

OJT Resource: Control Charts for Mass Calibrations

(Based on NIST SOP 9 – Control Charts for Calibration Laboratories)

Purpose

This resource explains how to create, read, and maintain control charts for monitoring your mass calibration process. It's written in plain language to support on-the-job training (OJT) and ensure every technician understands how control charts help detect drift, instability, or problems before they impact measurement results.

Why Control Charts Matter

Control charts are like a health monitor for your calibration process.

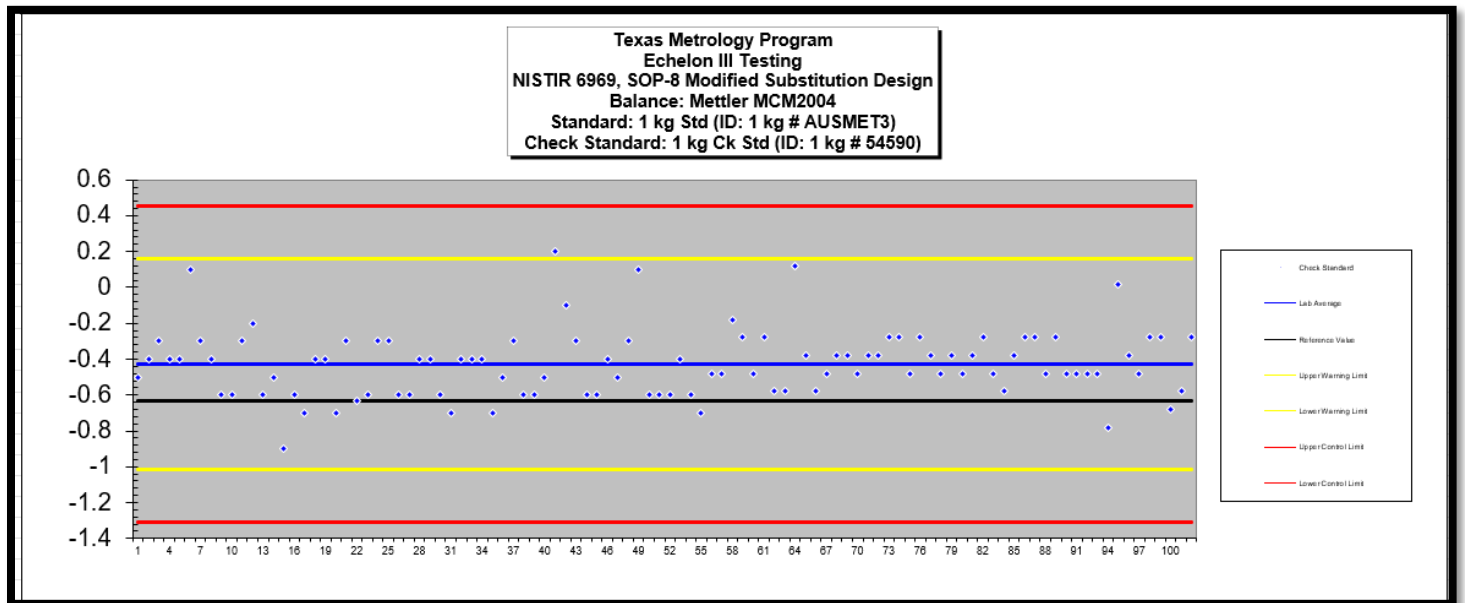
They help answer:

- Is my process stable over time?
- Are my standards and check standards stable or damaged?
- When do I need to recalibrate or investigate something unusual?

Control charts calculate components for your Uncertainty:

- s_p – Standard Deviation of the process
- u_d – bias (if your check standard is calibrated)
- k factor – degrees of freedom from the control chart determine the coverage factor when expanding uncertainty

Control charts show whether your balance, environment, or process is performing normally or if something's off.



Example Control Chart

What You'll Need

- Check Standard(s): A stable weight or artifact similar to the unknown
- Balance/Comparator: The same instrument used for measurements.
- Recorded Data: Routine check standard results (usually in mg or g).
- Spreadsheet or Software: To plot and calculate control limits.



