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# COMMON MISTAKES IN DIMENSIONAL CALIBRATION METHODS

## AN EDUCATIONAL PRESENTATION FROM THE LEADING MANUFACTURER OF METROLOGY INSTRUMENTS

EDUCATION


EDU-14002A-P

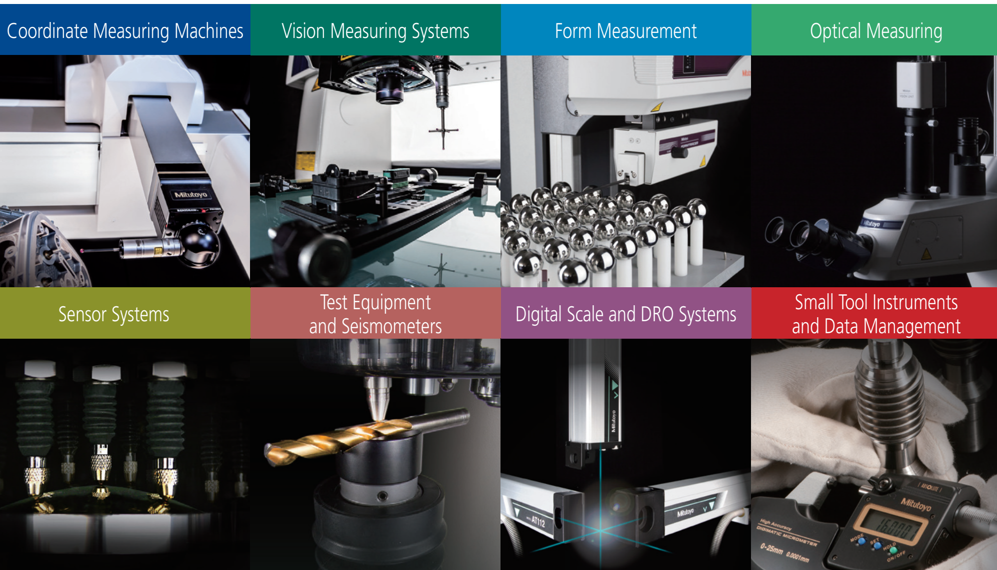
## Mitutoyo Institute of Metrology

The Mitutoyo Institute of Metrology provides educational courses and on-demand resources across a wide variety of measurement related topics including basic inspection techniques, principles of dimensional metrology, calibration methods, and GD&T. Visit **www.mitutoyo.com/education** for details on the educational opportunities available from Mitutoyo America Corporation.

## About this Presentation

Mitutoyo America Corporation has a long history of providing world-class calibration services as well as premier educational instruction in calibration methods and techniques. This presentation is based on some of the key issues that have been observed in our popular Hands-On Gage Calibration course over the years. Calibration is all about maintaining quality and establishing traceability for measuring equipment. To achieve these goals, calibration must be a well-engineered search for errors. Economic realities limit the amount of time and testing in calibration, and therefore methods must be chosen wisely to provide the most information with the least amount of work. This presentation leverages the excellent American national standards available in dimensional metrology – the B89 series of standards developed under the auspices of the American Society of Mechanical Engineers (www.asme.org). This presentation has been delivered by Mitutoyo America personnel at a number of conferences and other events, in particular at national and regional NCSL International meetings (www.ncsli.org).



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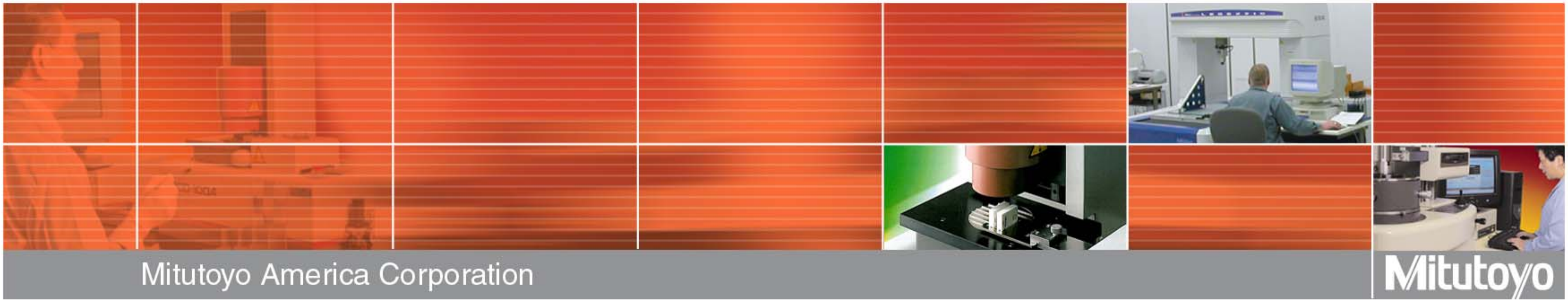
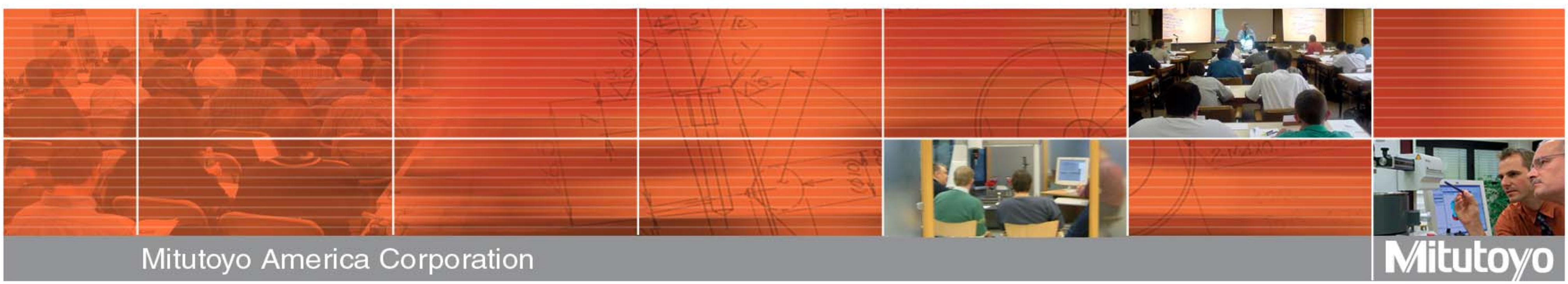




