Monitoring the Performance of Laboratory Standards

A study of techniques for the intermediate checking of standards as required in ISO 17025

The reference multimeter as a tool for

monitoring precision sources

Session Topics

- Benefits of monitoring a lab's standards
- The control chart tool
- Monitoring alternatives for lab standards
- Using a reference DMM to monitor a calibrator
- Making decisions on monitoring trends
- Considering actual performance of a standard
- Using additional standards to complete the monitoring process

Benefits Of Monitoring Laboratory Standards

Why is monitoring important?

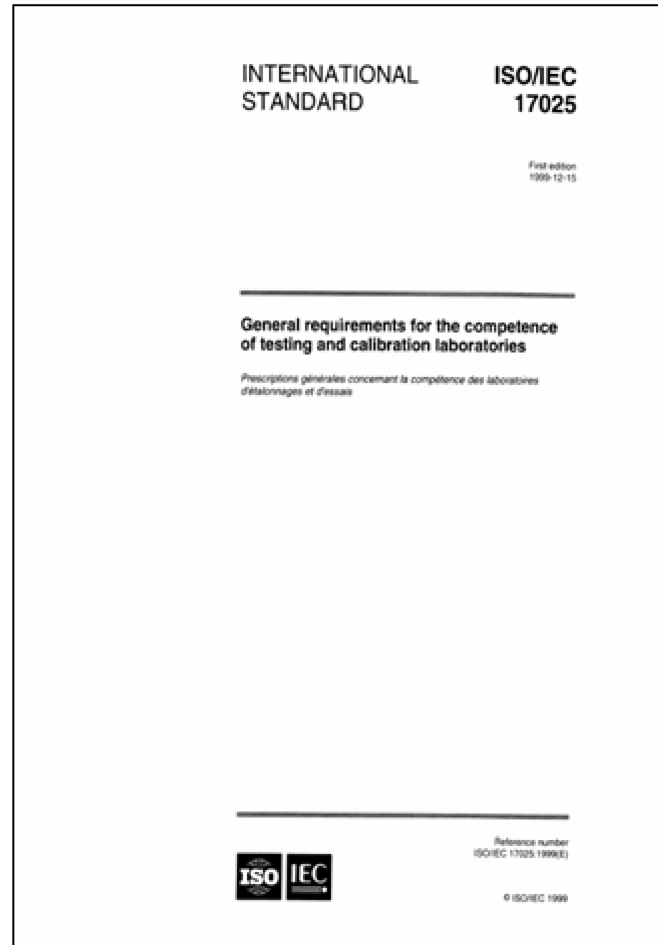
- DRIFT: Calibration instruments' performance always changes over time and with usage.
- Instruments usually perform much better than their specifications, but with long term drift, eventual out-of-spec performance is possible.
- RANDOM FAILURES: A few instruments will have random failures, which also cause out-of-spec operation.
- Out-of-specification performance causes calibration measurements and tests to be wrong.
- The cost of wrong or incorrect calibration test decisions can be significant.
  - Incorrectly failing a good instrument has minor costs to the organization and instrument user.
  - Incorrectly passing a failed instrument can have serious costs.
- A process to detect a marginal/incorrect calibration instrument is critical to maintaining quality with minimal costs.

ISO 17025 Recognizes the Need for Intermediate Checks

Section 5.6.3.3

Intermediate checks –

Checks needed to maintain confidence in the calibration status of reference, primary, transfer or working standards and reference materials shall be ***carried out according to defined procedures and schedules.***



Metrology Accreditation Requires Ongoing Measurement Assurance

Measurement assurance as defined in NIST's Handbook 150, NVLAP Procedures & General Requirements, section 1.5.28 –

Measurement assurance: Process to ensure adequate measurement results that may include, but is not limited to:

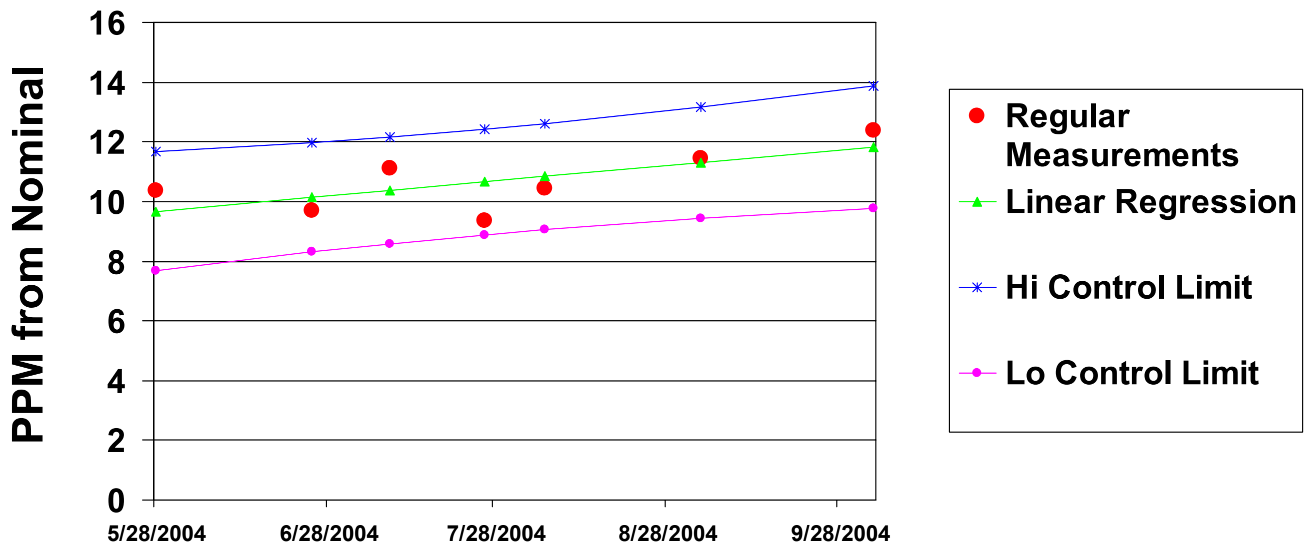
1) **use of good experimental design principles** so that the entire measurement process, its components, and relevant influence factors can be well-characterized, monitored, and controlled;

2) **complete experimental characterization** of the measurement process uncertainty including statistical variations, contributions from all known or suspected influence factors, imported uncertainties, and the propagation of uncertainties throughout the measurement process; and

3) **continuously monitoring** the performance and state of statistical control **of the measurement process** with proven statistical process control techniques including **the measurement of well-characterized check standards** along with the normal workload and the use of appropriate **control charts**.

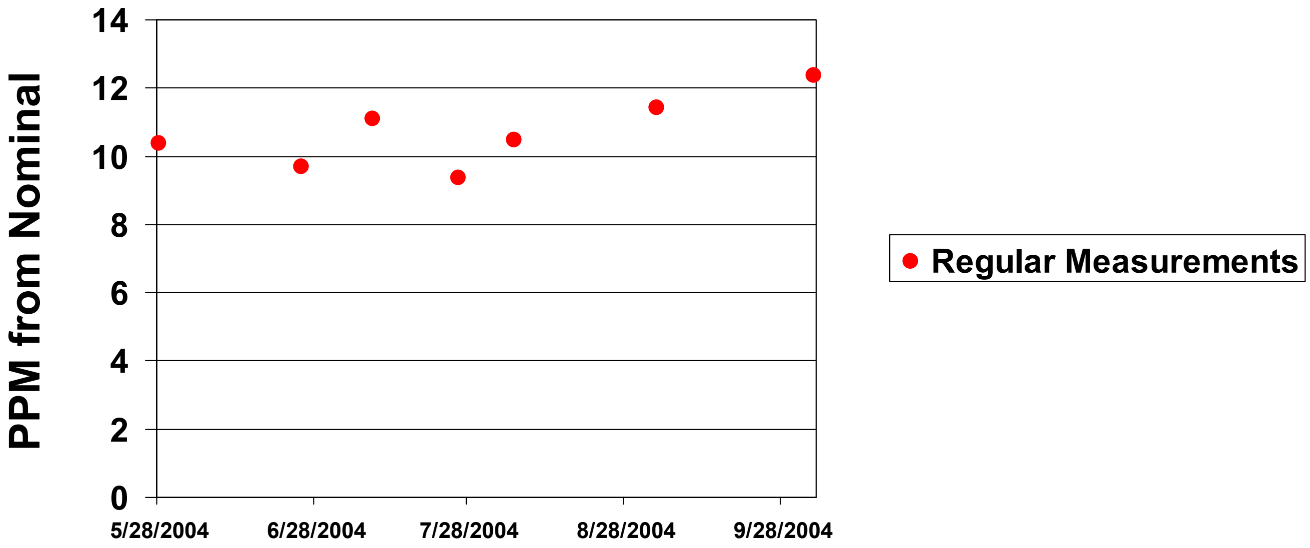
The Control Chart Tool

- Here is an example of a control chart for one point on a regularly verified Fluke Primary Lab check standard (a 5720A calibrator used for production quality SPC).
- It charts one of 200 individually measured points that are routinely tracked on the standard.



