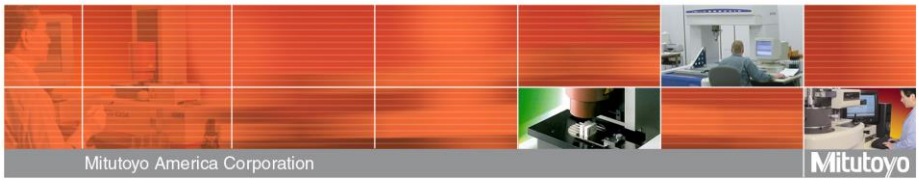
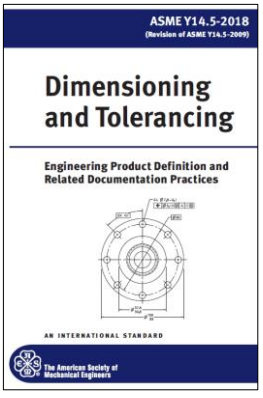
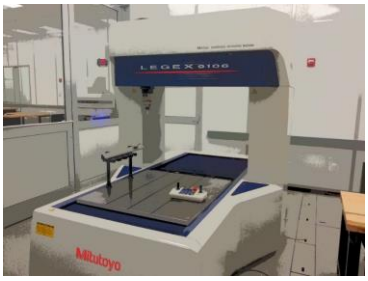




GD&T and the new ASME Y14.5-2018

Jim Salsbury, Ph.D., General Manager Corporate Metrology



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Mitutoyo America headquarters in Aurora, Illinois

New facility opened October 2013

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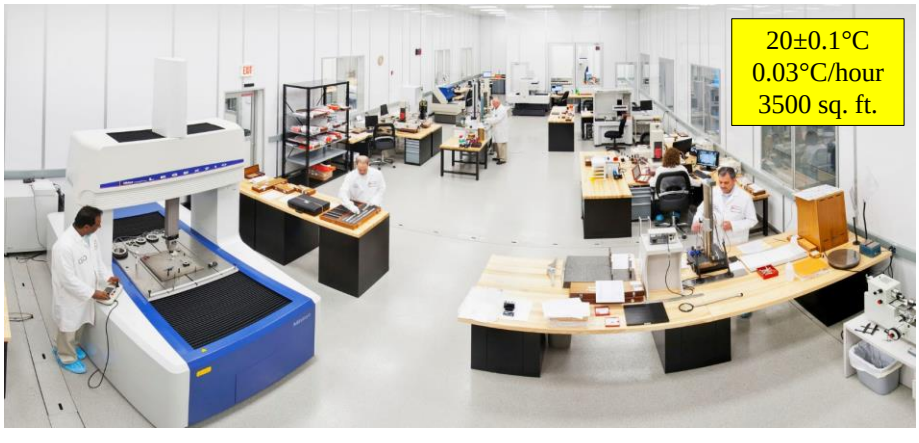
High Precision Calibration Lab



20±0.1°C
0.03°C/hour
3500 sq. ft.

A significant percentage of US manufacturing is traceable to our lab.

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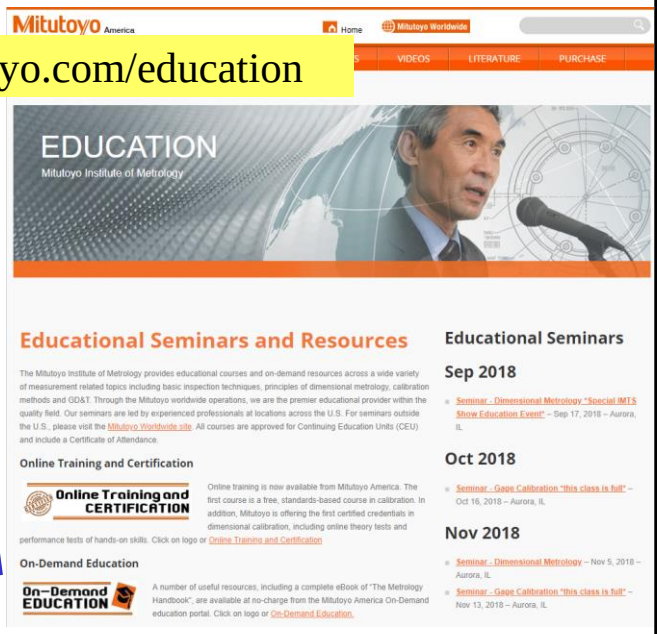