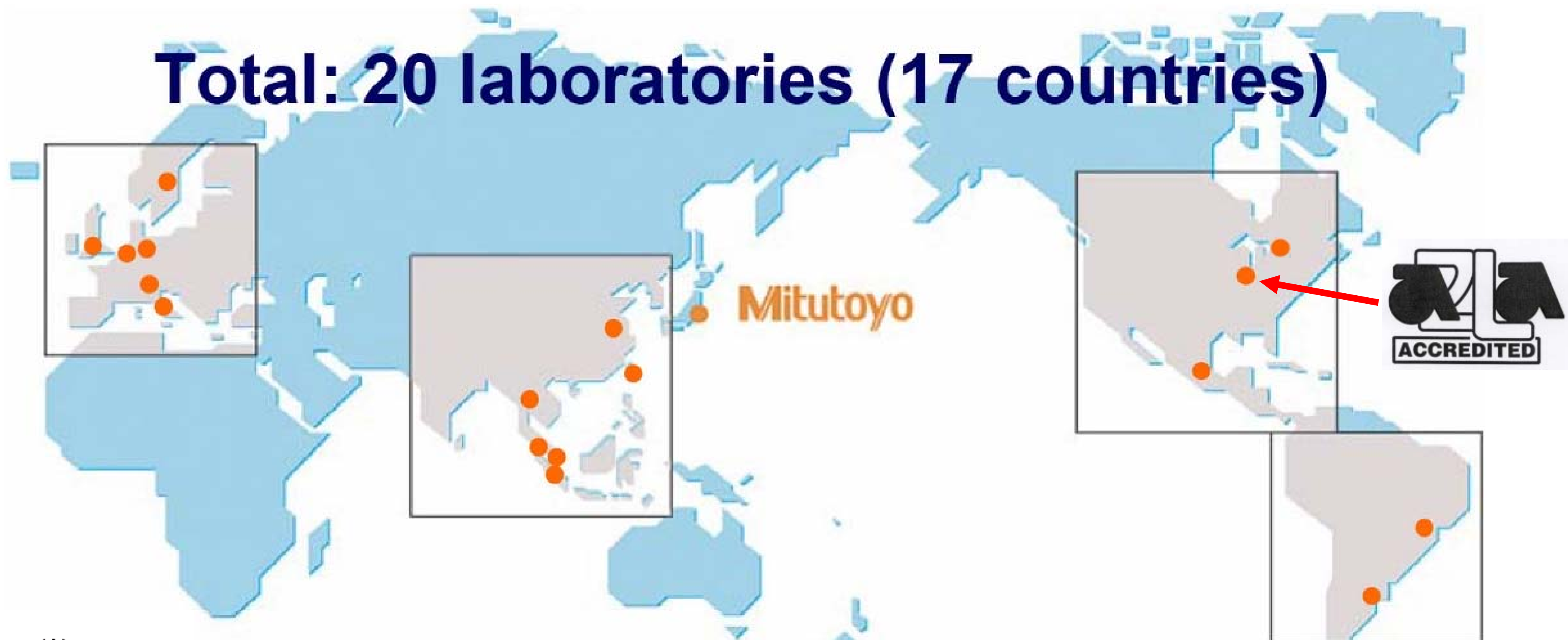
# Common Mistakes in Dimensional Calibration Methods

# Learning Objectives of this Presentation

- Identify common mistakes in dimensional calibrations.
- Determine proper test points when calibrating micrometers.
- Apply the proper calibration method for flatness and parallelism of micrometer measuring faces.
- Determine the need for the inclusion of hysteresis in the calibration of indicators.
- Analyze the single versus multiple point calibration of gage blocks.



# Mitutoyo Calibration Worldwide

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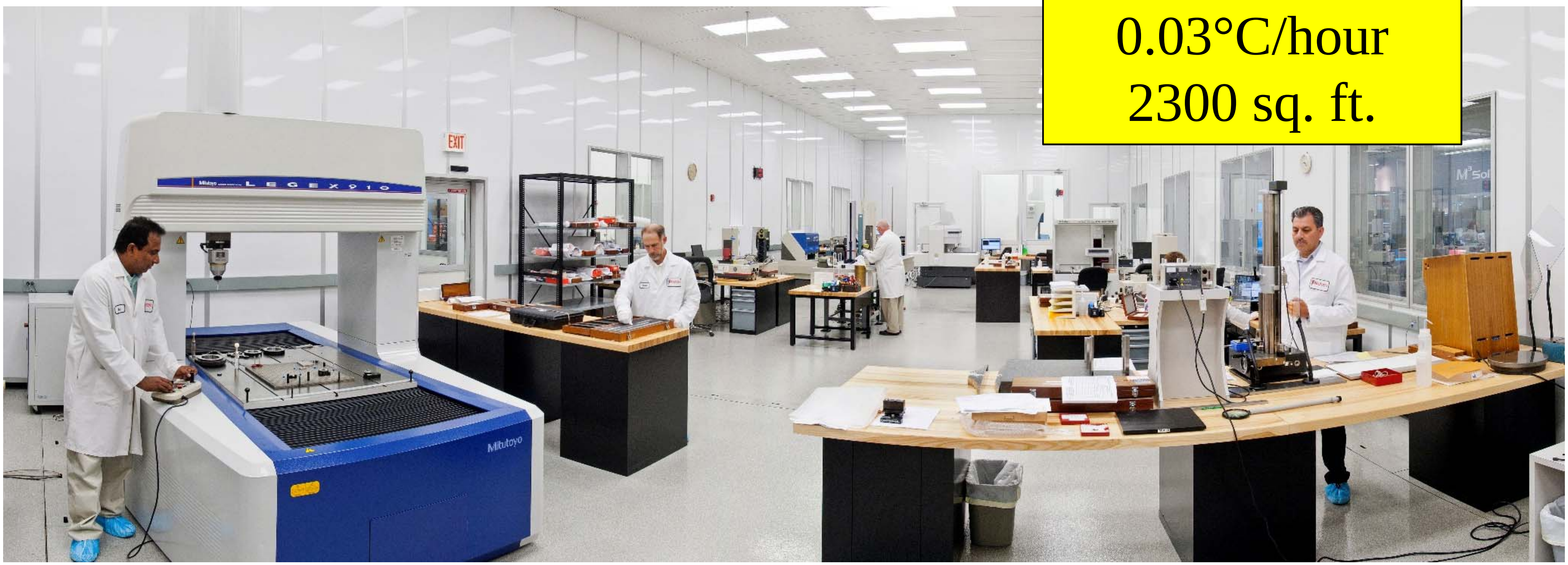
Accredited laboratories and field service departments offering calibrations around the globe that are supported by international mutual recognition agreements.