Photos of staged Standards and Check Standards

Step-by-Step: How to Create a Control Chart

Step 1. Collect Data

Use your check standard in the same way each time, in accordance with the SOP. You may want to vary what position you measure the check standard in SOP 8.

Record the result after each check standard measurement.

You will need 7 - 12 data points to create initial control limits because it provides a statistically sound baseline for identifying process stability, allowing for the detection of special cause variation without having too few points (which would make limits unreliable).

25 or more data points are needed to create a statistically valid control chart and accurately report process uncertainty.

Reference Check Standard Control Data					
Initials	Date	Nominal Value	Count	Zero Shift Value	Check Standard Value
kw	11/3/2025	0.05 lb	1	-0.01	3.431
ks	11/4/2025	0.05 lb	6	-0.02	3.431
kw	11/5/2025	0.05 lb	1	0	3.431
kw	11/3/2025	0.1 lb	1	0.01	3.83
ks	11/4/2025	0.1 lb	6	0.01	3.8
kw	11/5/2025	0.1 lb	1	0.01	3.82
kw	11/3/2025	0.2 lb	2	0.01	6.332
ks	11/4/2025	0.2 lb	10	0.05	6.322
kw	11/5/2025	0.2 lb	2	-0.02	6.322
he	10/28/2025	1 oz	1	0	0.588
ks	11/4/2025	1 oz	3	-0.01	0.578
kw	11/5/2025	1 oz	1	0.01	0.598
kw	11/5/2025	100 g	1	-0.01	0.219
he	10/28/2025	2 oz	1	-0.01	-0.505
ks	11/4/2025	2 oz	1	-0.15	-0.515
kw	11/5/2025	2 oz	1	-0.02	-0.525
ks	11/4/2025	200 g	2	0.02	14.486
kw	11/5/2025	200 g	2	-0.03	14.456
he	10/28/2025	4 oz	1	0	-2.3
ks	11/4/2025	4 oz	3	-0.03	-2.34
ks	11/4/2025	4 oz	4	0.01	-2.45
ks	11/4/2025	4 oz	1	0.01	-2.27
kw	11/5/2025	4 oz	1	-0.01	-2.32
kw	11/5/2025	50 g	1	-0.02	0.233

Collection of Check Standard Measurement Results

Step 2. Calculate the Average and Standard Deviation

In Excel or your software, calculate:

- Mean ($\bar{x}$): The average of all your data points.
- Standard Deviation (s): The typical amount your data varies.

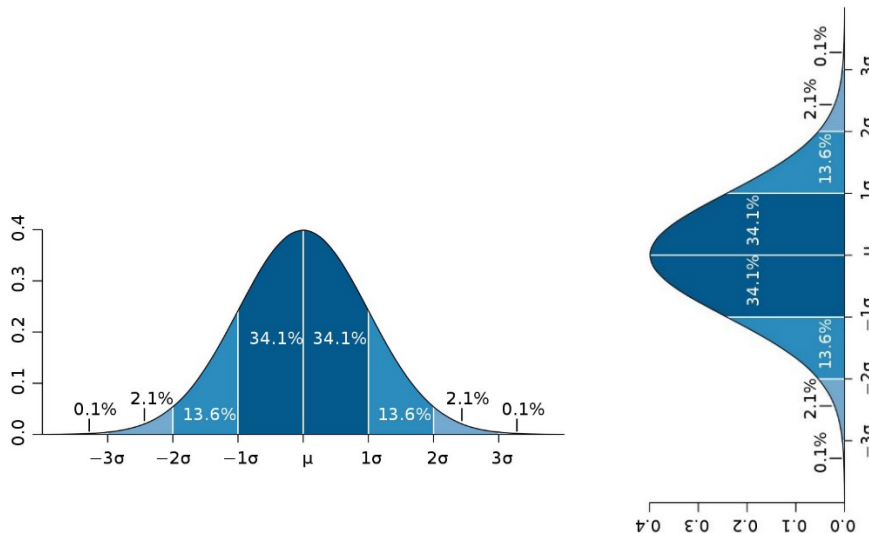
These form the basis for your control limits.