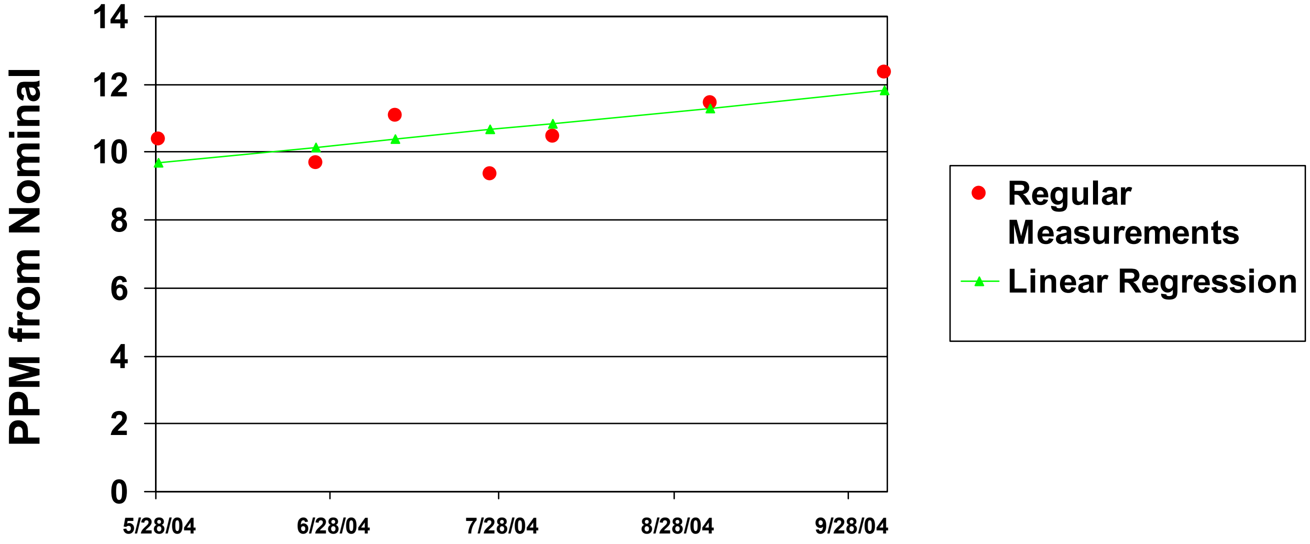
Tracking Individual Measurements

- The standard is measured regularly and graphed to illustrate the historical measured values.
- The metrologist determines the appropriate measurement criteria (measurement value, techniques, interval, etc.).
- In this instance, the graph follows the standard's differences in ppm from a nominal of value of 2 Volts at 40 Hz.



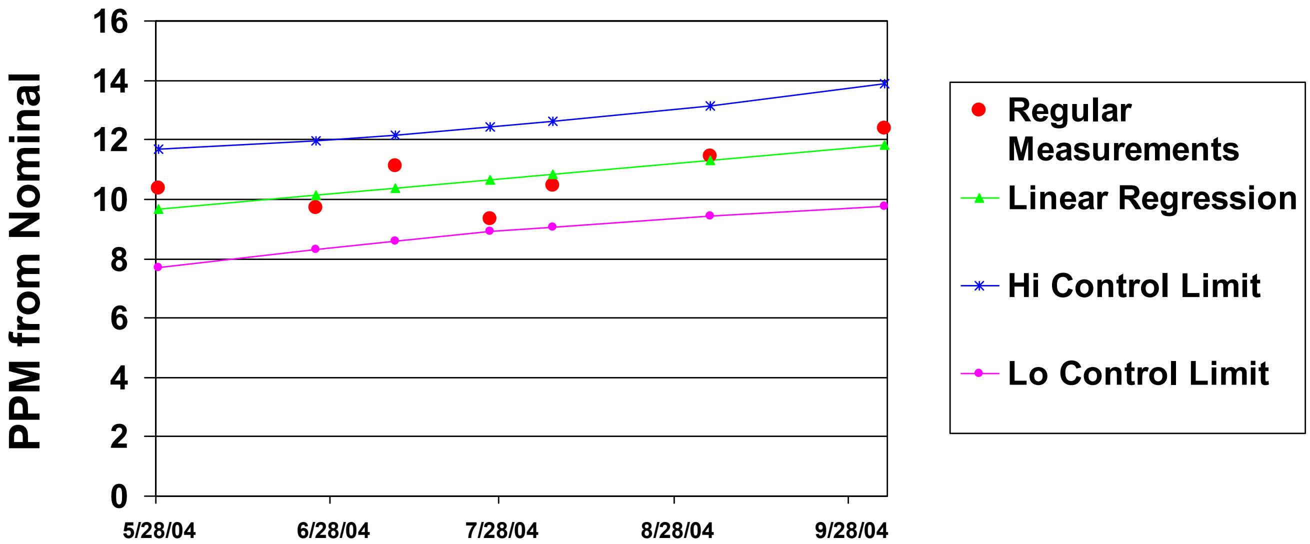
Understanding Drift and Change Using Linear Regression

- A linear regression line is calculated to assist in estimating the normal drift rate and future values.
- The metrologist designs the analysis process to best fit the individual situation.
- In this example, it is a linear regression of the last seven measurements.



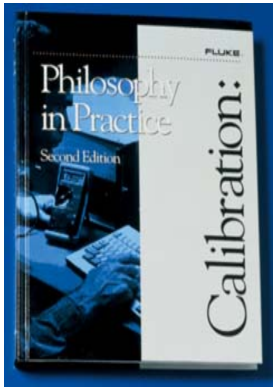
Drift Evaluation Using Control Limits

- Upper and lower control limits are used to indicate whether or not an individual measurement needs to be evaluated for any out-of-control situations, measurement errors, etc. (It is not an absolute pass/fail threshold.)
- The limits are determined by the metrologist to best fit the individual situation.
- In this situation, the limits are set to bound the average of the last seven measurements as expanded to a 95 % confidence limit, using the Students'-T distribution for six degrees of freedom.



Control Chart Summary

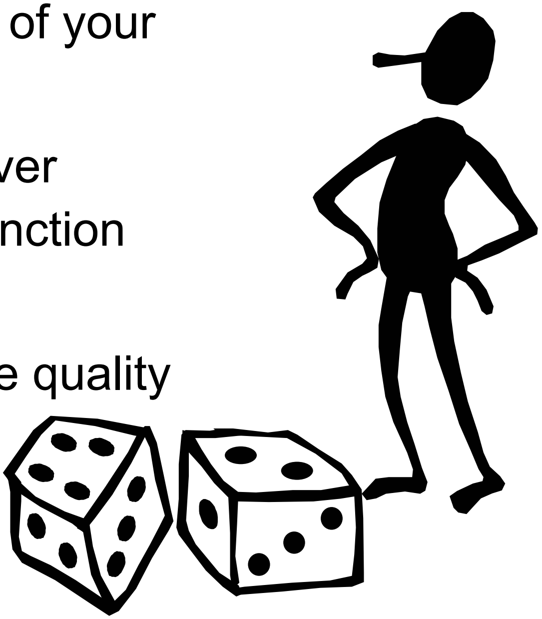
- Control charts are a important tool to assist the metrologist in controlling calibration quality.
- There are many types of control for a variety of purposes.
- For more information, refer to:
  - *Calibration: Philosophy in Practice*, chapters 21 through 23
  - Material taught in the classes on the **Principles of Metrology** or **Cal Lab Management**, as well as other Fluke web-based training courses



Monitoring Alternatives for Lab Standards

A cal lab's problem: What process is used to insure that key standards continue to perform properly during the 12 months between annual calibrations?