# Mitutoyo America Calibration Lab

## (Primary Standards Lab, Aurora, IL)

20±0.1°C
0.03°C/hour
2300 sq. ft.




Close to 100% of calibrations are ISO/IEC 17025 accredited

# Educational Classes in Dimensional Metrology

Hands-On Training Lab used primarily for teaching “Gage Calibration” to customers

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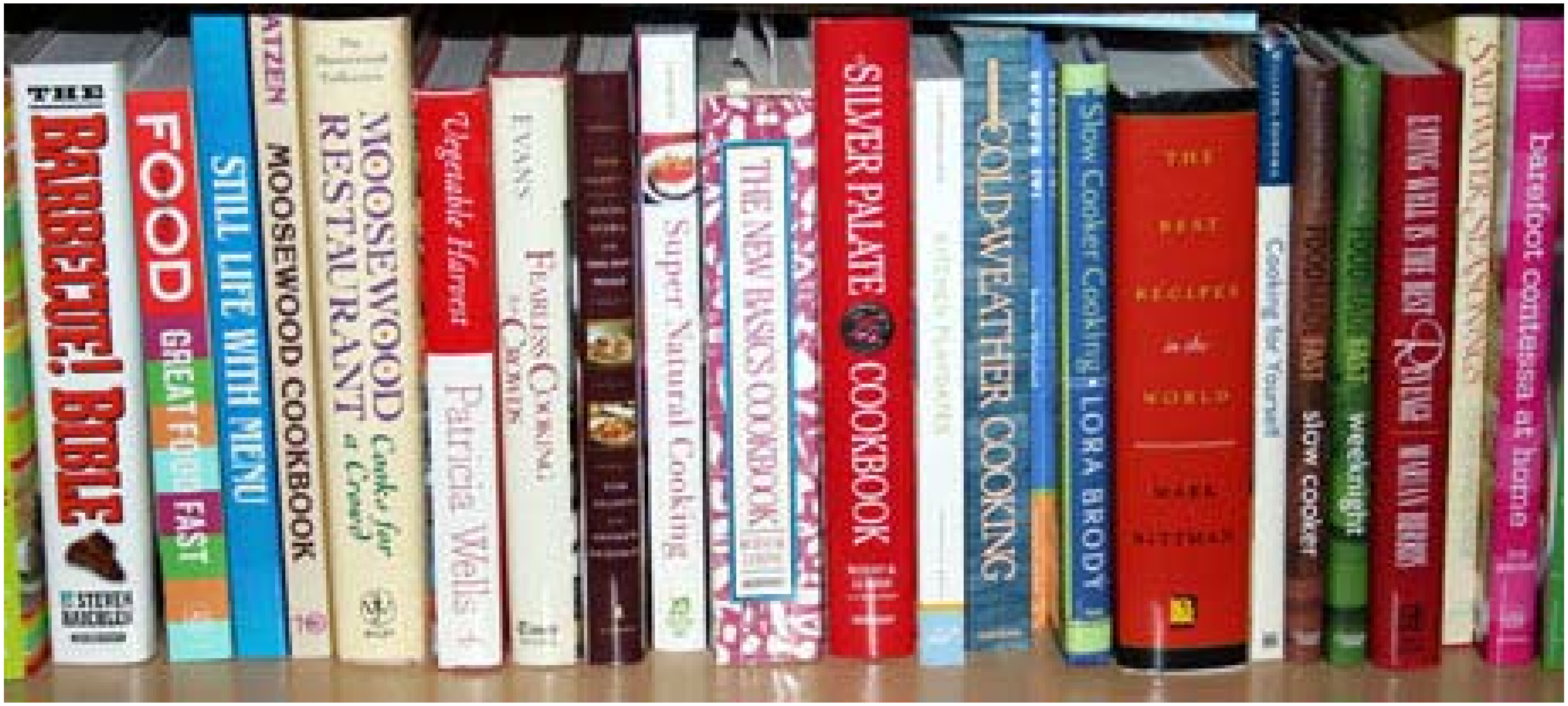
# Metrology Standards Work

- Mitutoyo is an active leader in the development of national and international metrology standards and practice.
- ASME B89 Dimensional Metrology
- ASME Y14 Dimensioning and Tolerancing.
- ISO/TC 213 Tolerancing and Metrology.
- NCSLI Dimensional Metrology Committee.

NCSL International




- In calibration, we tend to document "what" and not "why".
- What happens when technology, tolerances, or assumptions change?
  - Do we have the expertise to change the recipe correctly?
  - How do we know when we need to change the recipe?
- Calibration methods must be updated over time or may become incorrect.

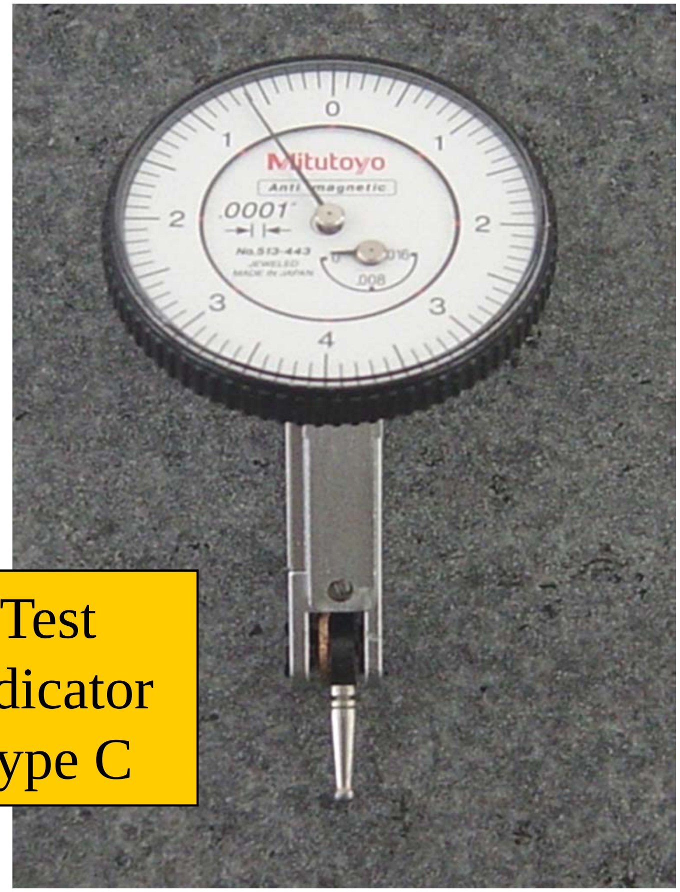
# What is Calibration?