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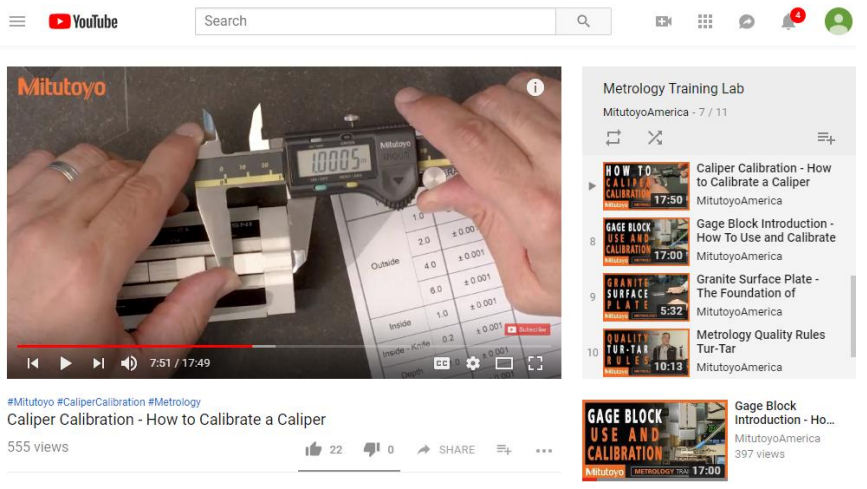

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Significant Changes in ASME Y14.5-2018

- 4.1 (q) The as-designed dimension value does not establish a functional or manufacturing target.
- 4.1 (s) Elements of surface include surface texture and flaws (e.g. burrs and scratches).
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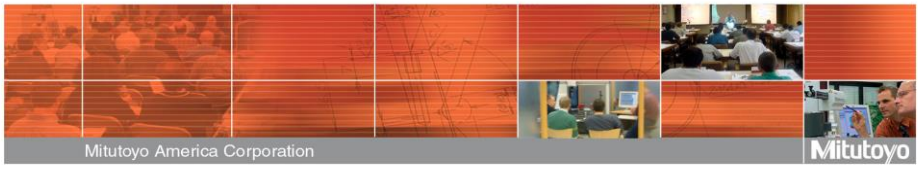

Important Disclaimers

- In general, the use of any standards is voluntary.
- For many organizations, it may be years before they start using the new ASME Y14.5 standard, if at all.
- Regardless, understanding the changes is important as it may impact your understanding of GD&T.
- You need to know which standard you are using.
- The opinions expressed in this presentation are my own – others may disagree (and that's ok).
- Theory and best practices often clash – every organization needs to find their best solution.

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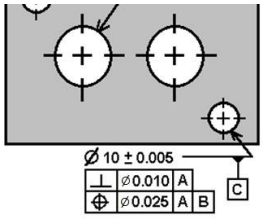
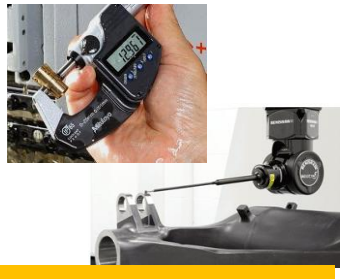
It would be so nice if the engineering design simply told us how to measure?



?



Engineering Design

Measurement Method

A design captures product requirements - a measurement method must then be developed that meets business needs.

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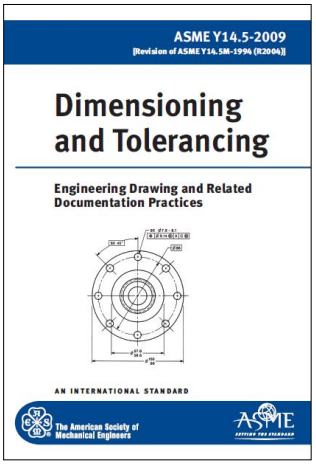
ASME Y14.5-2009 and 2018

- ASME Y14.5 states:

  "This document is not intended as a gaging standard."

