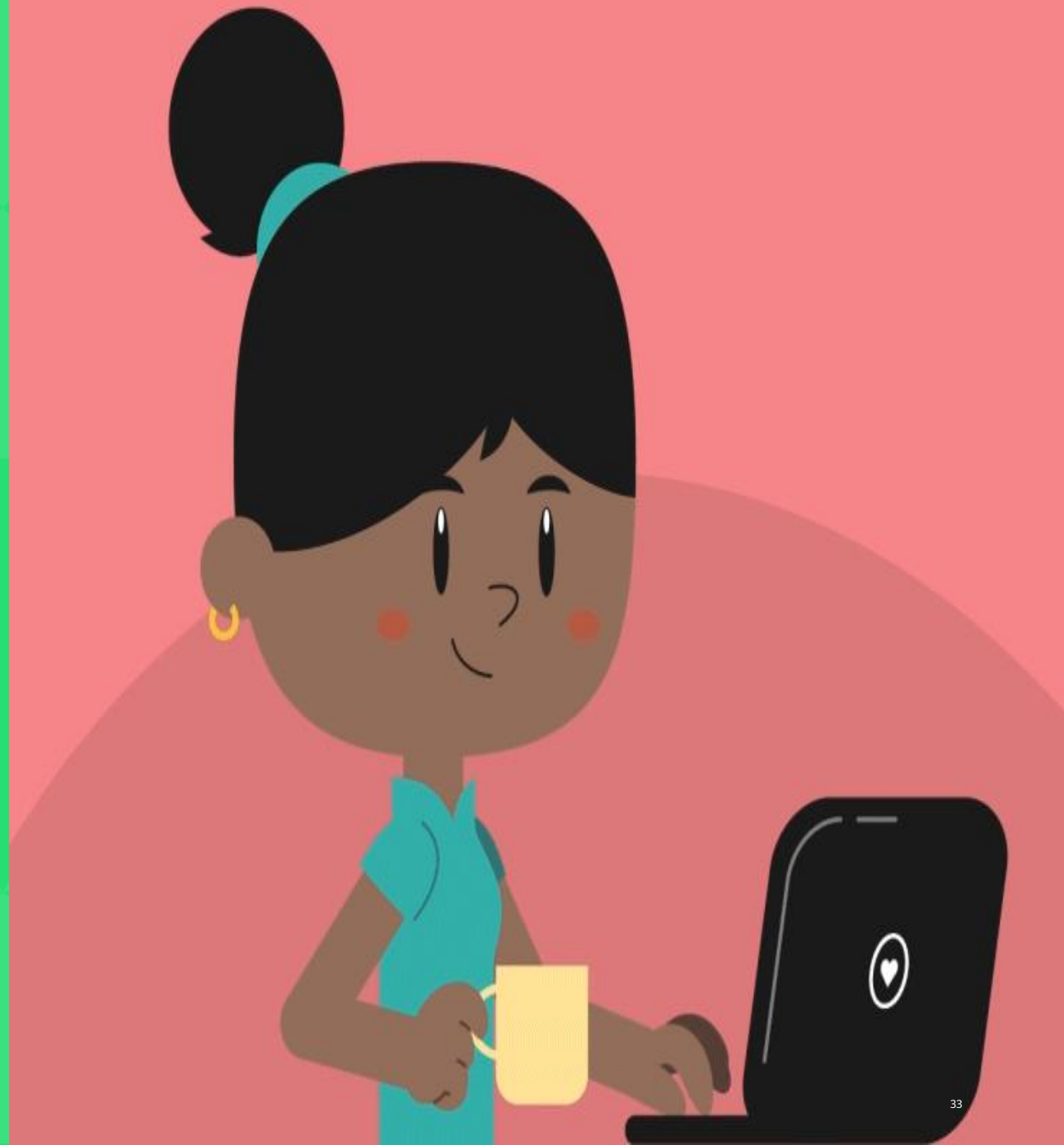
Conclusion

- Molding B resin is effective in improving the yield of magnetic noise density, thus reducing waste and cost.

- JMP recommends appropriate sample quantity prior evaluation sample build.
- It provides great graphical representation and detailed analysis.

USER Experience

- How do I find JMP as a statistical tool?



User Experience

- I love the Red Triangles 
  - Reveals options relevant to our current steps
  - Easy to navigate instead of finding through top-level ribbons
- The distribution platform in just seconds
  - With just few clicks and ticks you have the mean, Stdev, Cpk, Failure rate, ect.
- Great data visualization

Thank you

TDK In Everything, Better

TDK

In Everything, Better