- Specifically, how do you protect yourself from calibration instrument malfunctions so such undesired malfunctions don't seriously impact your calibration workload and the quality of your calibration services?
- Considering a calibration workload of instruments done over weeks or months of time, the cost of an undetected malfunction could be enormous.
- Without interim checking, a lab is simply gambling with the quality of its work.

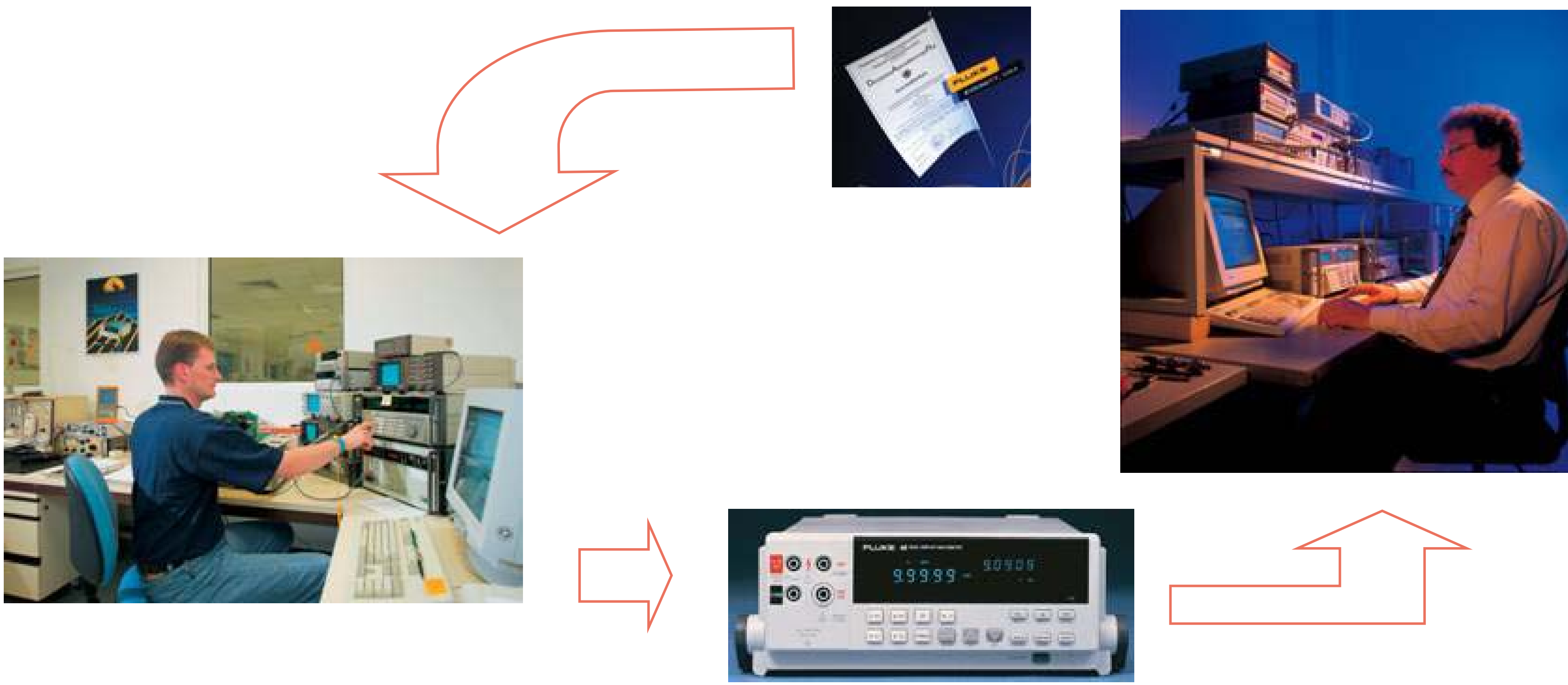


Possible Solutions (1)

- Shorten calibration/verification intervals from once per year to two, three, or four times per year.
- Within the laboratory, use superior reference standards to regularly verify your working standards.
  - Artifact Calibration assists with the high performance 5700 Series calibrators.
  - For other traditional calibrators, full external verification by a full compliment of superior standards is required.

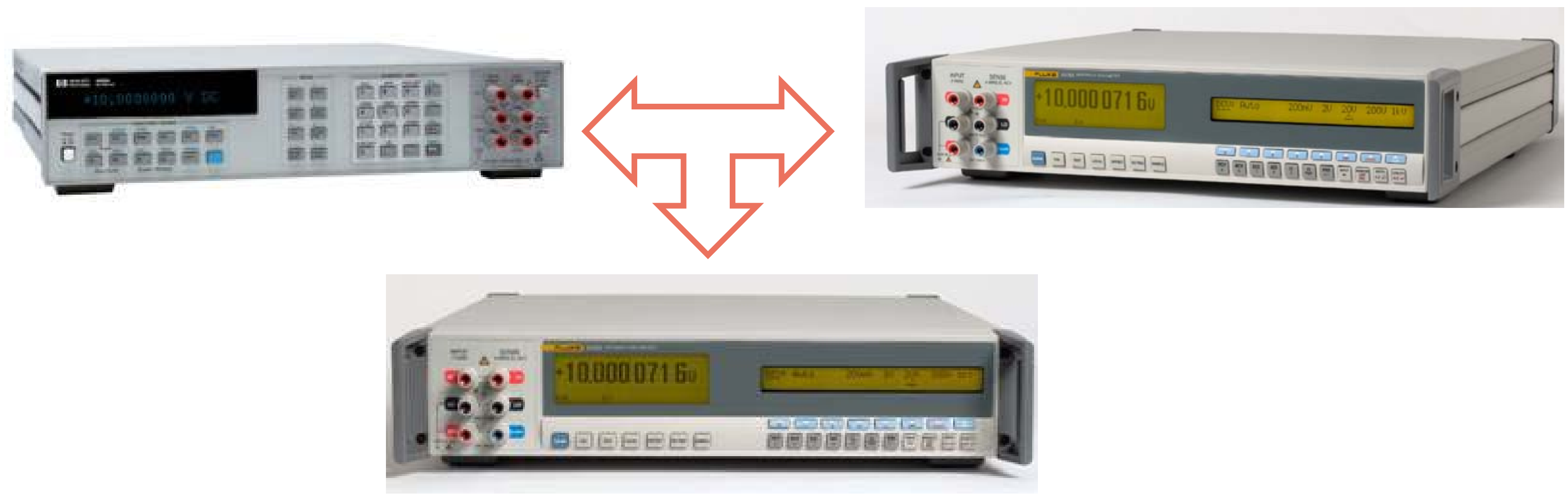
Possible Solutions (2)

- Periodically send out an already certified higher performance UUT to another lab to confirm the results of your lab's calibration tests



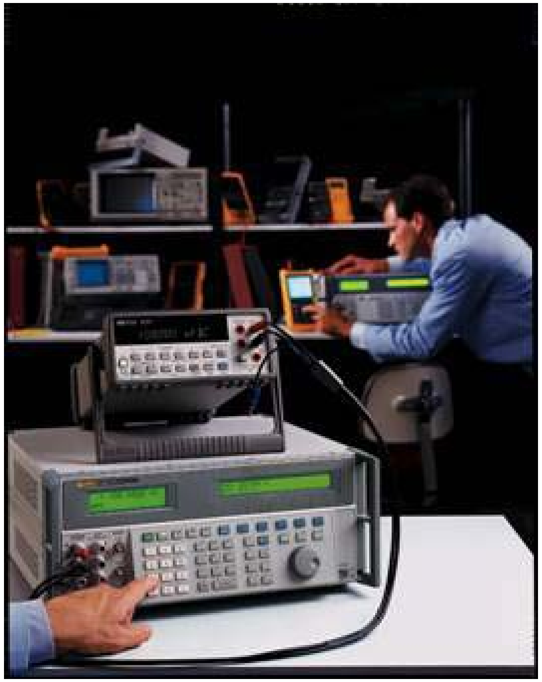
Possible Solutions (3)

- Inter-compare multiple (three, four or more) similar standards.
  - Use a process to track their drift characteristics.
  - Develop individual drift histories against the group’s average value.