Laboratory: Texas Department of Agriculture					Mass Nominal Value: 2				Nominal Value Unit: g			
Check ID Code: 2 g #179350 (3-1 CKSTD)					Specification: ASTM E 617				Class: ASTM 2			
Check Description: 2 gram weight					MPE = 0.000054 g				CC MPE % = 0%			
Balance ID Code: MCM36					Chk Std TM (g) = 2.00000716							
Balance Description: Mettler					Chk Std Mean (g) = 2.000006995				K Factor			
Procedure: SOP 5					Number of Values = 51				2.051251			
Parameter: Mass Echelon II					Std Dev. (g) = 4.78234E-06							
Control Chart Unit: g					Std Bias / Drift (g) = -1.64611E-07							
					Best Unc. (k=2) = 0.000004				Precision Test (P _n) = 0.22			
Tech. Initials	Date	Nominal	Check Observed Value	Balance ID	Start Temp. (° C)	Finish Temp. (° C)	Start Pressure (g/cm³)	Finish Pressure (g/cm³)	Start Humidity (% RH)	Finish Humidity (% RH)	Average Air Temp. (° C)	
lc	8/18/2025	2 g	2.000007167 MCM36		20.89	20.9	750.188	750.175	52.58	52.41	20.895	
lc	8/18/2025	2 g	2.000003 MCM36		20.91	20.81	750.175	748.503	51.99	51.6	20.86	
ks	8/20/2025	2 g	2.0000075 MCM36		20.82	20.77	748.68	748.9	51.3	52.91	20.795	
ks	8/20/2025	2 g	2.000007333 MCM36		20.72	20.7	748.865	747.831	51.82	51.17	20.71	
kw	8/21/2025	2 g	2.000007 MCM36		20.83	20.82	748.082	748.167	51.26	51.12	20.825	
kw	8/21/2025	2 g	2.0000085 MCM36		20.84	20.82	748.106	748.11	51.48	51.47	20.83	
he	8/18/2025	2 g	2.000011168 MCM36		20.78	20.8	747.785	748.787	54.19	54.23	20.79	
he	8/18/2025	2 g	2.0000085 MCM36		20.78	20.81	747.785	747.791	54.19	53.98	20.795	
lc	9/2/2025	2 g	2.000008333 MCM36		20.81	20.92	750.025	750.8	50.87	50.81	20.865	
lc	9/2/2025	2 g	2.000012667 MCM36		20.92	20.95	750.099	750.106	50.82	50.77	20.935	
he	9/2/2025	2 g	2.000007667 MCM36		20.95	20.84	750.079	750.134	50.82	51.34	20.895	
he	9/2/2025	2 g	2.000008667 MCM36		20.84	20.77	750.118	750.014	51.36	51.6	20.805	
he	9/2/2025	2 g	2.000005333 MCM36		20.7	20.58	750.033	749.965	51.52	51.82	20.64	
lc	9/2/2025	2 g	2.000006833 MCM36		20.58	20.55	749.967	749.965	51.81	51.88	20.565	

Step 3. Establish Control Limits

- Upper Warning Limit (UWL): $\bar{x} + 2s$
- Lower Warning Limit (LWL): $\bar{x} - 2s$
- Upper Control Limit (UCL): $\bar{x} + 3s$
- Lower Control Limit (LCL): $\bar{x} - 3s$

These limits tell you what's "normal" variation versus "out of control."



