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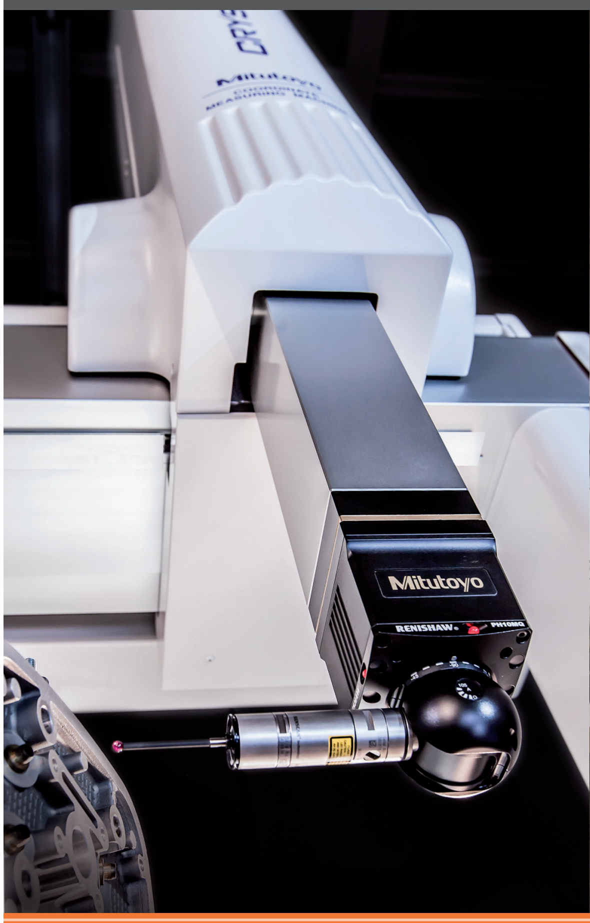
UNDERSTANDING CMM SPECIFICATIONS AND CALIBRATION METHODS

A TECHNICAL PRESENTATION FROM THE LEADING MANUFACTURER OF METROLOGY INSTRUMENTS

EDUCATION



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About this Technical Presentation

This technical presentation provides an overview of the specifications used to describe the accuracy of coordinate measuring machines (CMMs) along with the methods and tools used to calibrate CMMs in the field. The national and international standards used by all CMM manufacturers, including the ISO 10360 series, will be discussed. The history and purpose of standardized testing will also be briefly reviewed to provide understanding on how the calibration of CMMs differs from other measuring equipment. This presentation will also discuss the role of CMM calibration in traceability and show how Mitutoyo America provides traceability to CMM calibrations.

Whatever your challenges are, Mitutoyo supports you from start to finish.

Mitutoyo is not only a manufacturer of top-quality measuring products but one that also offers qualified support for the lifetime of the equipment, backed by comprehensive services that ensure your staff can make the very best use of the investment.

Apart from the basics of calibration and repair, Mitutoyo offers product and metrology training, as well as IT support for the sophisticated software used in modern measuring technology. We can also design, build, test and deliver measuring solutions and even, if deemed cost-effective, take your critical measurement challenges in-house on a sub-contract basis.

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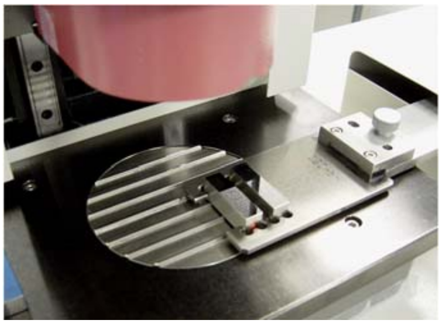
Understanding CMM Specifications and Calibration Methods: Protecting Your CMM Investment over Time

Objectives of this Presentation

- CMM calibration, verification, and performance testing.
- History and purpose of standardized tests.
- Understanding ISO versus ASME CMM test standards.
- ISO 10360-2 testing.
- CMM calibration practices.
- CMM traceability.
- Mitutoyo America and CMM calibration.

Calibration in Dimensional Metrology

In dimensional metrology, most calibrations involve measurements that are similar or identical to the typical use of the measuring equipment.



Gage block calibration by mechanical comparison to master gage blocks.

Micrometer calibration using a gage block.

CMM Calibration?