Possible Solutions (4)

- With just two standards - do a comparison to monitor the relative drift trends.
- Compare two similar calibrators, or two similar meters or a meter/calibrator combination.



Using a Reference DMM to Monitor a Calibrator

- It is a common situation for labs to have one calibrator and one precision meter.

  What process can be used to help insure these key standards continue to perform properly during the 12 or more months between annual calibrations?

- Usually the precision calibrators and measurement standards found in many calibration laboratories must be sent to superior labs for verification/calibration.
- These standards usually cannot be fully verified by the owning cal lab doing their own internal testing.
- So without superior standards, how do you do such monitoring?

Cross-Check the DMM and the Calibrator

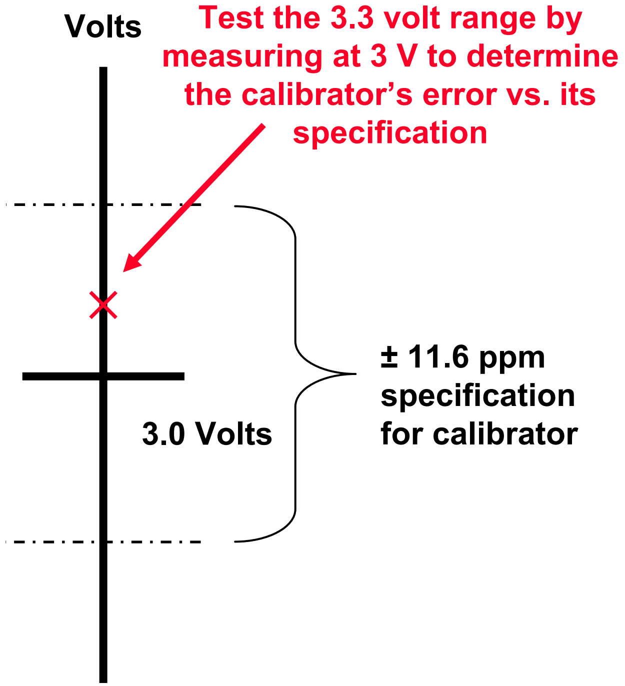
- A DMM and a calibrator can be used together to do mutual cross-checking of dc and low frequency ac sourcing and measurement functions.
- Routine cross-checking to monitor the performance will establish the drift trends of your working standards as well as assist to identify out-of-specification conditions.

Cross-Checking Philosophy

- Precision sources and measurement standards – check all functions and ranges, or, at least, the key functions and ranges, for operational consistency in the times between regular calibrations.
  - Use the most accurate and/or highest risk calibration workload items to identify key monitoring points.
- You don't necessarily need to re-certify a standard using higher performance standards, unless, of course, the workload requirements need it.
- Usually you need to confirm standards against other standards whose precision is sufficient to detect changes.
  - This would serve to indicate the presence an out-of-control condition.
  - Such a procedure will help to prevent/minimize problems due to failures in a standard's performance.
- **How can this be done???**

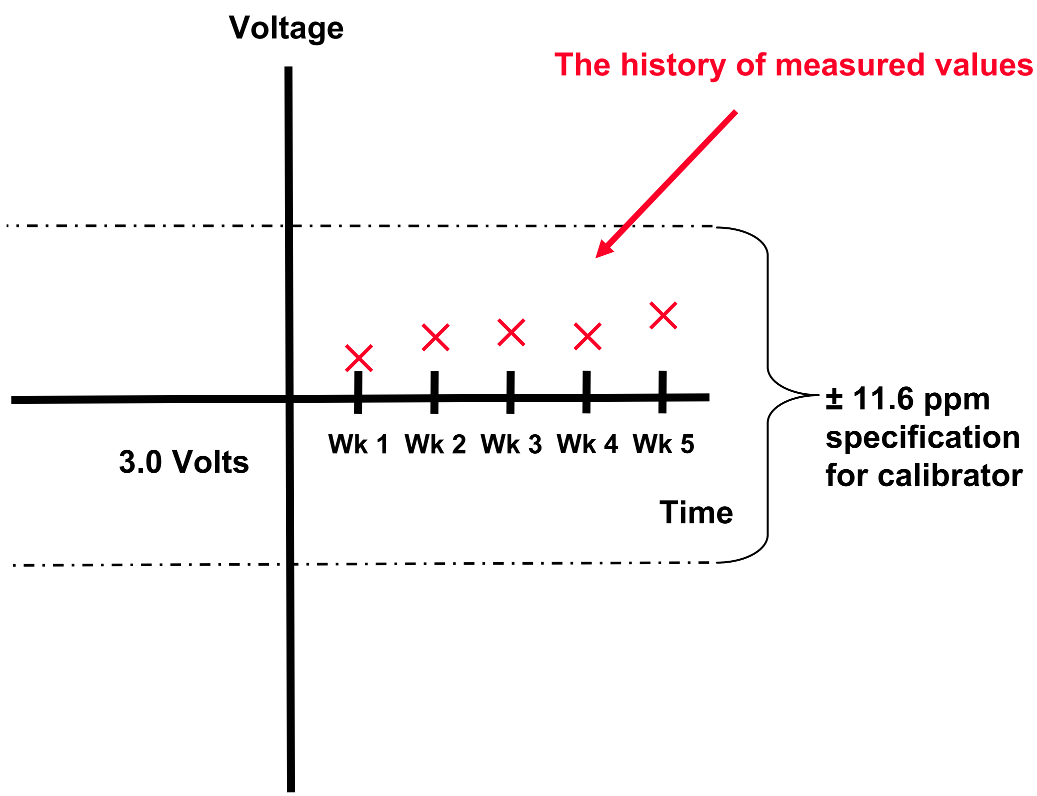
Step 1 – Measure the Calibrator with the DMM

- With this, you know the measurement at a single point in time.
- Depending upon DMM measurement uncertainty versus calibrator specs, you may or may not determine if the calibrator is in specification.
- In any case, use this measurement to compare with future similar measurements.