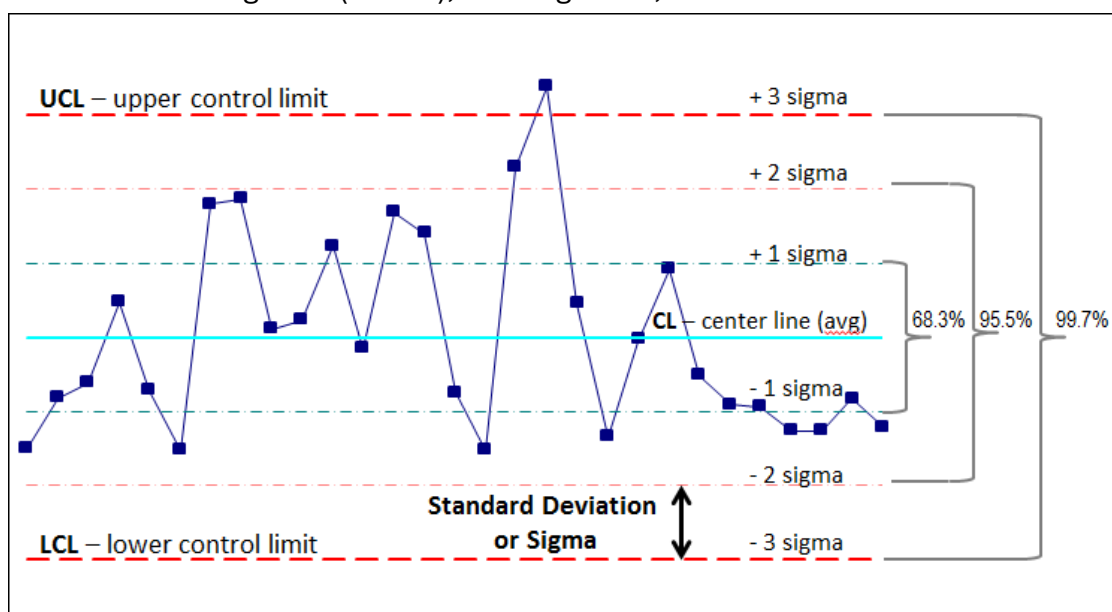
Examples of Gaussian Curves (normal distribution)

Step 4. Plot the Data

Create a line chart:

- X-axis = Date or Run Number
- Y-axis = Measurement Value (Deviation from nominal)

- Draw the average line (center), warning limits, and control limits.



Plotted Data with limits

Step 5. Add New Data Over Time

Each time you measure your check standard, add the new point to the chart.

Watch for trends — not just points outside limits.

How to Read Your Control Chart

Observation	What it Means	What to Do
One point outside $\pm 3s$	Process may be out of control	Investigate immediately, the system is out of control. Data is rejected, corrective actions must be taken and re-attainment of statistical control demonstrated before data may be accepted
Two consecutive points outside $\pm 2s$	Possible drift starting	Check balance/environment
7 points in a row trending up or down	Systematic change	Review of recent updates or changes
Sudden Jump in data	Something changed abruptly	Check balance, air currents, standard, check standard
Random scatter within limits	Normal Variation (in control)	Continue monitoring

Maintaining and Reviewing Control Charts

Update the chart after each check standard measurement.

Review monthly, quarterly (or per internal processes) for trends.

Recalculate limits annually or if you make a significant equipment change.

Document all investigations and corrective actions.

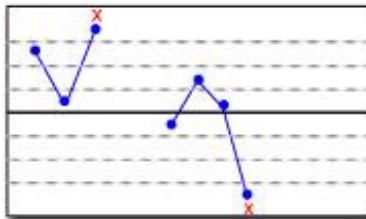
Additional Resources

- NIST SOP 9
- NIST SOP20
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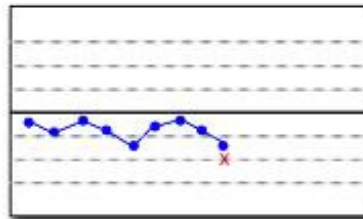
Troubleshooting Trends and Issues

General Rules for Detecting Out of Control or Non Random Situations¹

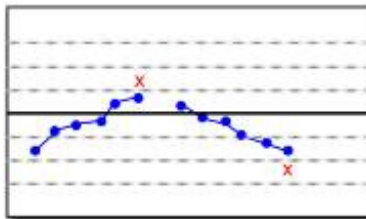
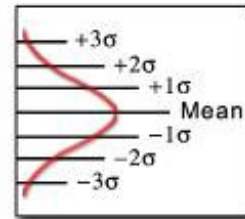
The WECO rules are based on probability. We know that, for a normal distribution, the probability of encountering a point outside ± 3 is 0.3%. This is a rare event. Therefore, if we observe a point outside the control limits, we conclude the process has shifted and is unstable. Similarly, we can identify other events that are equally rare and use them as flags for instability. The probability of observing two points out of three in a row between 2 and 3 and the probability of observing four points out of five in a row between 1 and 2 are also about 0.3%.