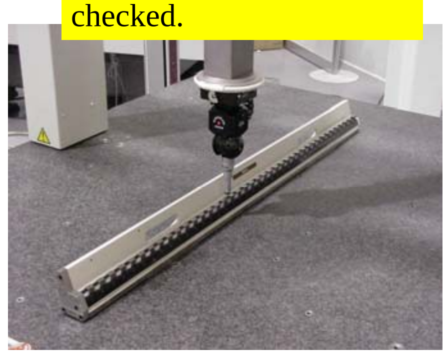
- A CMM can measure almost anything – does it need to be calibrated for everything?
  - Size, length, diameter
  - Distance, angle, position,
  - Concentricity, symmetry
  - Angularity, parallelism, perpendicularity
  - Straightness, roundness
  - Flatness, cylindricity
  - Profile, runout
  - Etc., etc., etc.

Mitutoyo Legex 12128 CMM at U.S. Navy

History of CMM Calibration

Modern CMMs have been around since 1956

For many years, just 1D length (“linears”) and maybe “squareness” was checked.

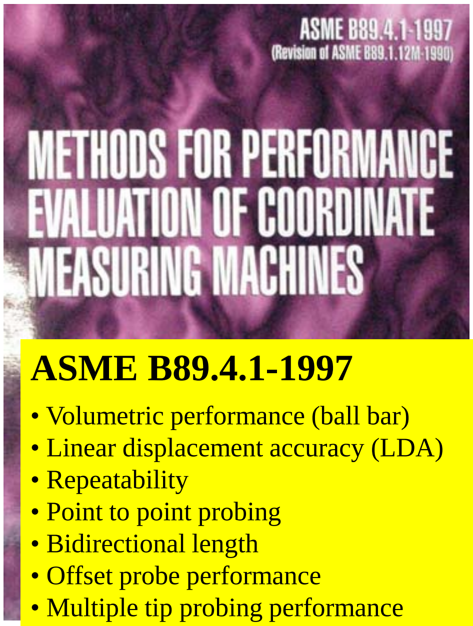


Standardized CMM Performance Tests

- ASME B89.1.12-1985
  - First American standard on CMMs.
  - Ball bars across CMM volume.
  - Laser interferometers along axes.

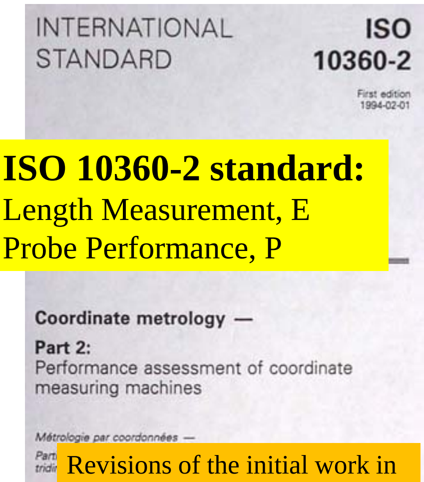
- VDI/VDE 2617:1986
  - First German standard.
  - Step gages across the CMM volume.

As CMMs grew to become the 3D measuring instrument of choice, the calibration method needed to address 3D volumetric measurement. This was first standardized globally in the mid-1980’s.



ASME B89.4.1-1997

- Volumetric performance (ball bar)
- Linear displacement accuracy (LDA)
- Repeatability
- Point to point probing
- Bidirectional length
- Offset probe performance
- Multiple tip probing performance



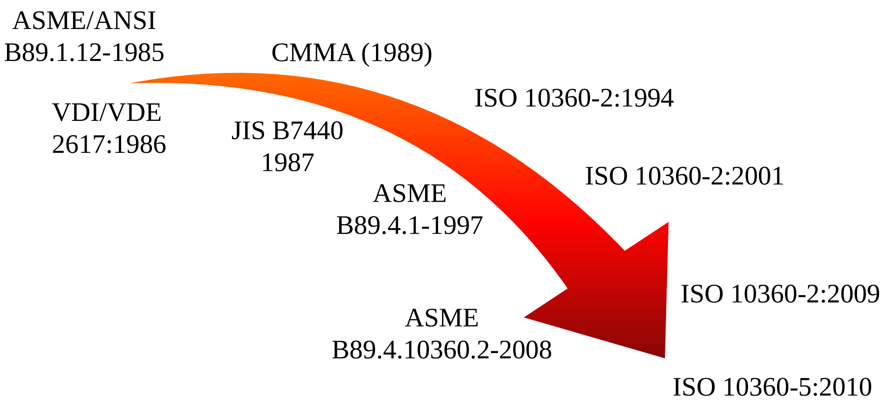
ISO 10360-2 standard:
Length Measurement, E
Probe Performance, P

Revisions of the initial work in the 1980's lead to refined and well adopted American and international (ISO) standards in the 1990's.

Harmonization in CMM Standards

The 2009 revision of ISO 10360-2 was developed concurrently with the 2008 release of ASME B89.4.10360.2. The American and ISO standards are finally harmonized and essentially identical.