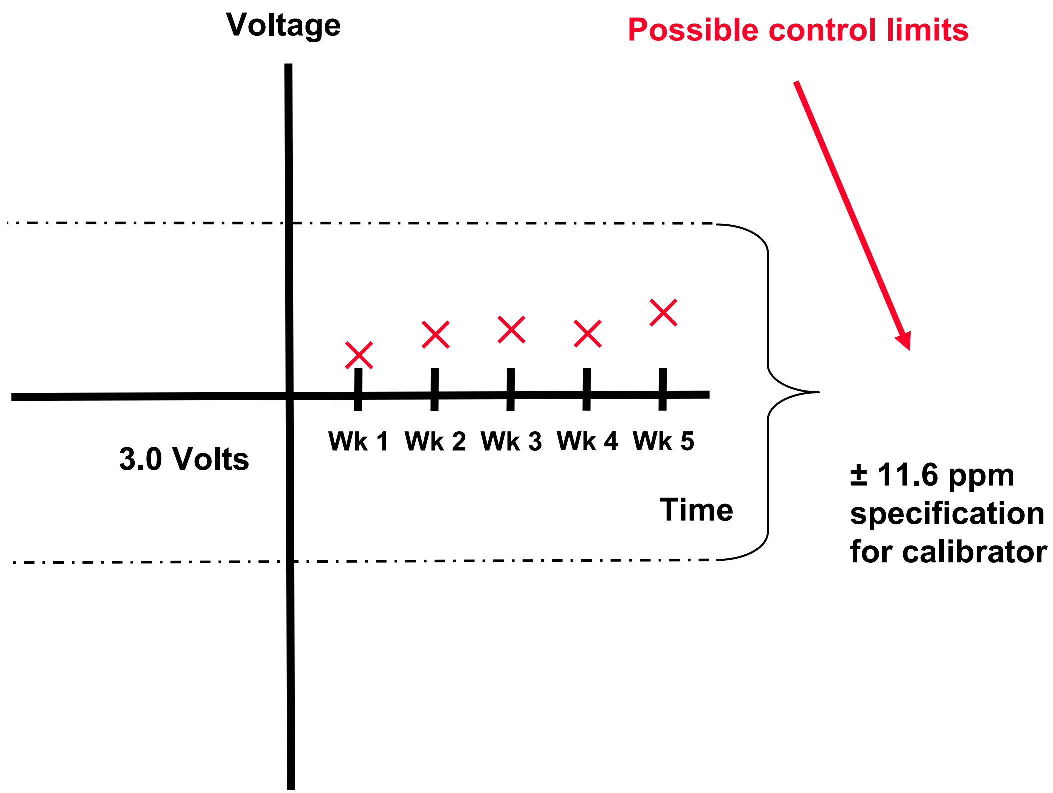
Step 2 – Measure It Regularly

- This establishes the common characteristics of the calibrator.
- You still may or may not know whether it is in specification.
- This becomes a base to evaluate for unusual changes.
- Natural drift characteristics can also be determined.
- Look for unusual shifts, changes in drift rates, stability, etc.
- It also will indirectly confirm the general measurement characteristics of the DMM and guard against gross undetected DMM failures.



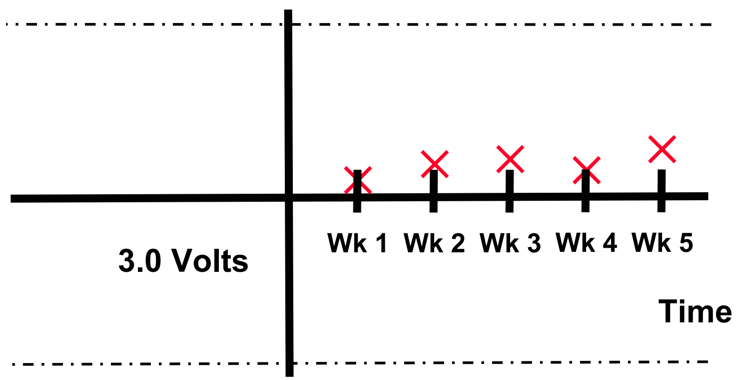
Step 3 – Set Your Control Limits

- The control limits are set against individual considerations.
- Usually, they are based on the required specification.
- Additional factors are applied to balance risk and cost considerations.
- For examples on limits to cause additional evaluation:
  - Use the instrument spec
  - 80 % of specification

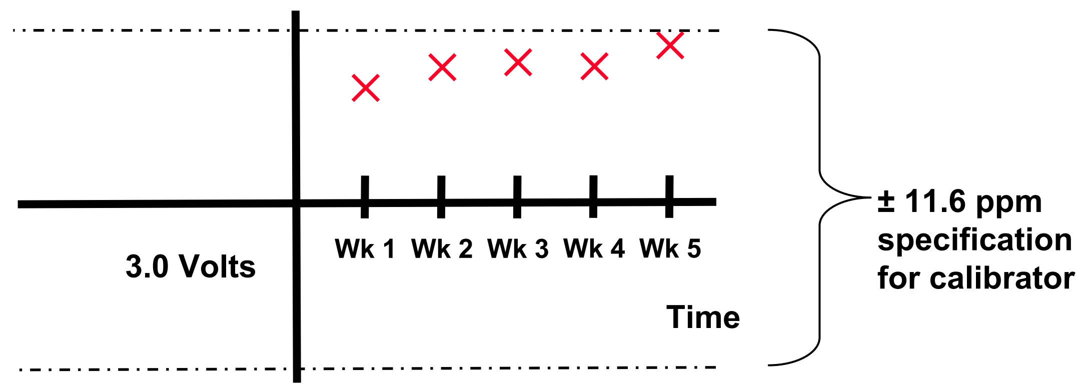


Drift and Trending Examples

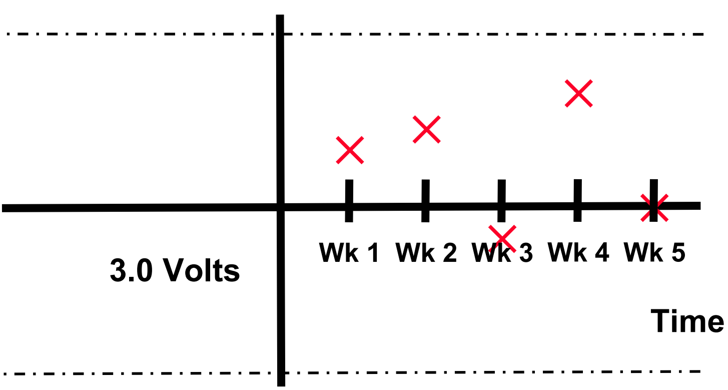
Acceptable trend



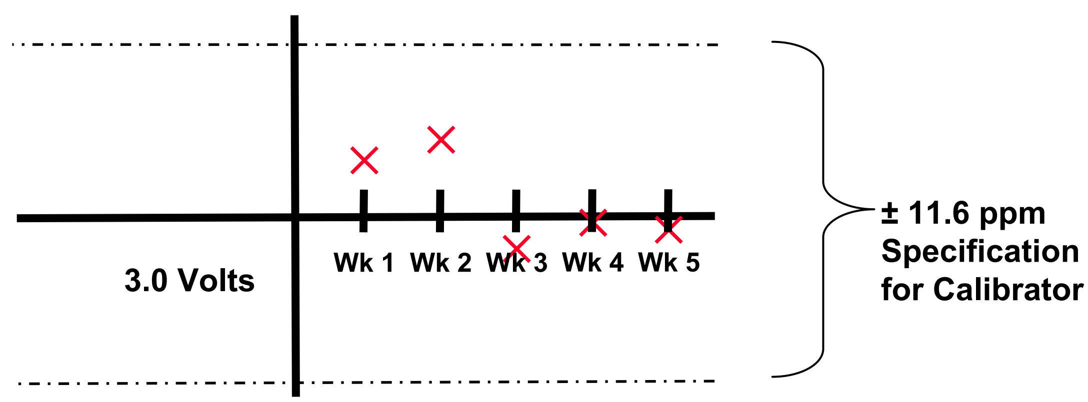
Marginal trend



Noisy trend



Shifted trend

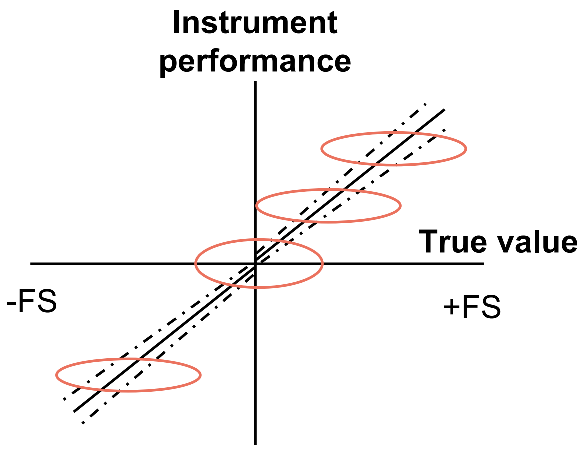


More Comments Trends Evaluation

- For effective monitoring, the checking standard isn’t necessarily required to have substantially better accuracy than the monitored standard.
- As a minimum, the checking standard needs only to be of similar resolution/sensitivity as the monitored standard, so as to detect unusual performance changes.
- Additional independent measurement data, such as a recent calibration report on either or both instruments, will provide confidence that there aren’t simultaneous opposing gross errors in both instruments, which are canceling each other when cross-checking.

Deciding What to Measure

- Precision measurement and sourcing instruments are designed to be linear, with only small errors.
- This graph illustrates the performance within one range.
- Key full scale, zero and linearity points are shown.