- Developing measurement methods can be challenging at times.
- ASME Y14.5 defines tolerance zones only and therefore reporting <u>any</u> measured value requires assumptions beyond the standard.
- ASME Y14.5.1 GD&T math standard



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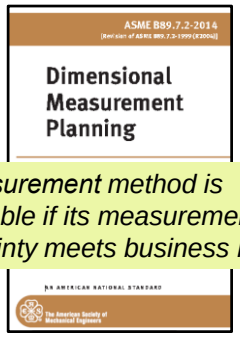
Measurement Planning

- Measurements can never "conform" to ASME Y14.5.
- But measurement methods are influenced by ASME Y14.5.
- ASME B89.7.2-2014 Dimensional Measurement Planning.



"a measurement method is acceptable if its measurement uncertainty meets business needs"

- Must consider business needs:
  - Cost of measurements.
  - Purpose of the measurement.
  - Impact of pass and fail errors.
  - Legal/liability issues.
  - Organizational policies.
  - Customer requirements.

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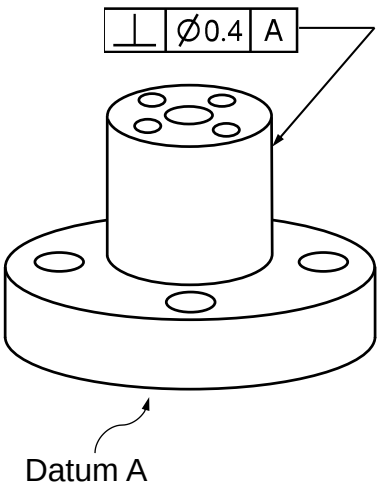
The Inspector who said "So What?"

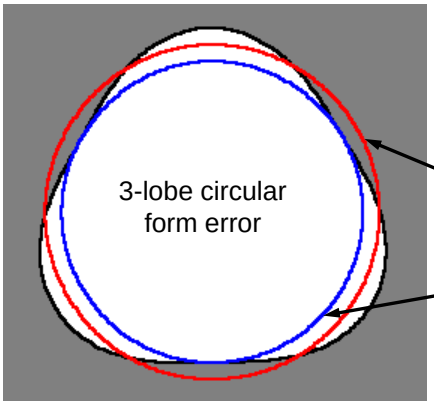
A radical and controversial case study in determining if measurement uncertainty meets business needs

The inspector who said "so what"

- Real example from audit of contract inspection lab.
- Measure: perpendicularity of cylinder axis.
- Measured on a CMM. The usual advanced concerns:
  - Number of points.
  - Software algorithms.
  - CMM/probe configuration.
  - Datums and part coordinate system.



Power = Responsibility



- Modern measuring instruments offer options, particularly in software.
- Typical circle fitting:
  - Least squares
  - Minimum zone
  - Maximum inscribed
  - Minimum circumscribed

Different experts may argue one method or another is "correct".

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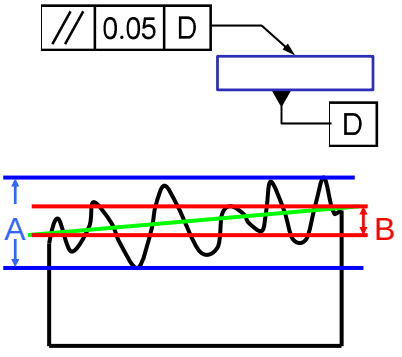
What is the Software Doing?

- Modern software provides many tools to support GD&T measurement challenges. The user must understand their software.
- "Methods Divergence" is a term used to describe how equally valid methods may give very different results.



In 1988, a GIDEP Alert shut down CMM use for GD&T in some industries. The key example was parallelism not including the form error (reporting B, not A, shown above).
(GIDEP is Government-Industry Data Exchange Program)

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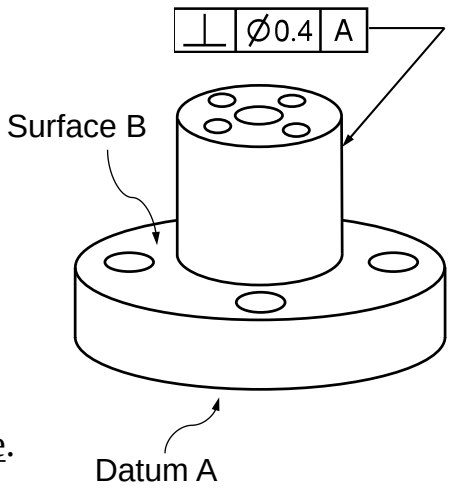
The inspector who said “so what”