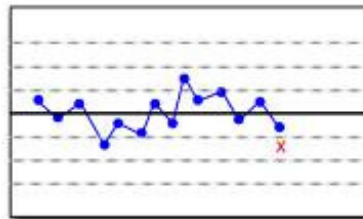
Any point outside of $\pm 3\sigma$



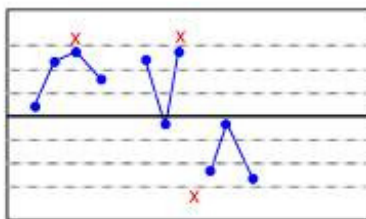
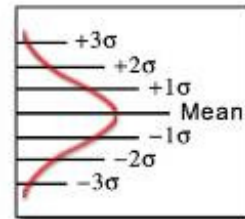
Eight consecutive points on one side between control line and 1σ .



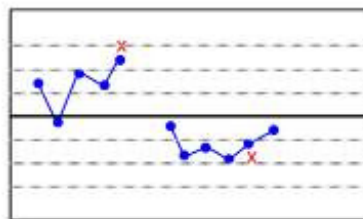
Six points on a row trending up or down.



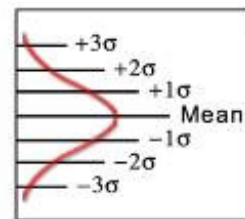
14 points in a row alternating up and down.



Two of the last three points are above or below 2σ .



Four of the last five points above or below 2σ .



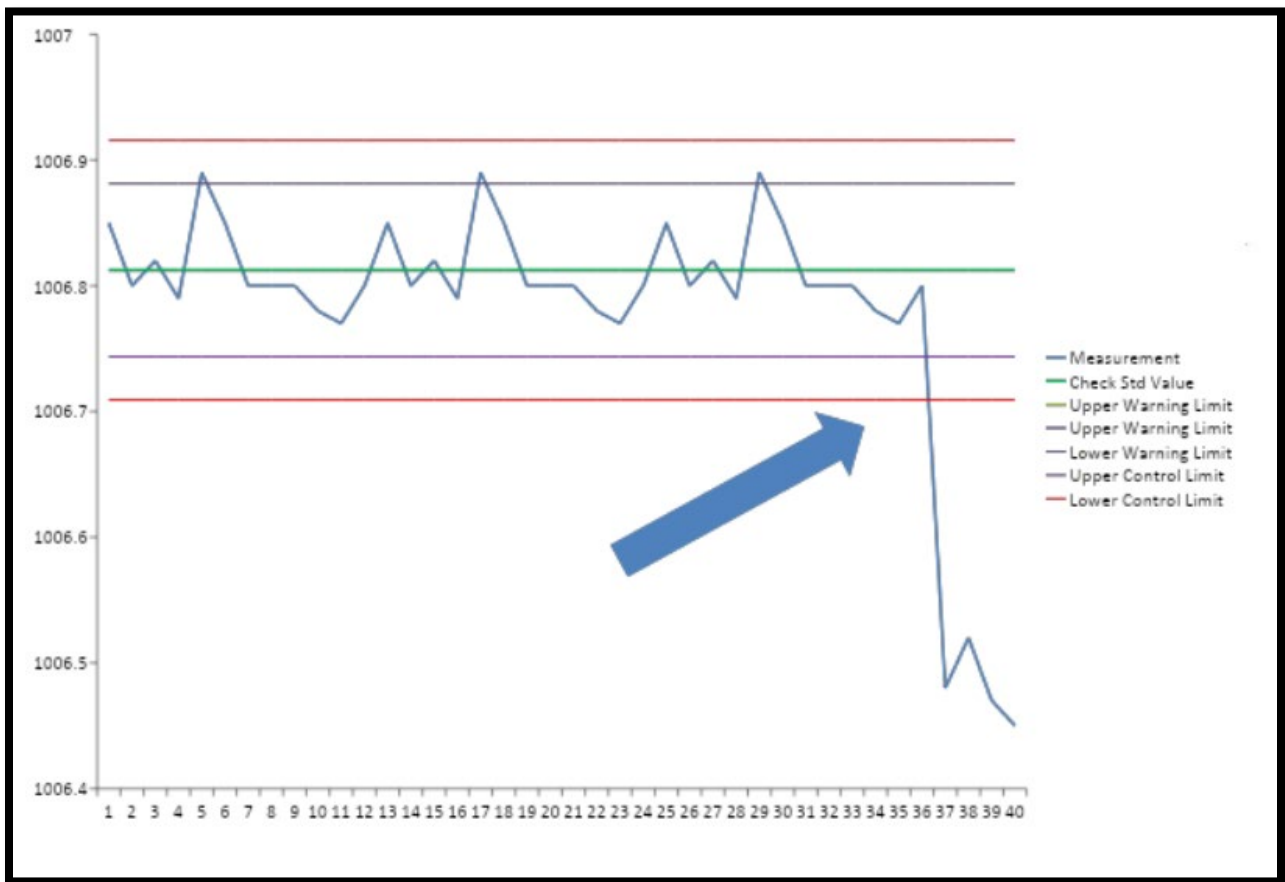
¹NIST/SEMATECH e-Handbook of Statistical Methods, <http://www.itl.nist.gov/div898/handbook/>, 2003.

