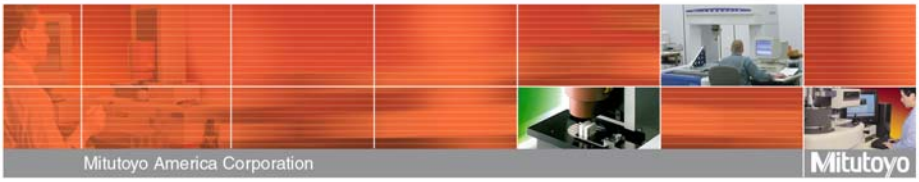
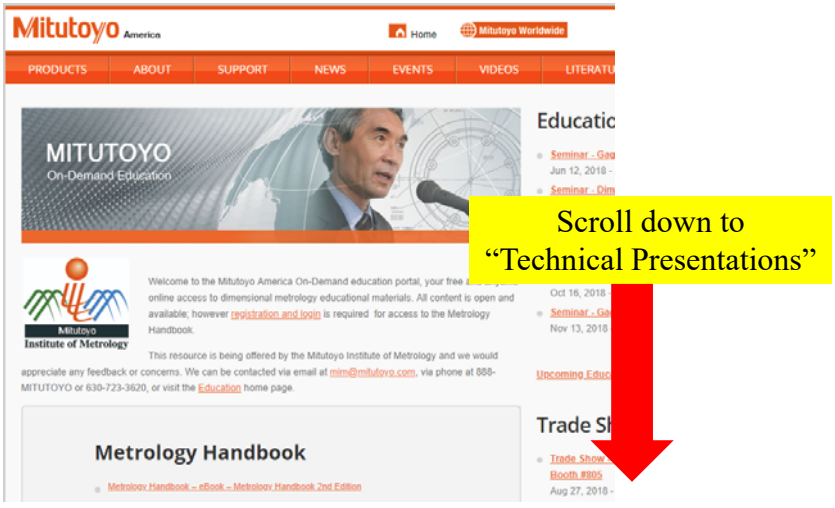


Temperature and Dimensional Measurements

Jim Salsbury, Ph.D., Corporate Metrology
Mitutoyo America Corporation

www.mitutoyo.com/on-demand



Mitutoyo America Calibration Lab

Environmental specifications based on accuracy requirements

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Temperature Impacts all Measurements

- Listen and understand. Temperature is out there. It can't be bargained with. It can't be reasoned with. It doesn't feel pit, or remorse, or fear. And it absolutely will not stop, ever, until all your measurements are screwed up.

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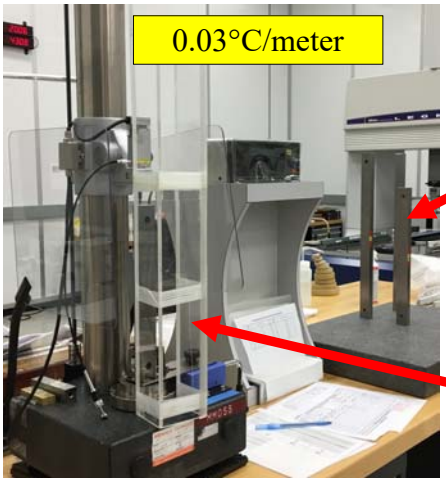
4

Example: Long Gage Block Calibration



0.03°C/meter

Master and test block soak overnight

Match materials

Heat shields to block operator heat

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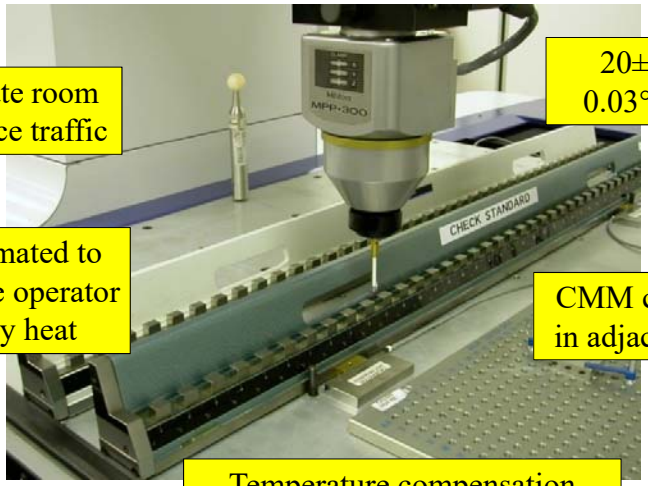
Example: Step Gage Calibration on CMM