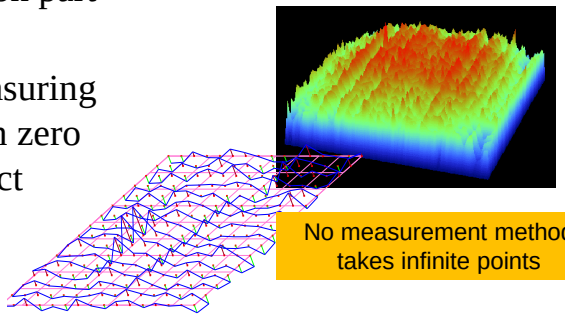
- Inspector used Surface B as datum instead of A.
- He measured the *wrong* surface and then said “so what” when questioned.
- If A and B are parallel *enough*, then is this ok?
- With the large 0.4 mm tolerance, the difference was negligible, <u>in this case</u>.



Measurement Planning & Assumptions

- Do we always measure at exactly 20°C (68°F)?
- Do we always measure infinite points on part surfaces?
- Do we use measuring equipment with zero error and perfect repeatability?

- All measurements involve balancing costs versus accuracy.



No measurement method takes infinite points

Measurement Quality

- You don't necessarily have to do a formal uncertainty analysis – you just need to recognize and manage the important sources of variation (error).

Source of Uncertainty	Management Technique
Instrument accuracy	Calibration
Measurement process variation	Gage repeatability (or Gage R&R)
Methods divergence	Understand and assess impact or establish best practices

Industry doesn't have deep experience with managing methods divergence issues

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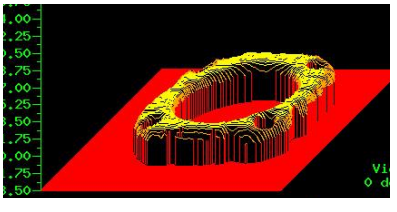
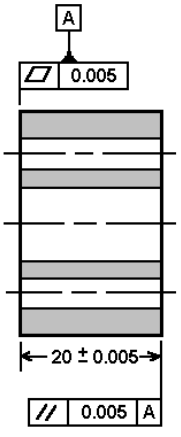
Case study – that's not what I meant

- Flatness of Datum Feature A.
- Existing measurement method used multiple contact points.
- Interferometry introduced and suddenly "good" parts failed.





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Is the Drawing even "Correct"?

- In theory, tolerances are supposed to be independent of measurement methods.
- But many drawing tolerances were developed based on data from measurements.
- In some cases, the drawing simply attempts to capture the functional manufacturing and measurement process.

Which came first – a functional part or the drawing?

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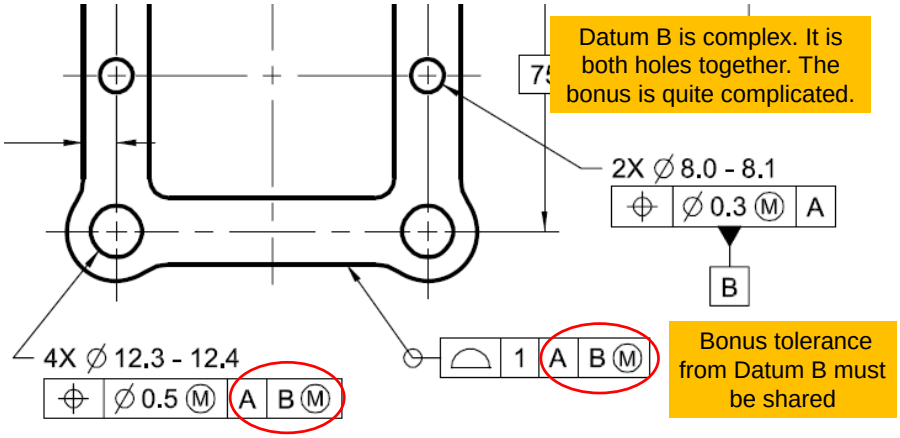
And sometimes measurement is a real challenge…



Patterns, simultaneous requirement, and Ⓜ on datums can create measurement challenges.

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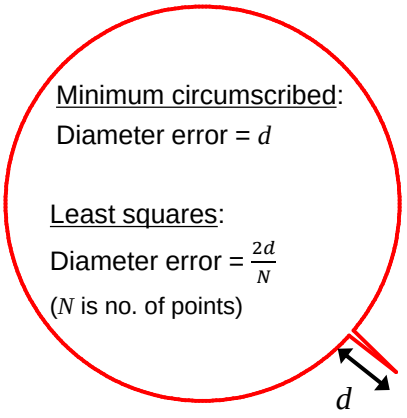
Wrong is best (?) – our love affair with the least squares algorithm



- Easy to implement in software.
- Historically developed for handling imperfect measurement data.
- Most repeatable results.
- Averages out errors, like shown here for diameter influenced by “dirt”.