Technical Recommendations

- Monitor for changes gain and offset on all ranges
  - Monitor three points on each of the bipolar dc voltage and dc current ranges
    - Near the positive full scale
    - Zero
    - Near the negative full scale
  - Monitor two points on dynamic resistance ranges
    - Near full scale and near 1/10th range
  - For fixed resistance, measure and track the specific resistance value.
- Consider adding mid-scale points on one or more ranges to monitor linearity.
- For ac voltages and currents
  - Check amplitude at both near the full scale and near the minimum on that scale
  - Check bandwidth flatness through consistency of operation at various frequency points in each frequency band.
- Remember to balance the time requirements with the risk.

Example of Cross Checking DC V Between the 5520A and 8508A

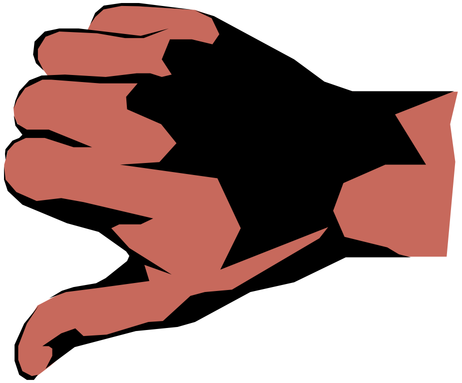
- Examining how to set up cross checking for the 3.3 volt range of a 12 ppm calibrator using the 2 and 20 volt ranges of a 5 ppm reference meter

How to Monitor the 5520A with an 8508A

- **8508A Multimeter**
  - Ranges are at 2.0 decades
  - Consider measuring at +1.9 & -1.9 points for best accuracy
- **5520A Calibrator**
  - Ranges are at 3.3 decades
  - Test at +3.0 & -3.0 points
- **Best practice:** test multiple points plus zero to verify gain, offset and linearity on at least one range.
- **Recommendation:** use points based on the 5520A's characteristics
  - +3.0,+1.9, 0, -1.9 and -3.0 points on key ranges
  - Multiples of the +3.0 & -3.0 points on other ranges plus zero

Making Decisions on Monitoring Trends

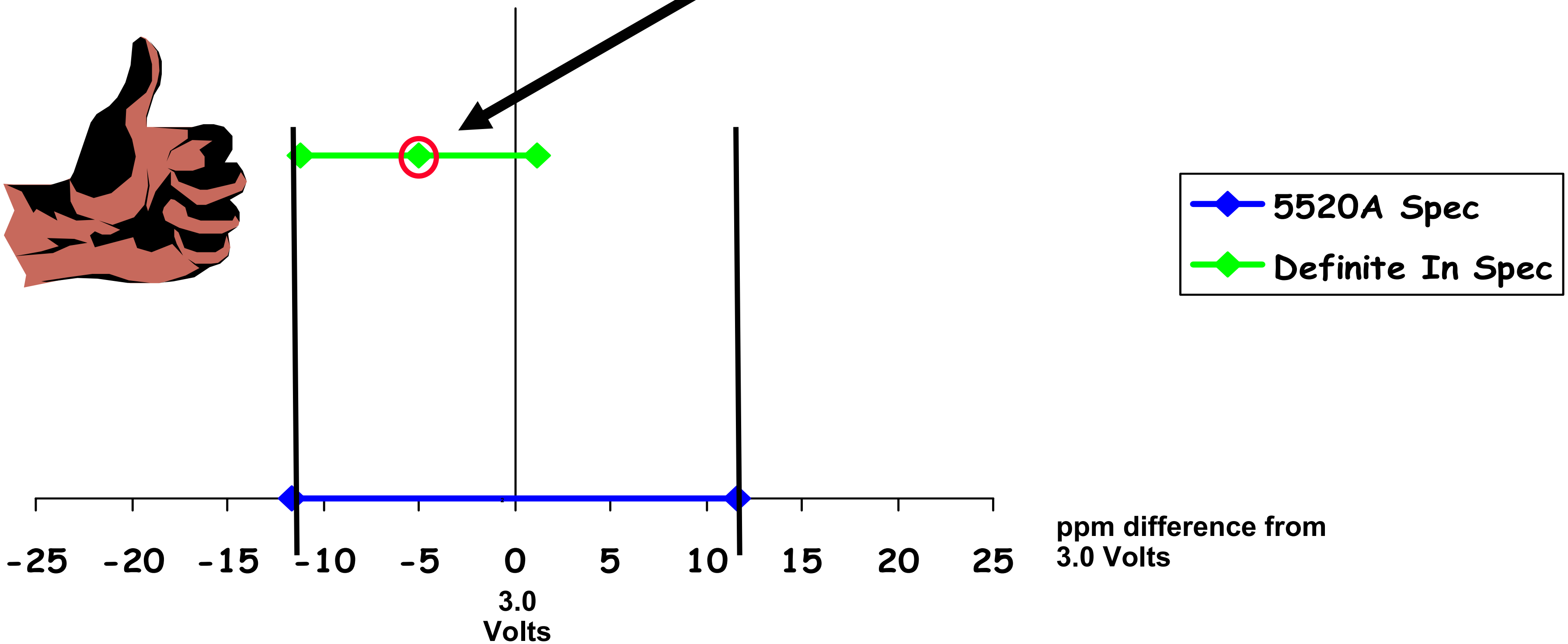
- Summarizing various accepted metrology practices and regulations throughout the world
  - It is common practice that if the specification of the checking standard is from approximately 3 to 5 times better than the unit tested, then definitive pass/fail monitoring decisions can be made.
- Common ratio terminology:
  - TURs, TARs, TSRs
- With smaller-than-desired ratios, limited decisions can still be made -- for example, consider the 8508A meter and 5520A calibrator with about a 2:1 ratio at 3 V...



A Definite “In-Spec” Decision

Consider the uncertainty when an 8508A measures 3 V on a 5520A

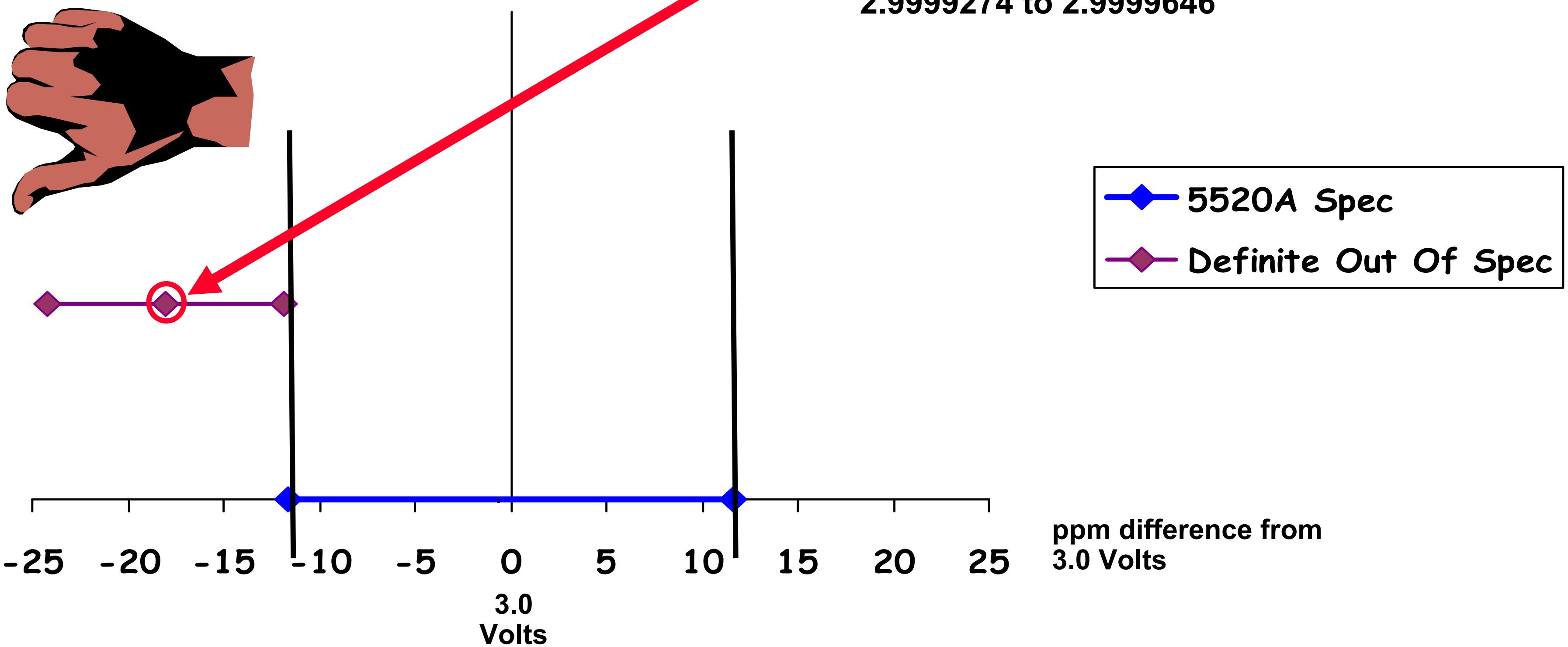
The 8508A measures the 5520A at 2.999985 V (indicating an error of -5 ppm), but with the 8508A spec, the measured value lies in a range between 2.9999664 to 3.0000036