Separate room to reduce traffic

20±0.1°C 0.03°C/hour

Automated to remove operator body heat

CMM controller in adjacent room

Temperature compensation

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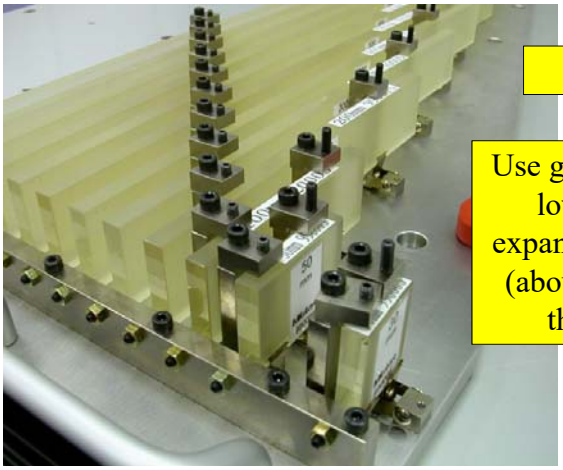
Example: High Accuracy CMM Calibration



20±0.1°C

Use gage blocks of low thermal expansion material (about 500X less than steel)

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Example: Ultra Accuracy Length Calibration

NIST Moore CMM in 20 ± 0.01°C room

Separate control room

No people in room for many hours prior to measurements

"Whoever has the best thermometer wins" - Dr. Doiron, NIST

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Justify Expense for Temperature Control

- CMM specifications in accordance to ISO 10360-2.
- Calibrate with Checkmasters.
- E_0 test run in 7 positions. In each position, 5 lengths and 3 repeats, for a total of 105 measurements.
- We need Checkmasters calibrated with adequate uncertainty.

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STA-Apex S Series

tem & workstation

Model No.		CRYSTA-Apex S 9106 / [9108]	CRYSTA-Apex S 9166 / [9168]	CRYSTA-Apex S 9206 / [9208]
Measuring range	X axis	35.43" (900mm)		
	Y axis	39.36" (1000mm)	62.99" (1600mm)	78.3" (2000mm)
	Z axis	23.62" (600mm) / [31.49" (800mm)]		
Resolution		0.000004" (0.0001mm)		
Guide method		Air bearings on each axis		
Drive speed		8 - 300mm/s (CNC mode), max. speed: 519mm/s 0 - 80mm/s (J/S Mode: High Speed) 0 - 3mm/s (J/S Mode: Low Speed) 0.05mm/s (J/S Mode: Fine Speed)		
Max. measuring speed		8mm/s (3mm/s for Type Z800)		
Max. drive acceleration		0.23G / [0.17G] (3D)		
Workpiece	Maximum height	31.49" (800mm) / [39.36" (1000mm)]		
	Maximum mass	2,645lbs. (1200kg)	3,306lbs. (1500kg)	3,968lbs. (1800kg)
Mass (including the control device and installation platform)		4,919lbs. (2231kg) [4,985lbs. (2261kg)]	6,322lbs. (2868kg) [6,389lbs. (2898kg)]	8,625lbs. (3912kg) [8,691lbs. (3942kg)]
Air supply	Pressure	58 PSI (0.4MPa)		
	Consumption	2.11CFM (60L/min) under normal conditions		
	Air source	3.53CFM (100L/min)		

CRYSTA-Apex S 900 Series Accuracy ISO 10360-2 unit: µm

Probe used	Maximum permissible error ($E_{0,MPE}$) ISO 10360-2:2009	Maximum permissible probing error ($P_{FTU,MPE}$) ISO 10360-5:2010
SP25M (Stylus: ø4 X 50mm)	1.7+3 L/1000 (temperature environment 1) 1.7+4 L/1000 (temperature environment 2)	1.7
TP200 (Stylus: ø4 X 10mm)	1.9+3 L/1000 (temperature environment 1) 1.9+4 L/1000 (temperature environment 2)	1.9
TP20	2.2+3 L/1000 (temperature environment 1) ure environment 2)	2.2