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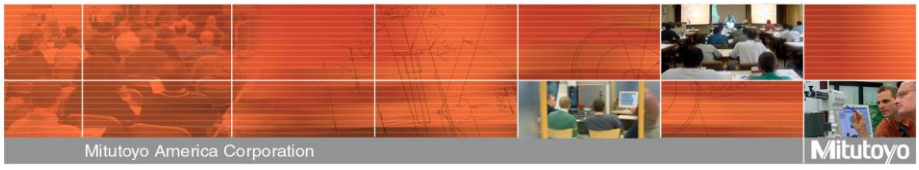
Significant Changes in ASME Y14.5-2018

- 4.1 (q) The as-designed dimension value does not establish a functional or manufacturing target.
- A-8.4 Concentricity and symmetry tolerances have been removed (term, symbol, and concept).
- 5.16 Changes to radius tolerance.
- 4.1 (s) Elements of surface include surface texture and flaws (e.g. burrs and scratches).



New Rule in ASME Y14.5-2018

- 4.1 (q):

"Unless otherwise stated by a drawing/model note or reference to a separate document, the as-designed dimension value does not establish a functional or manufacturing target."

This new rule eliminates some potential ambiguity.

- Example:

$32\ ^{+0.02}_{0}$

- The 32 is not the target.
- 32.01 is the middle of the tolerance zone and would be reported as the "best" part.

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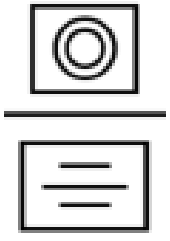
Elimination of Concentricity and Symmetry



- Why removed?

"Eliminate the confusion that surrounds these symbols and their misapplication."

- Many organizations had banned the use of these tolerances decades ago.

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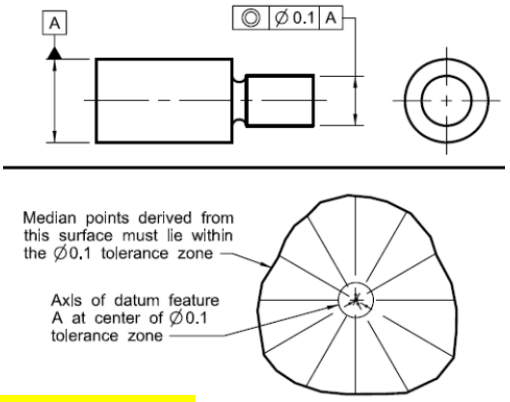
No More Concentricity

- ASME Y14.5-2009 Concentricity: condition where the median points of all diametrically opposed elements of a surface of revolution are congruent with a datum axis



Position and runout are better options for controlling location of coaxial features

2D only, not axis

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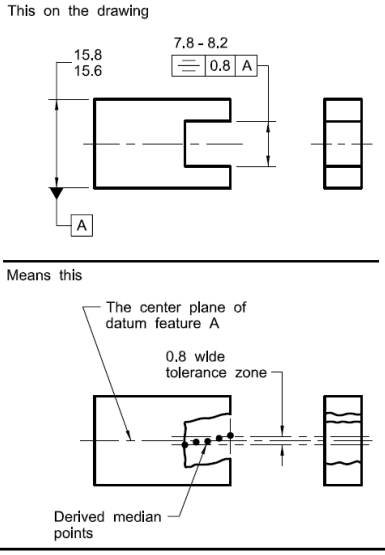
No More Symmetry

- ASME Y14.5-2009 Symmetry: condition where the median points of all opposed elements of two or more feature surfaces are congruent with a datum axis or center plane