VIM3: *operation that, under specified conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication*

- Bottom line: calibration is a search for errors in measuring instruments.
- In dimensional metrology, there are pretty solid US standards (ASME B89) that provide guidance on how to conduct that search.
- The collective and cumulative knowledge of many experts is available and pretty inexpensive – are you leveraging it? This presentation will discuss a few examples.

# Dial Indicator Calibration (ASME B89.1.10)

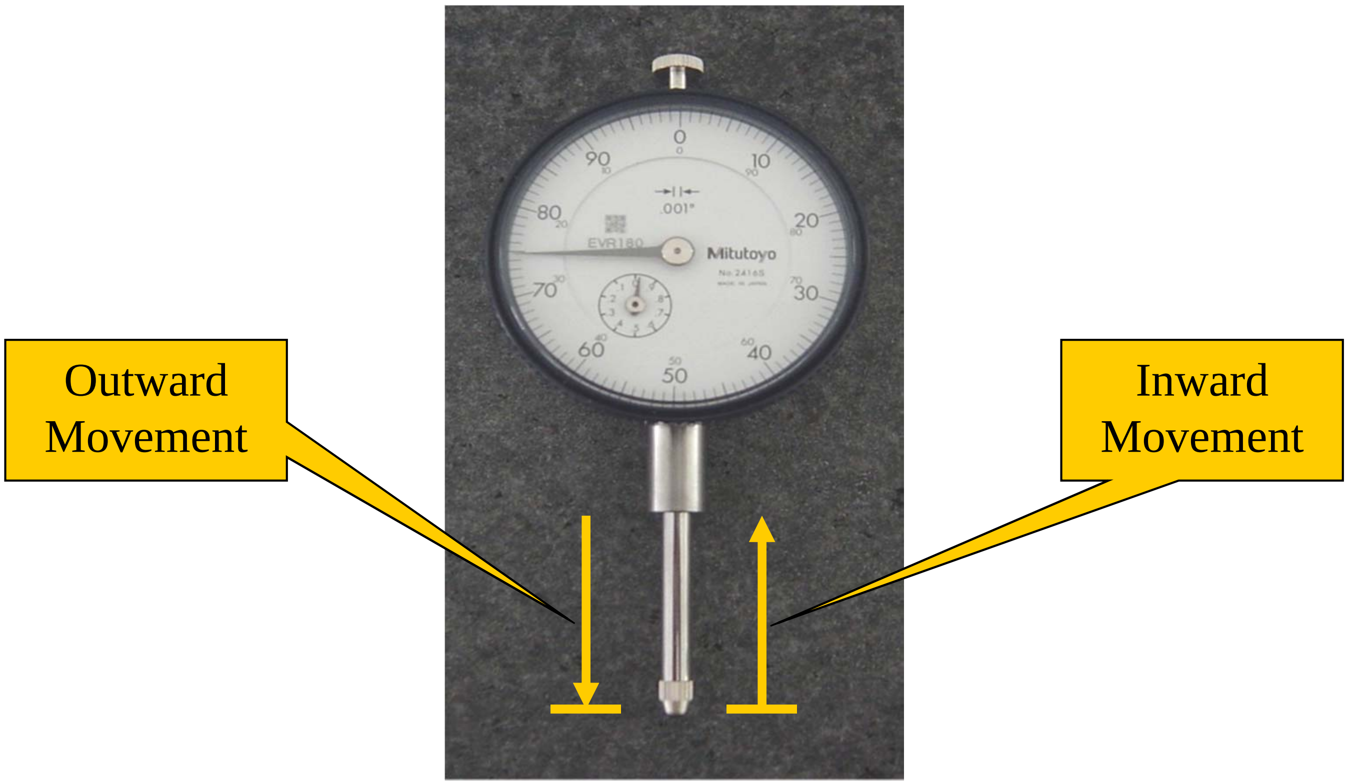

Dial Indicator Type A




Test Indicator Type C

# Specify the Measurand

- Repeatability
- Error of indication (Inward and Outward)
- Hysteresis



# Identify the Reference Standard

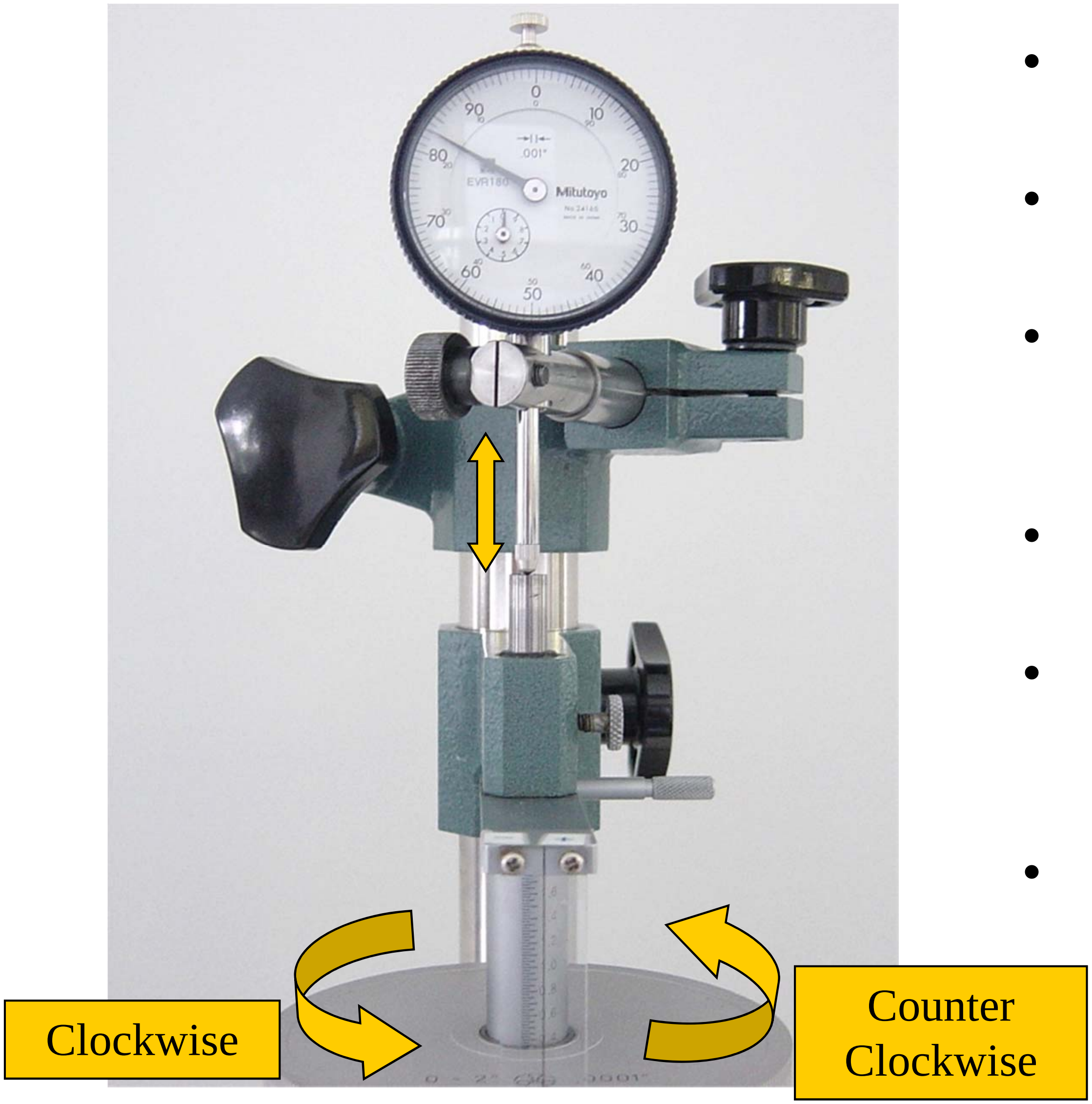
- Dial Indicator Calibrator (Course and Fine resolution)

Fine Res.10 µin/0.2 µm
Range 0.200 in/5 mm



Course Res. 0.0001 in
Range 2.00 in/50 mm

# Calibrating the Dial Indicator




- Secure the dial indicator on the calibrator
- Take four readings on the first revolution
- Depending upon the indicator take at least 6 to 10 readings over the full range
- Retrace the readings at the same corresponding points
- Difference between errors in inward and outward motion is the hysteresis
- Hysteresis is a common failure for used indicators

# Problem with using gage blocks


- Using gage blocks does not normally check hysteresis.
- Common failure mode is missed.