Evolution of CMM Performance Testing Standards



With the full adoption of the ISO 10360 series into the U.S. market, it is unclear if the U.S. will continue developing separate American CMM standards.

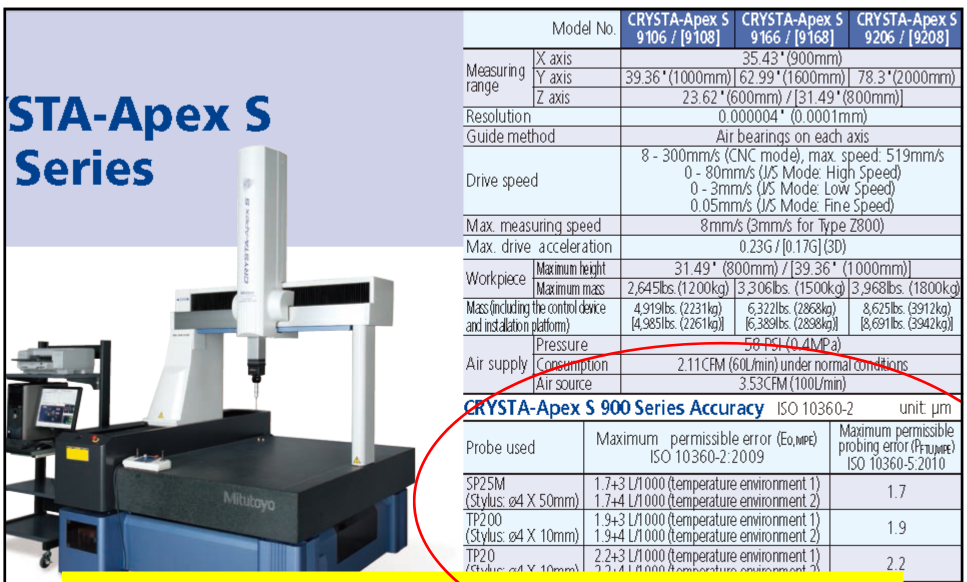
Summary of ISO 10360 CMM Standards

- ISO 10360-1:2000 Terminology.
- ISO 10360-2:2009 Length tests, E (contact probing systems).
- ISO 10360-3:2000 Rotary table tests.
- ISO 10360-4:2000 Contact scanning tests.
- ISO 10360-5:2010 Contact probing tests, P.
- ISO 10360-6:2001 Software testing.
- ISO 10360-7:2011 CMMs with imaging probing systems.
- ISO 10360-8:2013 CMMs with optical distance sensors
- ISO 10360-9:2013 CMMs with multiple probing systems
- ISO/FDIS 10360-10 Laser trackers (under development)
- ISO/DIS 10360-12 Articulated arm CMMs (under development)

Summary of Key ISO 10360 Specifications

Test	10360-2: 1994	10360-2:2001	10360-2:2009
Length	E	MPE_E	$E_{0,MPE}$
Probing	R	MPE_P	Moved
Repeatability	--	--	$R_{0,MPE}$
Offset probe	--	--	$E_{150,MPE}$

Test	10360-5:2000	10360-5:2010
Multi-stylus	MPE_{MF} MPE_{MS} MPE_{ML}	$P_{FTj,MPE}$ $P_{STj,MPE}$ $P_{LTj,MPE}$
Articulating	MPE_{AF} MPE_{AS} MPE_{AL}	
Probing	--	$P_{FTU,MPE}$


STA-Apex S Series

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

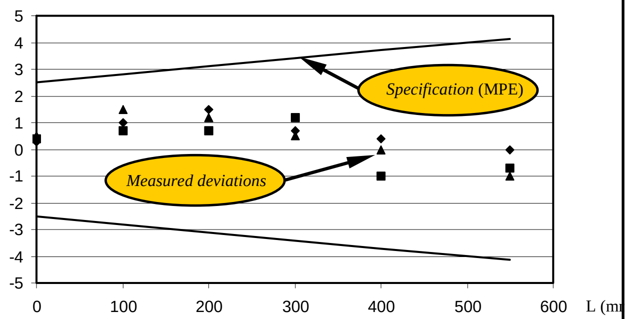
Probe used	Maximum permissible error ($E_{0,MPE}$) ISO 10360-2:2009	Maximum permissible probing error ($P_{FTU,MPE}$) ISO 10360-5:2010
SP25M (Stylus: ø4 X 50mm)	1.7+3 L/1000 (temperature environment 1) 1.7+4 L/1000 (temperature environment 2)	1.7
TP200 (Stylus: ø4 X 10mm)	1.9+3 L/1000 (temperature environment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

When comparing CMM accuracy, only the guaranteed accuracy specifications really matter (and are warrantied).