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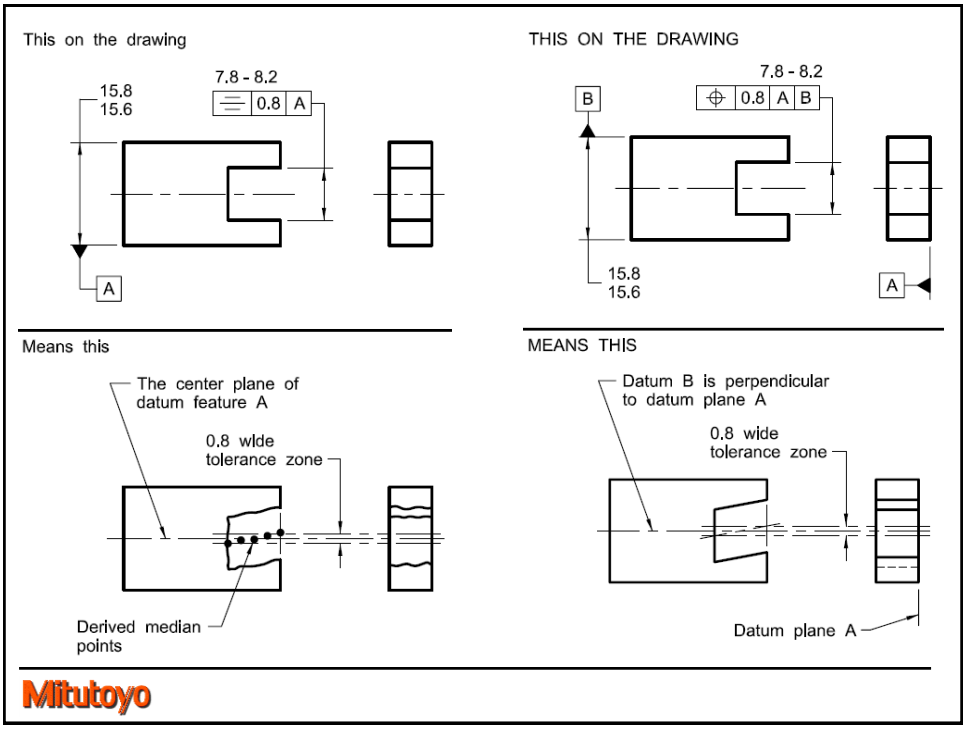

Concentricity/Coaxiality ◎

- ASME Y14.5 concentricity
  - Control of opposing median points.
- ISO 1101 concentricity
  - 2D control of a center point (position)
- ISO 1101 coaxiality
  - 3D control of derived median line (position)

Many commercially available measurement softwares (e.g. with CMMs) use ISO 1101 terms but evaluate concentricity like a Y14.5 position tolerance??

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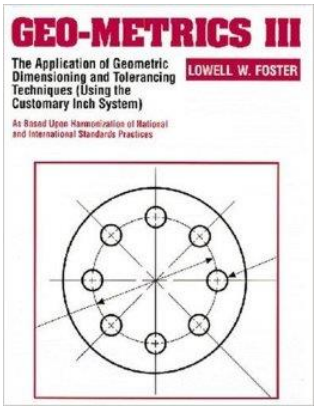
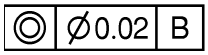
ASME Y14.5 versus ISO 1101

- There are two GD&T standards in use.
- In Lowell Foster's 1994 book GEO-METRICS III, he said there is 90 to 95% agreement between ASME and ISO.
- Example issue – same symbol, different meaning:





For concentricity, ISO controls axis but ASME controls opposed median points

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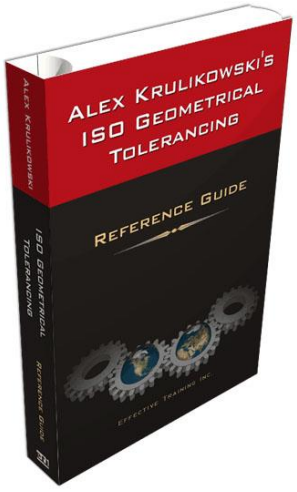
ASME Y14.5-2009

- In Alex Krulikowski's 2010 book ISO Geometrical Tolerancing, he says about 65% of the possible tolerances are either specified or interpreted differently between ASME and ISO.
- Though so much "looks the same", the difference in fundamental design principles continues to grow every year.