Table on opposite page describes

All manufacturers specify CMM accuracy following the ISO 10360 standards

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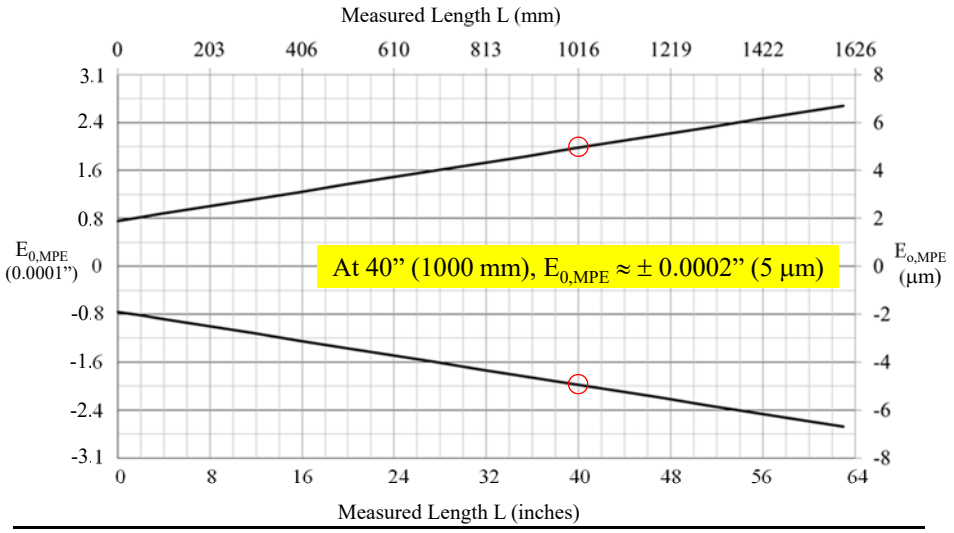
$E_{0,MPE} = 1.9 + 3L/1000$ µm, with L in mm

$E_{0,MPE} = 75 + 3L$ µinches, with L in inches



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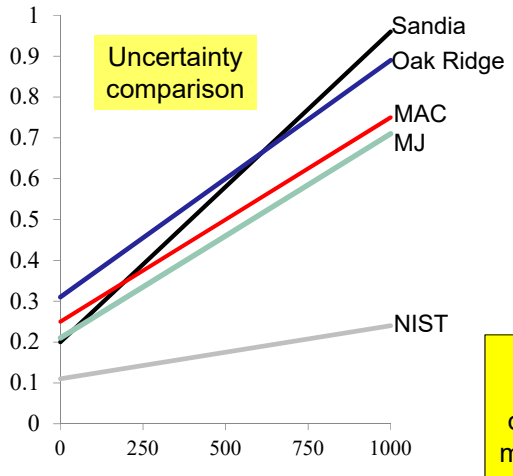
Legex CMM – Length Calibration



To ensure quality in CMM calibration, Mitutoyo America developed methods that are the most accurate of any commercial laboratory in the U.S.

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Fight Temperature to the Level You Need

- Temperature stability (vs 68°F).
- Match materials between gage and part.
- Allow proper thermal soak-out time.
- Reduce handling and operator influences.
- Reduce traffic and large doors.
- Reduce heat sources (lights/people/equipment).
- Eliminate direct blowing of air.
- Monitor the environment (with alarms).
- Keep the lights on all the time.
- Temperature compensation.

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Understanding Temperature Issues

- Thermal expansion:

  $\Delta L = (L)(\alpha)(T-20)$

  where α is the coefficient of thermal expansion, or CTE, of the material.
- 20” gage block at 21°C.

  $\Delta L = (20)(10.8)(21-20)$

  $\Delta L \approx 0.0002$ inches
- 20” gage block, Grade 00, tolerance is 10x smaller.