A Definite "Out-of-Spec" Decision

Consider the uncertainty when an 8508A measures 3 V on a 5520A

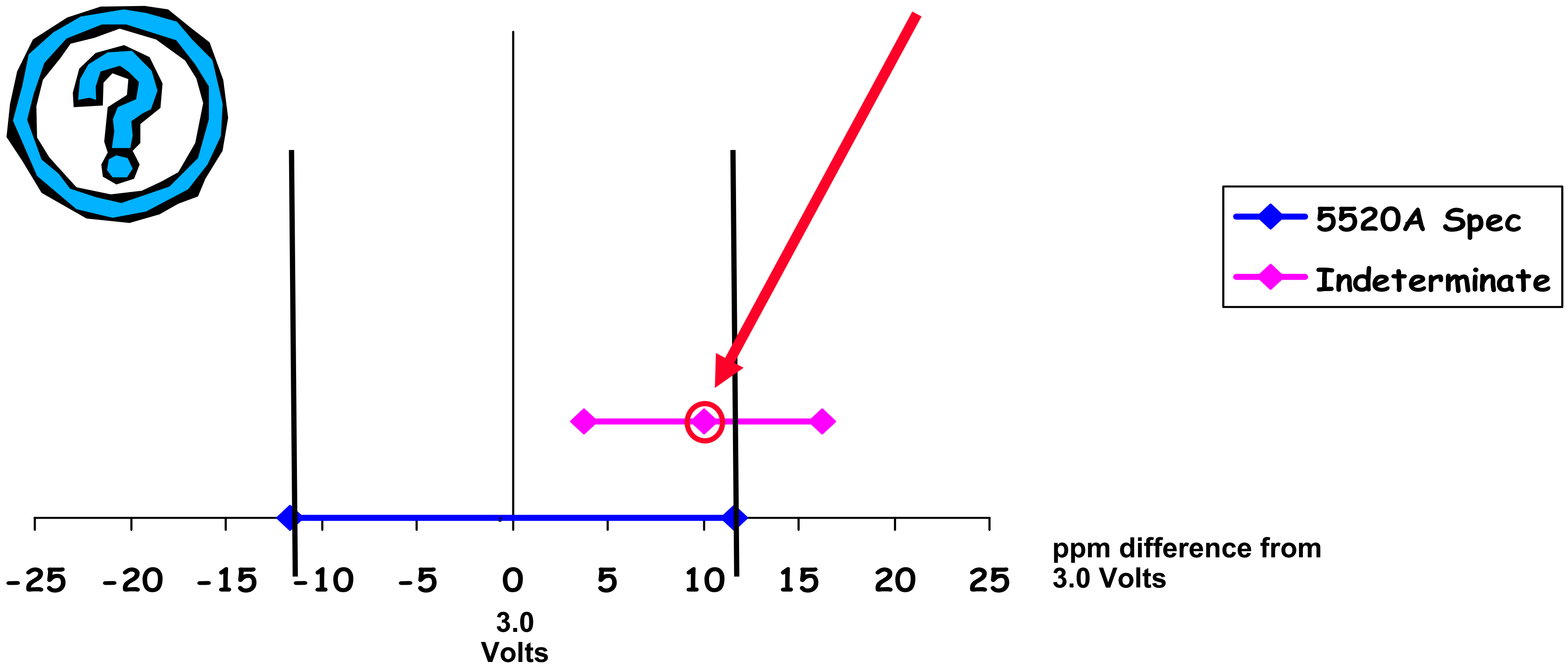
The 8508A measures the 5520A at 2.9999460 V (indicating an error of -18 ppm), but with the 8508A spec, the measured value lies in a range between 2.9999274 to 2.9999646



An Indeterminate Decision

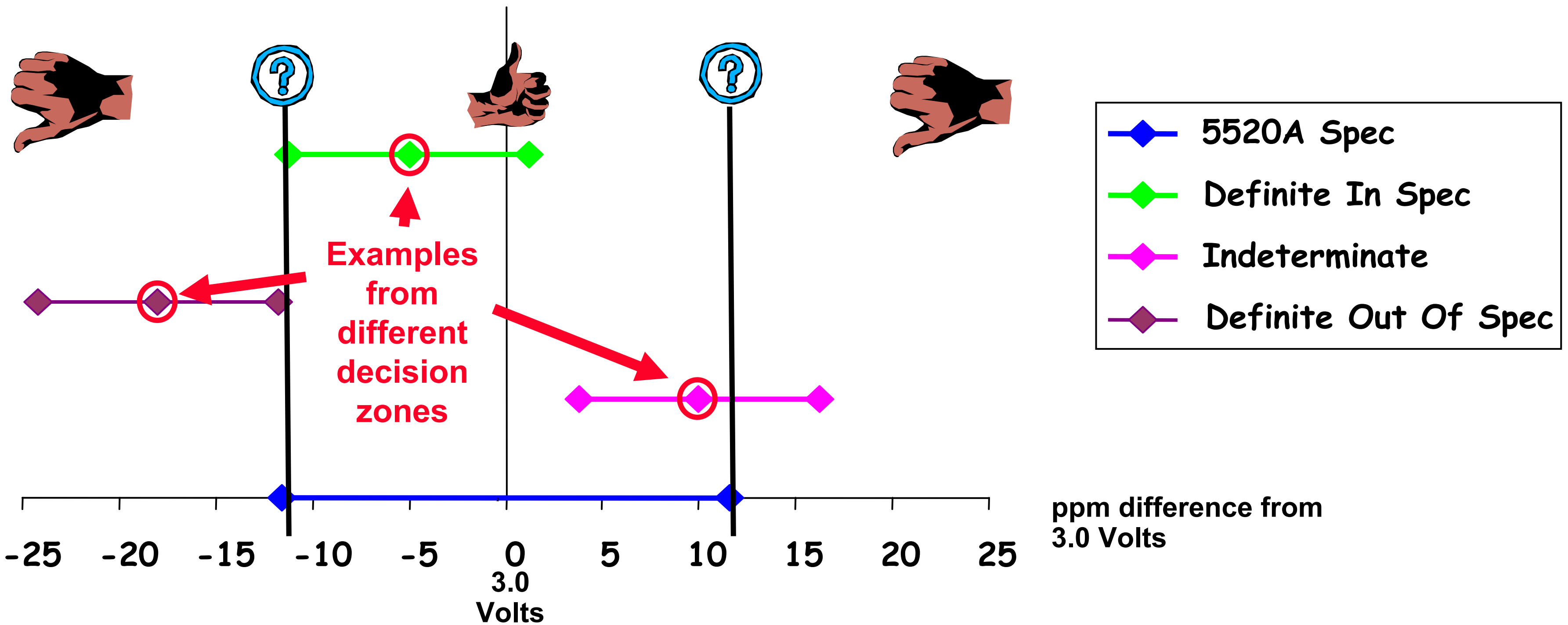
Consider the uncertainty when an 8508A measures 3 V on a 5520A

The 8508A measures the 5520A at 3.0000300V (indicating an error of +10 ppm), but with the 8508A spec, the measured value lies in a range between 3.0000114 to 3.0000486



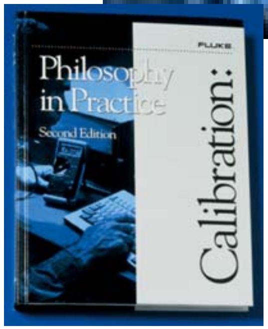
Pass/Fail Decision Zones (Guardbands)

With lower ratios, there are significant zones where no firm decision can be made – but trends can be monitored.