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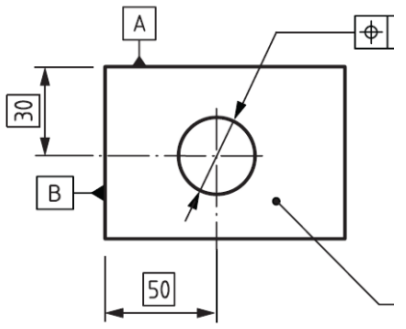
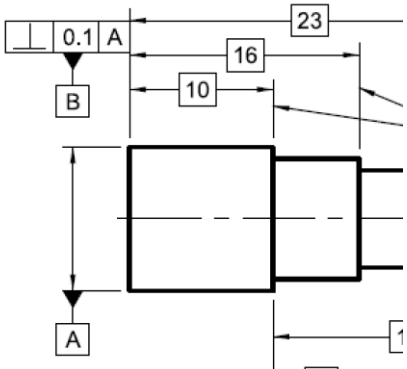
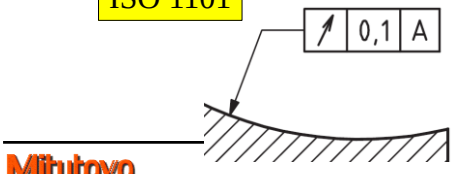
ISO vs ASME



ISO 1101



ASME Y14.5



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ASME vs. ISO for Size Tolerance

- In ASME Y14.5, a size tolerance controls the actual mating size and the local size.
- In ISO 1101, a size tolerance controls only a 2-point size, unless indicated otherwise.
  - To control the mating size in ISO, use the envelope symbol Ⓔ

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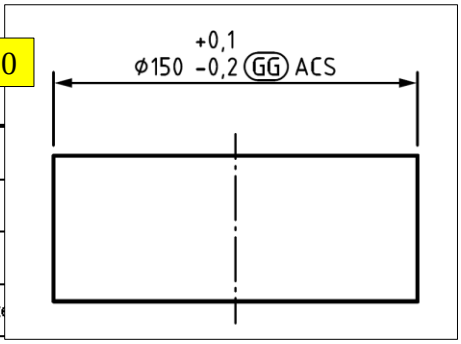
ISO divergence from ASME is growing

- ISO continues to change to align with modern functional issues and inspection techniques.

From ISO 14405-1:2010

Modifier	
(LP)	Two-point size
(LS)	Local size defined by a sphere
(GG)	Least-squares association criterion
(GX)	Maximum inscribed association crit
(GN)	Minimum circumscribed association criterion



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Rockwell Diamond Indenter from ASTM E18-19

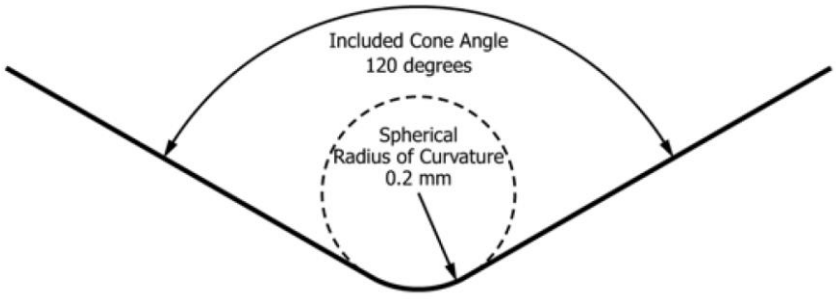

FIG. A3.1 Diagram of Cross-Sectional View of Spheroconical Diamond Indenter Tip

R0.2 ± 0.01 mm with included angle of arc of 60°

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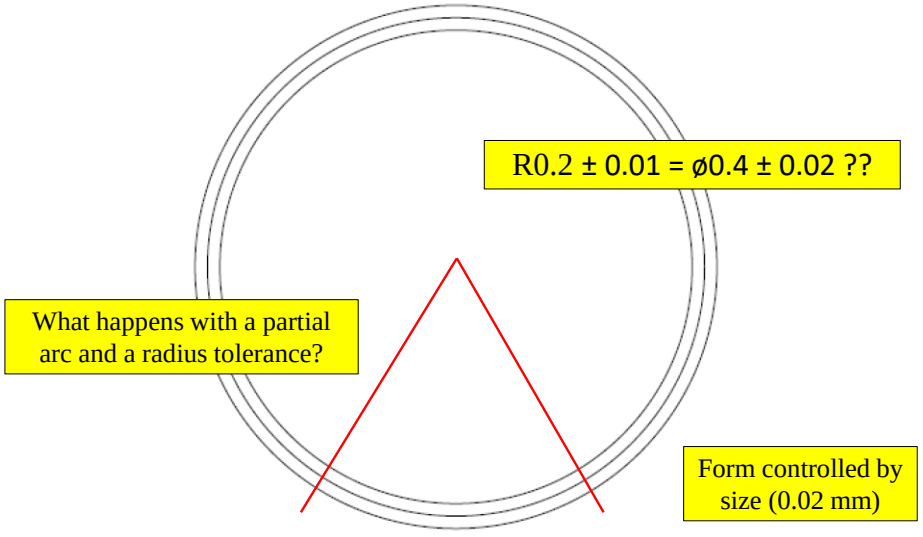
In ASME Y14.5 world, R ≠ ½ D