Long gage block calibration

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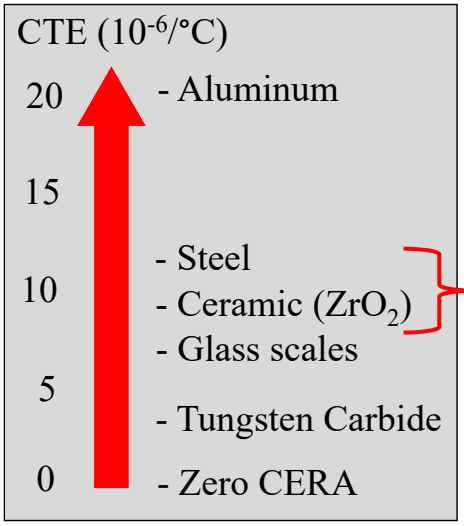
Coefficient of Thermal Expansion (CTE)



- 10.5 ± 1.5 x 10^{-6}/°C:
  - Most steels
  - Steel gage blocks
  - Ceramic gage blocks
  - Calipers
  - Carbon fiber calipers
  - Micrometers
  - Micrometers standards

Use of similar CTE reduces thermal errors

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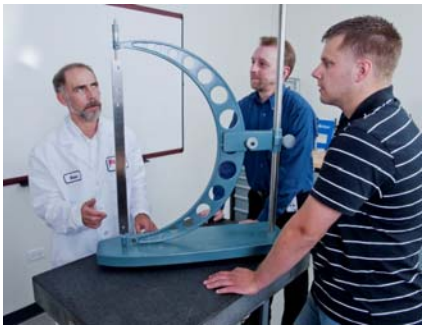
15

Matching Materials (similar CTE) is Good

- Similar CTE materials at same temperature (even not 68°F) will reduce thermal errors



Calibrate in lab and use on shop floor relies on similar materials between micrometer and standard

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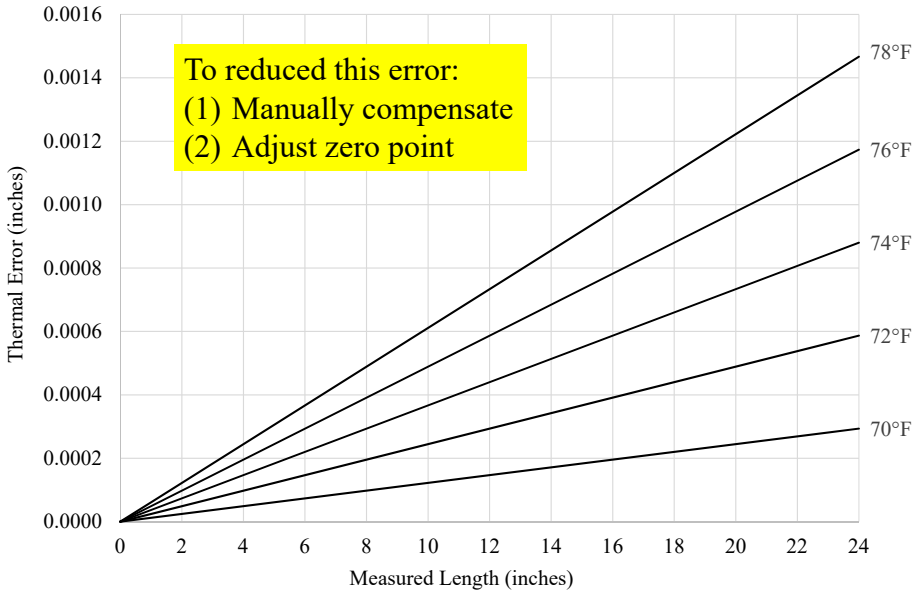
Thermal Error – Aluminum Part, Steel Micrometer