- However, depending on the use of the indicators, the hysteresis might not matter – this opens the door for confusion in calibration services.
  - Customer must understand their needs and request appropriate calibration service.

# Checking hysteresis with gage blocks


- Single point hysteresis check:
  - Use stand with fine adjust feature and raise gage block into indicator at a particular point.
  - Raise and lower spindle to measure the same point. Any difference is hysteresis.
- Another option:
  - Slowly push block into position to raise indicator, set zero, then raise and lower indicator.
- Both these methods are a bit tricky and are only a single point test.

# Calibration of Digital Indicator

- Digital indicator calibrations – no hysteresis check is normally ok and is often not done. Customer should evaluate their situation carefully.


# Micrometer Calibration (ASME B89.1.13)

- Length error of indication
- Anvil flatness
- Spindle Flatness
- Anvil-spindle parallelism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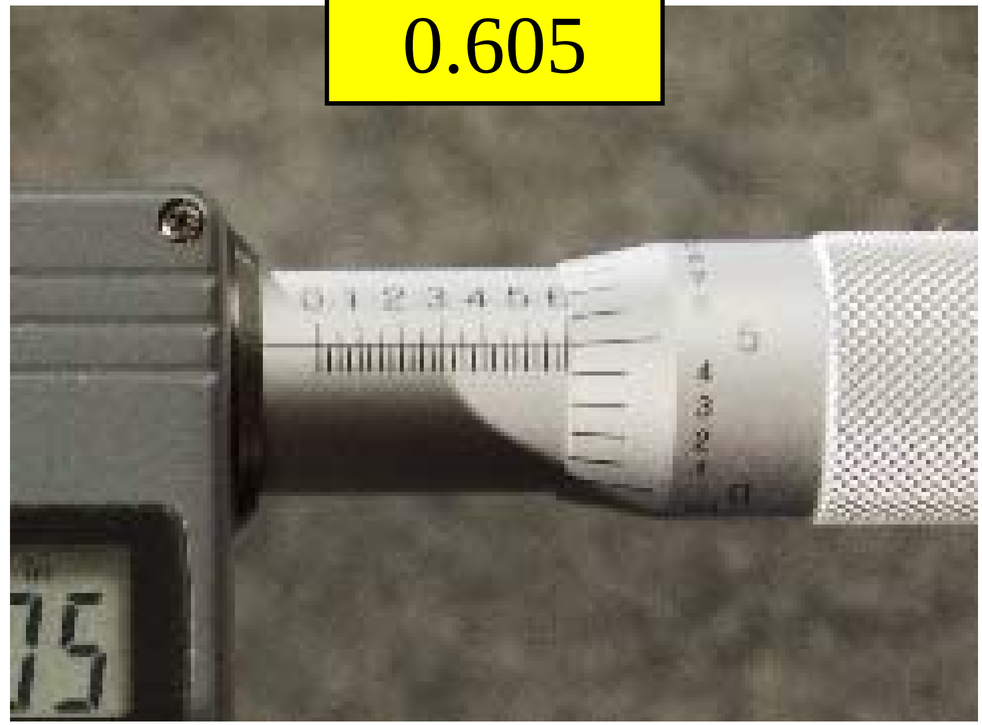
# Reference Standards


| Inch blocks |
|---|
| 0.210 |
| 0.420 |
| 0.605 |
| 0.815 |
| 1.000 |

Both the US and the ISO standard recommend very specific test points for micrometers.

0.420

0.605



Carefully engineered test points:

(0.210, 0.420, 0.605, 0.815, 1): Five test points over the 0-1” of travel plus five test points over the 0.025” in one rotation of the micrometer thimble.