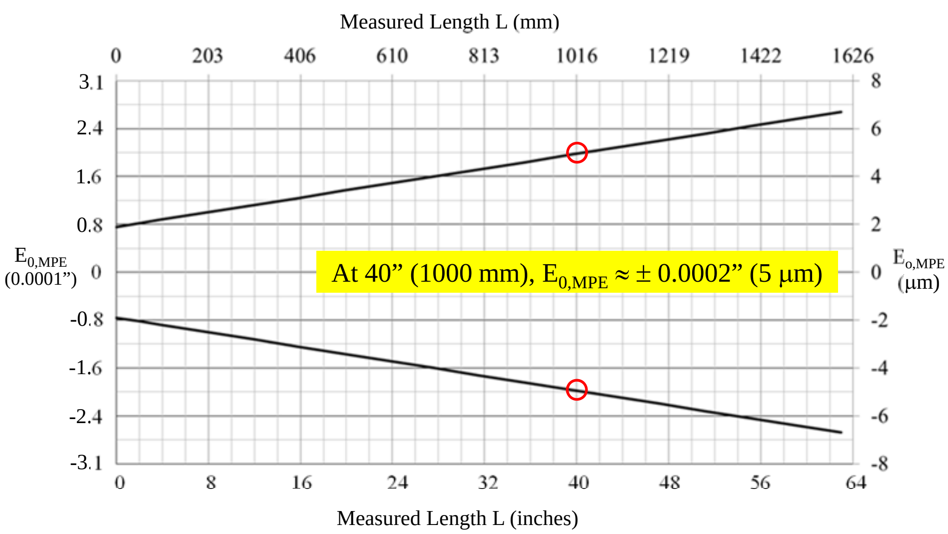
The Length Test: $E_{0,MPE}$

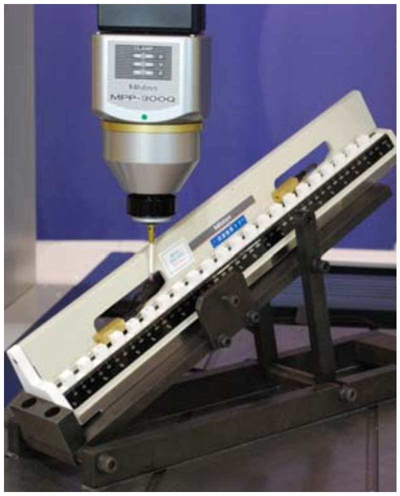
- How well can the CMM measure the distance between any two points?
- Applies to the entire measuring volume.

Example: $E_{0,MPE} = 2.5+3L/1000$ µm
$L = 500$ mm, $E_{0,MPE} = \pm 4.0$ µm



$E_{0,MPE} = 1.9 + 3L/1000$ µm, with L in mm
$E_{0,MPE} = 75 + 3L$ µin, with L in inches

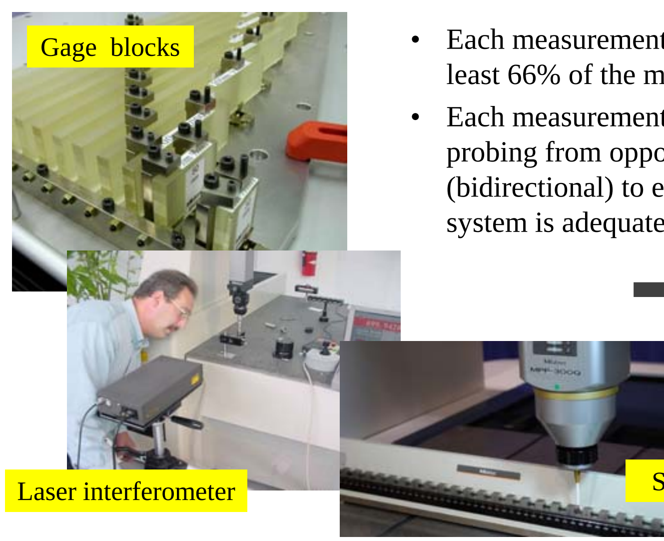




ISO 10360-2:2009 standard
Length Measurement, E_0

- E_0 test run in 7 positions. In each position, 5 lengths and 3 repeats, for a total of 105 measurements.
  - Four space diagonals.
  - Parallel to X, Y, and Z axes.
- Comprehensive overall test of CMM structure, probe system, and repeatability.
  - Each measurement is a single point to single point distance which thoroughly tests the CMM.