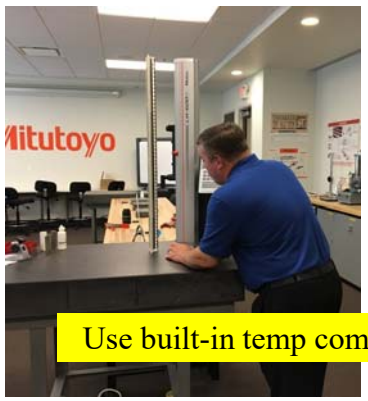


To reduced this error:
(1) Manually compensate
(2) Adjust zero point

High Accuracy Height Gage: Mitutoyo LH-600

Calibration at 20°C

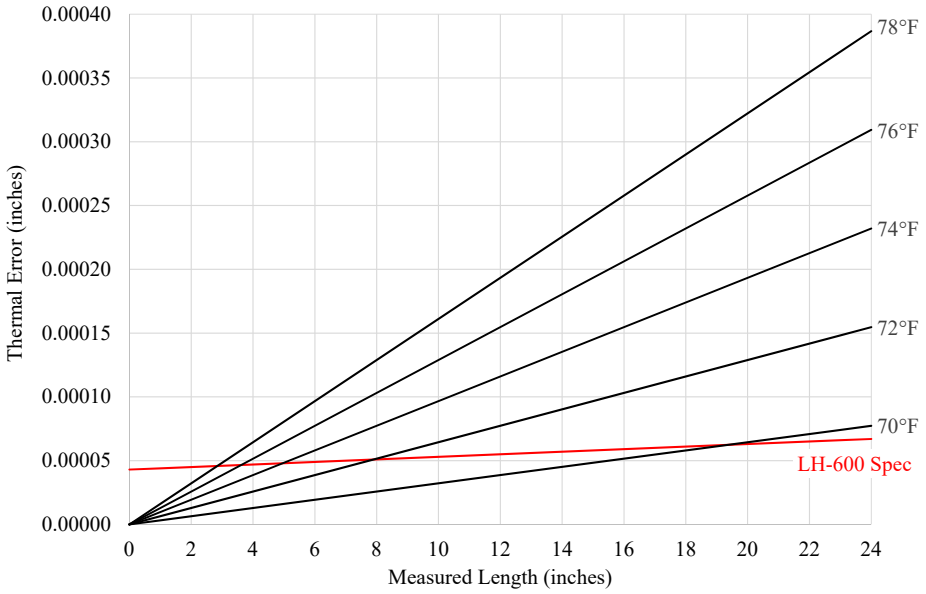
Used at 23°C



Use built-in temp comp

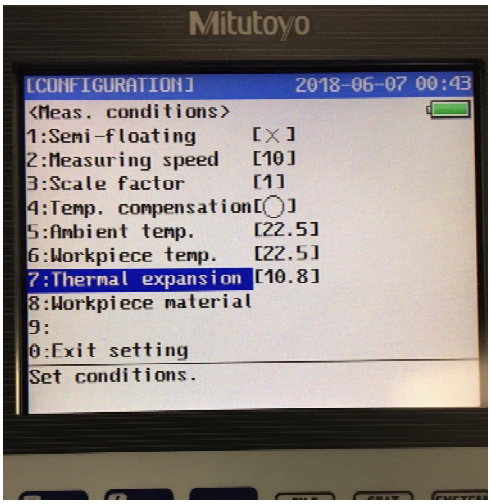
High accuracy equipment often requires temperature compensation to fully utilize the accuracy for which you paid