# Checking Flatness & Parallelism

- Use the optical parallel to check flatness and parallelism of anvil and spindle
- Flatness < 12 µin; Parallelism < 40 µin

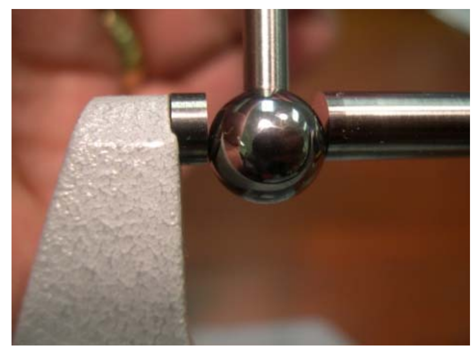
Optical parallel


Parallelism is this manner can be very tricky to do.

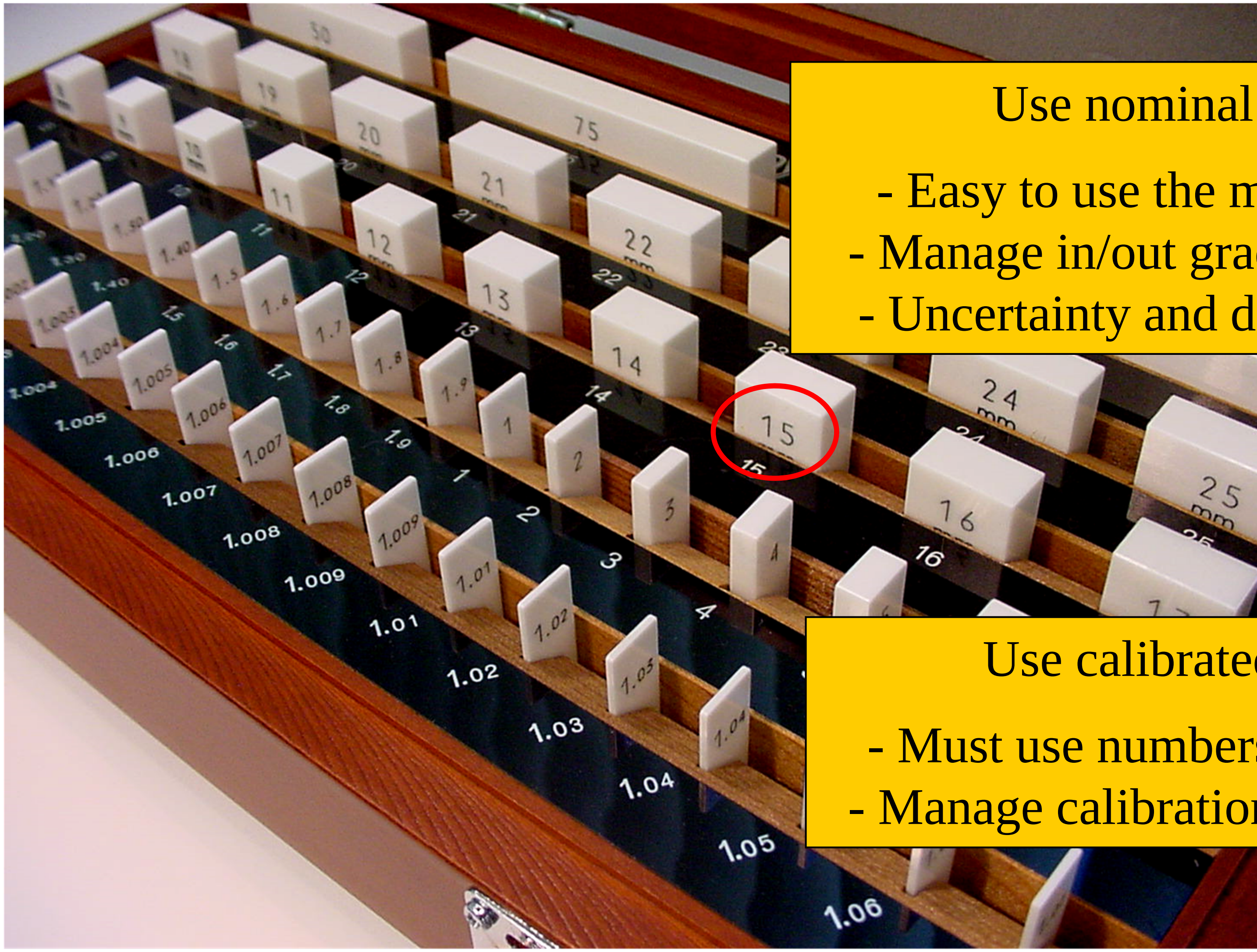

Another option for parallelism:

Measure the variation in length of a small diameter ball across the measuring faces.

This method is also sensitive to some of the anvil flatness errors.



# Gage Blocks (ASME B89.1.9)




Use nominal size:

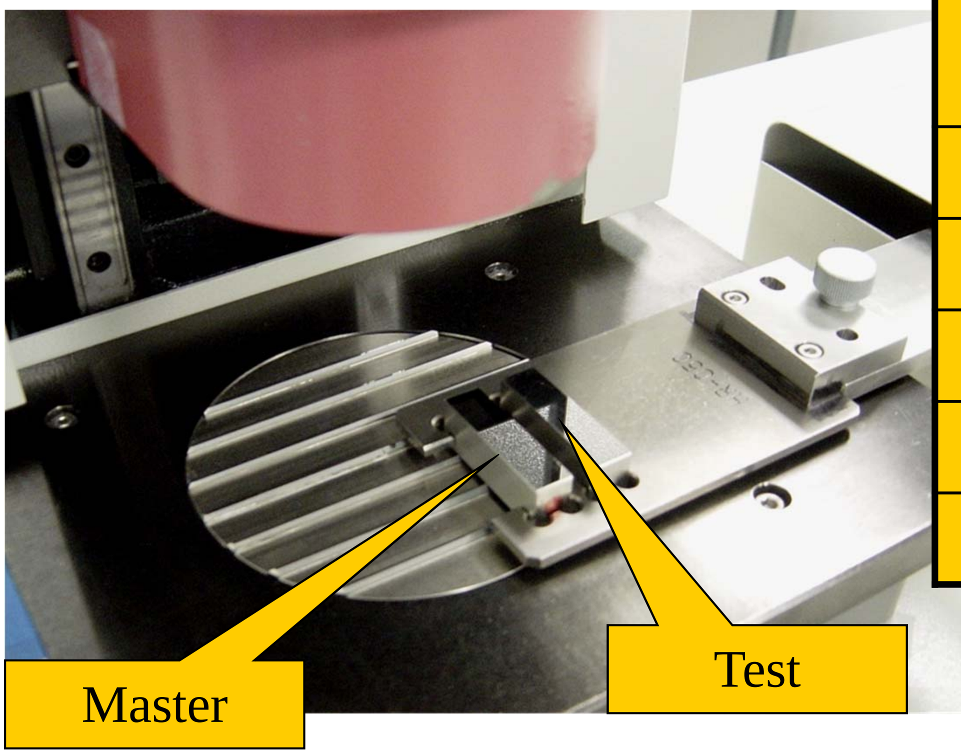
- Easy to use the marked size
- Manage in/out grade tolerance
- Uncertainty and decision rule