Pass/Fail Decision Summary

- With lower test specification ratios (TSRs), specific pass & fail decisions can be made.
- There are significant zones where no decision can be made.
- In any case, the trends can still be followed with appropriate risk management decisions made.
- For more information on decision techniques, refer to:
  - Technical material on ‘Guardbanding’ at www.fluke.com
  - Fluke training courses or the *Calibration: Philosophy in Practice* text book



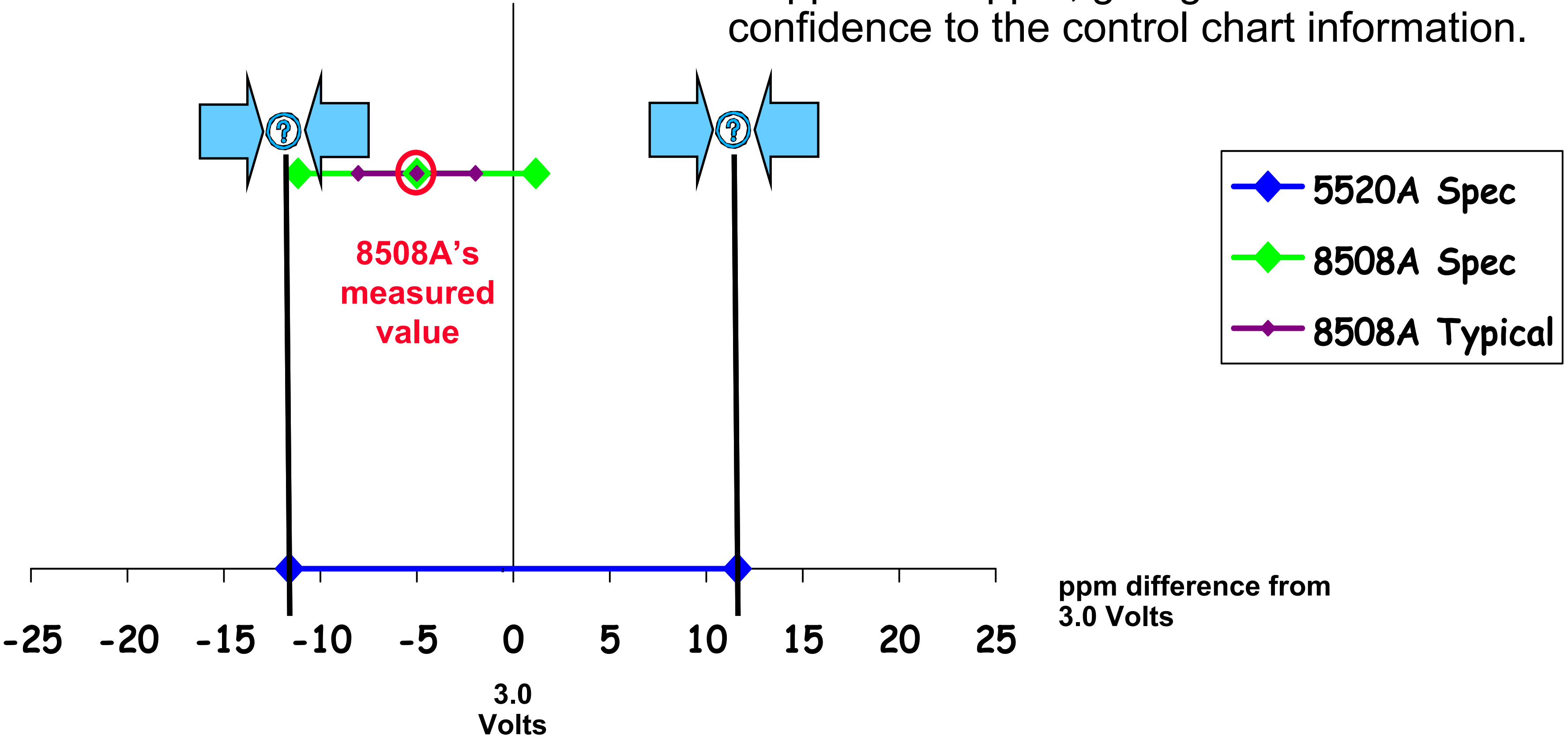
Considering Actual Performance of a Standard

- Instrument specifications are generic and apply to a total population of instruments ever produced (100s to 1000s to 10000s of units).
- With such a population, an individual instrument's performance is usually better than the specs – ***typically two to three times better.***
- Considering actual measurement errors versus specified errors of the DMM, the indecision zones can be less threatening
  - The actual error of the checking instrument is probably better than its spec, so the effective quality of the cross check is better and the indeterminate zones are effectively narrower.
  - The improved performance also applies to the tested calibrator as well. So the drift should be less on the standard being monitored providing a better margin of uncertainty for the calibrations that are done.
- This improvement of actual versus specified performance works to the benefit of the cross-checking process.

Actual Uncertainty vs. Specified Specifications

With better uncertainties, the indecision zones are smaller.

The true uncertainty of the 8508A is ±2 ppm to ±3 ppm, giving a better confidence to the control chart information.



Using Actual Performance vs. Specifications

- Regular monitoring gives a historical basis of actual performance.
- An instrument's actual long term drift and stability is documented.
- Once the standard is recertified and confirms the measurements, you have a basis to improve the value and usage of the standard.

Benefits of Better Actual Performance vs. Specifications

Proven and demonstrated performance characteristics are much better than generic specifications. This can provide:

- Economical benefit: a longer certification interval
- Technical benefit: accuracy improvement
- Quality benefit: improved measurement confidence and a lower incidence of measurement related failures

Using Additional Standards to Complete the Monitoring Process

1. If practical, do a full verification at more frequent intervals.
2. Use the calibrator drift data to identify larger drifts in the DMM.
3. Intercompare several DMMs for agreement on smaller drift changes.
4. Use a limited selection of artifact standards such as voltage and resistance to closely track drift of the DMM on key functions.
   - DC voltage
   - Resistance

Session Summary

- Benefits of monitoring a lab's standards
- The control chart tool
- Monitoring alternatives for lab standards
- Using a reference DMM to monitor a calibrator
- Making decisions on monitoring trends
- Considering actual performance of a standard
- Using additional standards to complete the monitoring process

Action Summary

To satisfy the intermediate check requirements, we recommend considering the following actions:

- Establish a regular process to cross-check your standards. Weekly is often a good interval.
- Check the proper test points for the functions and ranges which will give you confidence in the operation of your standards
- Use control charts to track these intermediate check measurements, so you can identify the output changes and drift rates of the important operating parameters.
- Set control limits and, when unusual or out of limit changes are observed, take appropriate actions to minimize any impact on calibration quality.

Action Summary (2)

To satisfy the intermediate check requirements, we recommend considering the following:

- Balance the risk with the metrology resources when developing your intermediate checking operational procedures.
- Use computer assistance, as this highly routine process lends itself toward automation to reduce manual involvement, improve data consistency and provide more data points for analysis.

Lab Instrumentation Recommendations

- Every lab should have both measurement and sourcing capability of similar uncertainties.
- Routinely measure your source standards to guard against undetected failures.
- Consider using a select group of check standards to guard against failures in your measurement standard.
- Automate the processes to minimize manual involvement and increase data quantity, quality, and consistency.

The Value of Intermediate Checking Processes

- The cost to correct errors due to failures in your standards is much higher without regular interim checking.
- ***Proactively*** correcting for quality problems when they occur is much more effective and economical than ***reactively*** correcting the quality problem and its results at a later time.
- The economics of equipping the lab with balanced measurement and sourcing capabilities, supplemented with several artifact standards, is less than the cost of weak quality control.

Questions?


INTERNATIONAL STANDARD

ISO/IEC 17025

General requirements for the competence of testing and calibration laboratories