Steel Part on LH-600 without Temp Comp

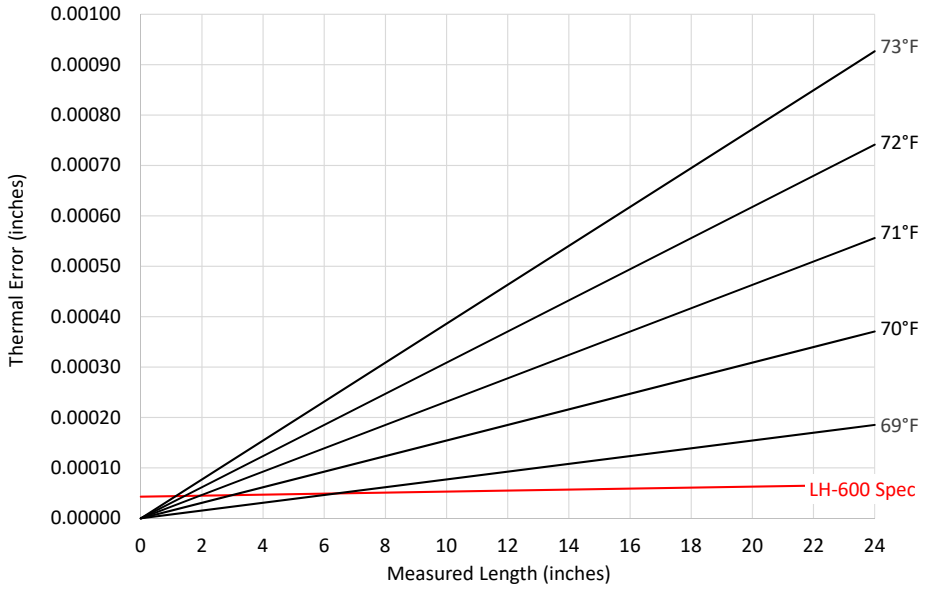


LH-600 Temperature Compensation

- LH-600 temperature compensation is built-in and is easy to use.
- Historical good practice of "thermal equilibrium" needs to be updated for modern equipment.



Aluminum Part on LH-600 without Temp Comp



Built-In Real-Time Temperature Compensation

- Temp comp is standard on many CMMs today.
- CMM accuracy relies on use of temp comp.
- If not used properly, you may create a false temperature differential that results in big errors.

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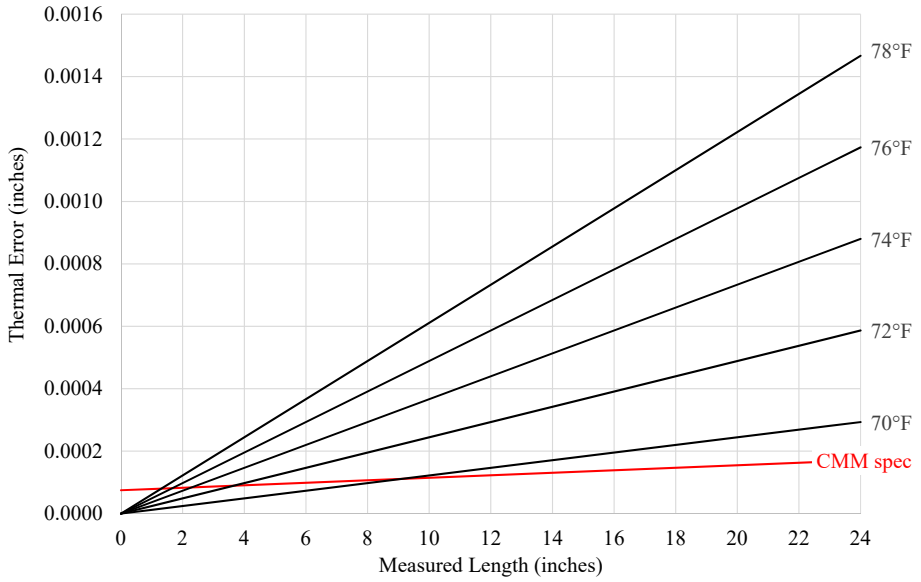
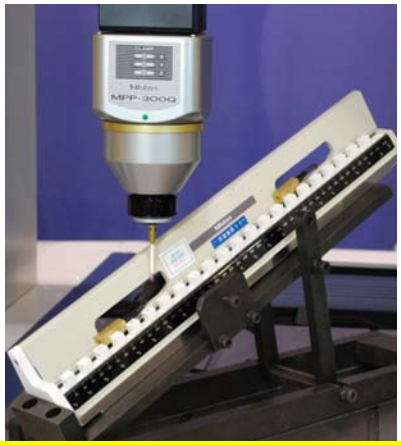
22

Steel part on temp comp CMM when NOT correctly using the temperature compensation



CMM Accuracy across Temperature Range

- CMMs are generally specified to be accurate across a range of temperatures.
- Example for Mitutoyo Crysta-Apex S:
  - 16–26°C (60.8–78.8°F)
- Specification assumes proper use of temperature compensation.



Workpiece temperature sensors in use during calibration

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24

Temp Comp on CMMs Made Easy

- Part temperature can be estimated by keeping workpiece temperature sensors attached to nearby fixturing.
- Must still use correct CTE of measured part.
- Also helps eliminate wear and tear on the temperature sensor.

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Thank You

Mitutoyo Institute of Metrology

Mitutoyo CALIBRATION LABORATORY

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