Use calibrated size:

- Must use numbers on cal cert
- Manage calibration uncertainty

# Calibrating Gage Blocks

- Measure length by comparison to traceable master.
- Check against grade tolerance.




| Nominal (inch) | Deviation (μin) | Tolerance Grade 0 (μin) |
|---|---|---|
| 0.210 | 3 | 5 |
| 0.420 | -2 | 5 |
| 0.605 | -1 | 6 |
| 0.815 | -4 | 6 |
| 1.000 | 2 | 6 |

A single-point check against tolerance is not recommended per ASME B89.1.9

# Gage block grades

| Nominal Length Range $l_n$ in inches | Calibration Grade K | | Grade 00 | | Grade ( |
|---|---|---|---|---|---|
| | Limit Deviations of Length at any Point From Nominal Length $\pm t_e$ µin. | Tolerance for the Variation In Length $t_v$ µin. | Limit Deviations of Length at any Point From Nominal Length $\pm t_e$ µin. | Tolerance for the Variation In Length $t_v$ µin. | Limit Deviations of Length at any Point From Nominal Length $\pm t_e$ µin. |
| $l_n \le 0.05$ | 12 | 2 | 4 | 2 | 6 |
| $0.05 < l_n \le 0.4$ | 10 | 2 | 3 | 2 | 5 |
| $0.45 < l_n \le 1$ | 12 | 2 | 3 | 2 | 6 |
| $1 < l_n \le 2$ | 16 | 2 | 4 | 2 | 8 |
| $2 < l_n \le 3$ | 20 | 2 | 5 | 3 | 10 |
| $3 < l_n \le 4$ | 24 | 3 | 6 | 3 | 12 |
| $4 < l_n \le 5$ | 32 | 3 | 8 | 3 | 16 |
| $5 < l_n \le 6$ | 32 | 3 | 8 | 3 | 16 |
| $6 < l_n \le 7$ | 40 | 4 | 10 | 4 | 20 |
| $7 < l_n \le 8$ | 40 | 4 | 10 | 4 | 20 |
| $8 < l_n \le 10$ | 48 | 4 | 12 | 4 | |
| $10 < l_n \le 12$ | 56 | 4 | 14 | 4 | |
| $12 < l_n \le 16$ | 72 | 5 | 18 | 5 | |
| $16 < l_n \le 20$ | 88 | 6 | 20 | 6 | 44 |
| $20 < l_n \le 24$ | 104 | 6 | 25 | 6 | 52 |
| $24 < l_n \le 28$ | 120 | 7 | 30 | 7 | 60 |
| $28 < l_n \le 32$ | 136 | 8 | 34 | 8 | 68 |
| $32 < l_n \le 36$ | 152 | 8 | 38 | 8 | 76 |
| $36 < l_n \le 40$ | 160 | 10 | 40 | 10 | 80 |

NOTE: Grade K is direct measurement by interferometer.

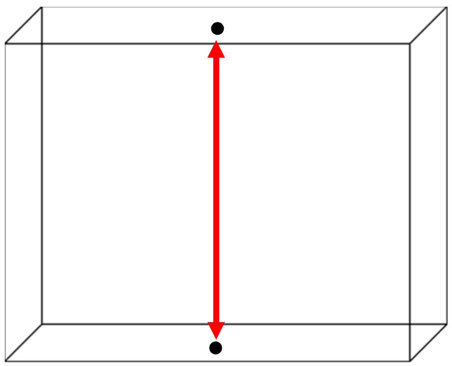
For 1”:

| Grade AS-1 | |
|---|---|
| Limit Deviations of Length at any Point From Nominal Length $\pm t_e$ µin. | Tolerance for the Variation In Length $t_v$ µin. |
| 12 | 6 |
| 8 | 6 |
| 12 | 6 |
| 16 | 6 |
| 20 | 6 |
| 24 | 8 |
| 32 | 8 |

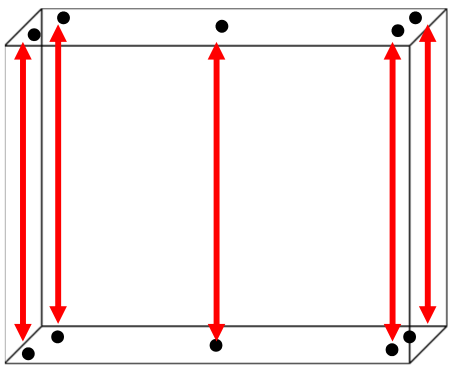
T-3

# Specify the Measurand

- Central Length Deviation (not for comparing to tolerance)
- Length Deviation at Any Point
- Variation in Length (sort of flatness and parallelism)
- ASME and ISO standards recommend testing at 5 points



No tolerance on just the central length !!