Scenario 1: If Data Shifts Up or Down

Possible cause: Balance drift, environmental change, or check standard contamination.

Action:

- Verify balance calibration.
- Reclean and reweigh the check standard.
- Review temperature/humidity logs.

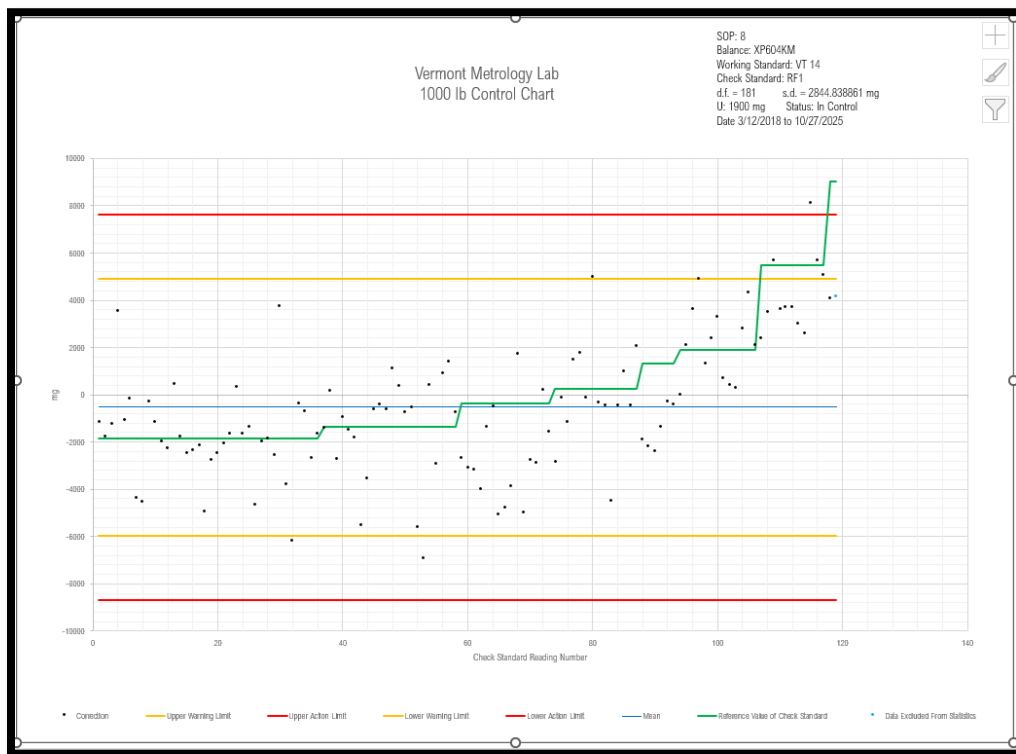


Scenario 2: If Data Shows Gradual Drift

Possible cause: Slow drift in balance performance, air buoyancy changes, or mass aging.

Action:

- Verify environmental stability.
- Check that the balance is level and not moving.
- Compare results to a secondary standard.