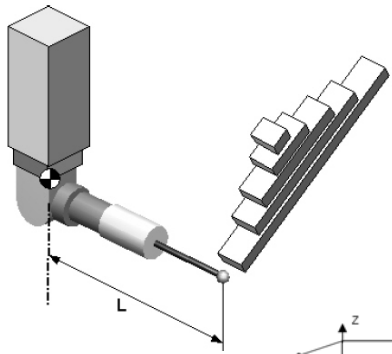
ISO 10360-2:2009 Test Artifacts



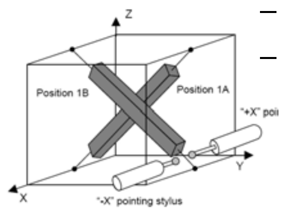
- Each measurement line must cover at least 66% of the maximum possible.
- Each measurement must involve probing from opposing directions (bidirectional) to ensure the probe system is adequately tested.

Bidirectional

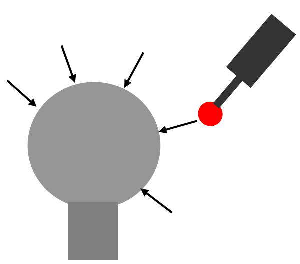
Offset Probe Test E_{150} in ISO 10360-2



- Optional test in new 2009 revision of ISO 10360-2.
- Offset probe test has default of L=150 mm (E_{150}).
- Required to test two planar diagonals (XZ or YZ).
  - Eight possibilities.
  - User free to choose.



ISO 10360-5:2010 Probing Tests



- Probing performance tests, P.
- Not a test of the probe system alone, but the probe and CMM combination.
- P_{FTU} requires 25 points around small test sphere and report the spherical form.
- Previously known as R in 1994 and P in 2001 versions of ISO 10360-2 (but same test).

Specified versus Tested

- Standards describe the tests, but not the extent of testing for every installation or calibration.
- Some tests are “standard”, some not, and some service providers can’t do them all.
- Important contractual issue to consider.

Is the cal still good?

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CMM Calibration Practices

- Test method: recommend using ISO 10360 for CMM calibration.
- Complete as-found readings.
  - Don’t allow partial as-found readings.
- Preventative maintenance.
- Adjustments – usually in software and usually OEM controlled.
  - Linears and squareness are common.
- Complete as-left readings.

Calibration maintains your investment. Be careful with low cost calibration services.

ISO standards were written for comparison and adopted for use in calibration.

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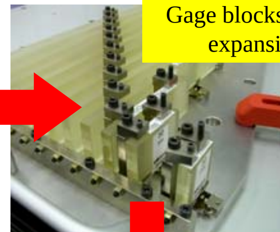
Mitutoyo CMM Traceability

Many quality systems require ISO/IEC 17025 accredited calibrations

NIST Moore CMM in 20 ± 0.01°C room
Uncertainty < 0.3 µm over 1000 mm

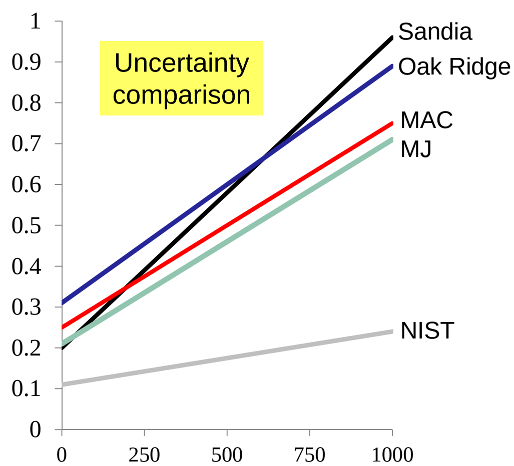


Gage blocks of low thermal expansion material

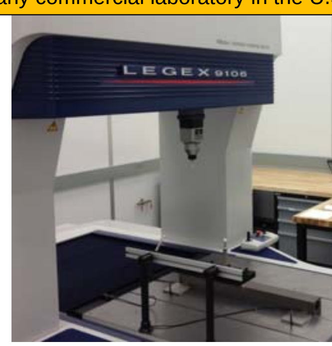
Mitutoyo America Calibration Lab
Uncertainty < 0.75 µm over 1000 mm

Field calibration with adequate uncertainty

Length Calibration Capability



Using a Mitutoyo Legex CMM, Mitutoyo America offers the lowest uncertainty for length calibrations of any commercial laboratory in the U.S.



Comparison of Mitutoyo Japan (MJ), Mitutoyo America (MAC), and three premier government laboratories in the U.S.

Thank You

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