1. All lengths individually within $t_e$ tolerance
2. Range (max-min) of lengths within $t_v$ tolerance

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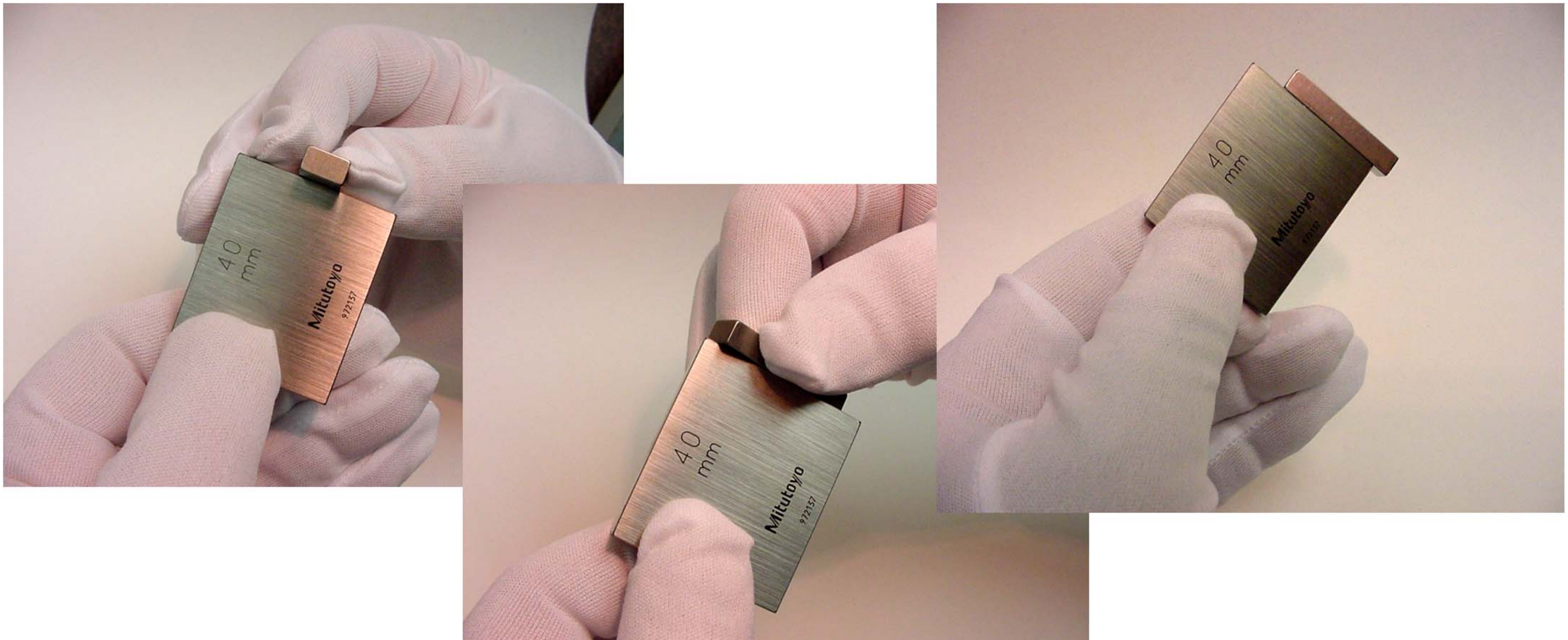
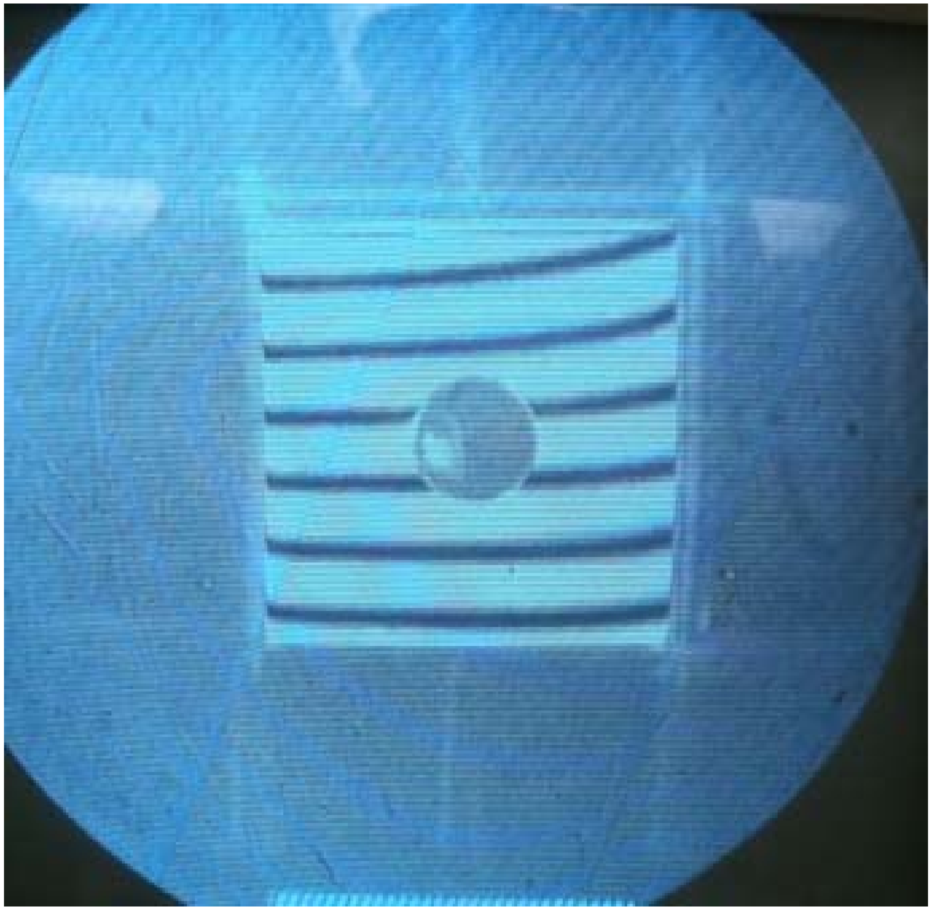
# Wringing gage blocks




- Parallelism (variation in length) can significantly influence length of wrung blocks.

# Gage block face flatness



- Rarely checked.
- Mostly controlled by checking the variation in length.

# Summary

- There are some pretty good American (ASME/ANSI) standards in dimensional metrology – use them.
- This presentation discussed the following:
  - ASME B89.1.10, Dial Indicators
  - ASME B89.1.13, Micrometers
  - ASME B89.1.9, Gage Blocks
- Some others to investigate:
  - ASME B89.1.5 and 1.6, Plug Gage and Ring Gages
  - ASME B89.1.7, Steel Measuring Tapes
  - ASME B89.1.17, Thread Wires

# Thank You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990351
ABSOLUTE
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0.815010
MODE
SET
HOLD
ON/OFF
in/mm
0-1"
.00005"
0.001mm
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ORIGIN
ZERO/ABS
HOLD
in/mm
RANGE (in)
ERROR (in)
0.210
0.420
1.000
ANVIL
FLATNESS
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