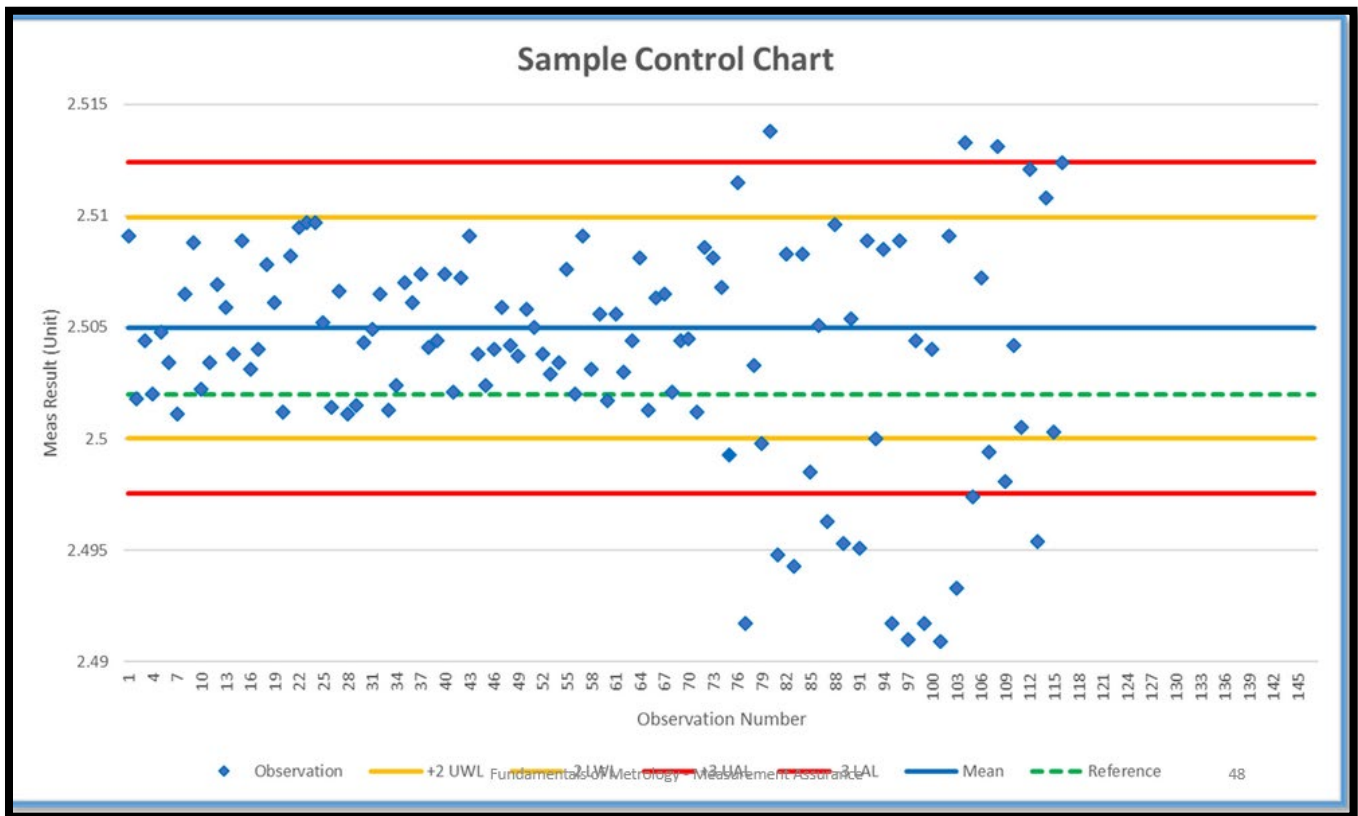


Scenario 3: If Data Becomes More Scattered

Possible cause: Operator inconsistency, unstable environment, or worn balance.

Action:

- Tighten procedural consistency.
- Monitor vibration or temperature fluctuations.
- Schedule preventive maintenance.



Scenario 4: If a Single Point Is Out of Limits

Possible cause: Operator error, data entry error, static, or random event.

Action:

- Recheck the data entry.
- Repeat the measurement.
- If still out of control, investigate before continuing.