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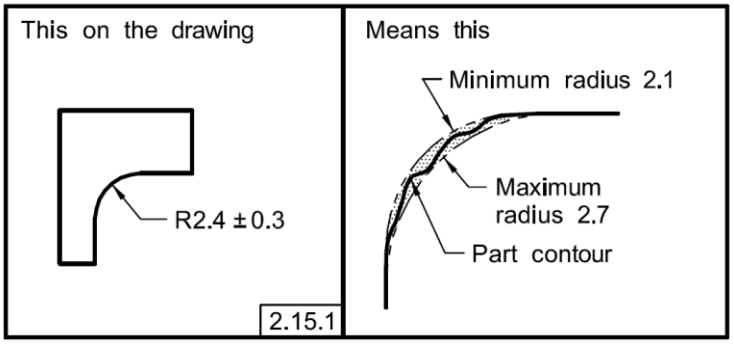
Poor definition: Y14.5-2009 radius

- Ambiguous, R ≠ ½ D
- Tolerance zone tapers to zero.
- Measurement repeatability problems due to ambiguity.



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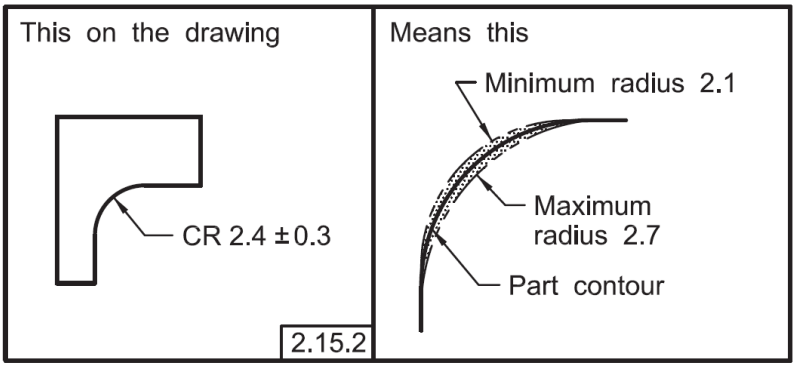
Y14.5-2009 Controlled Radius

- Controlled radius:
  - "…fair curve without reversals"???
  - Should be "further defined"???



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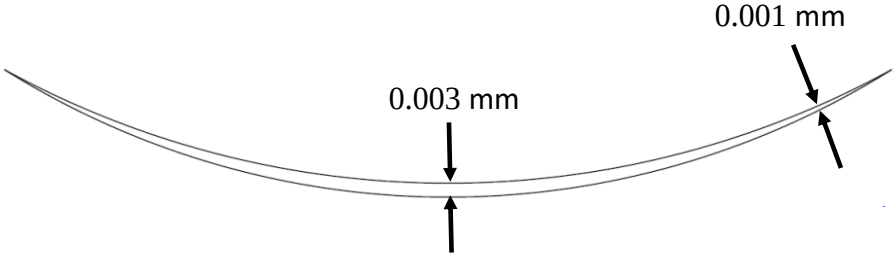
Diamond Indenter Example

R0.2 ± 0.01 mm with included angle of arc of 60°



What do we measure? We want to measure a radius to compare to the tolerance, but a radius tolerance really creates a nonuniform profile tolerance with a zone that tapers to zero at the ends. But that sort of sucks, so we generally ignore it.

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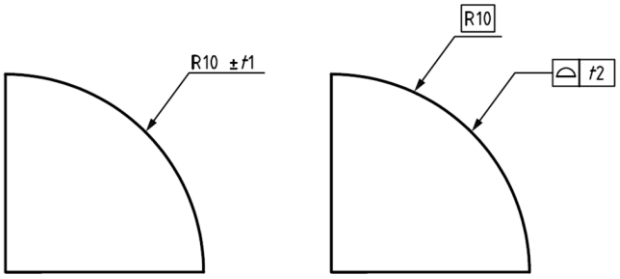
Replace +/- radius with profile?



- From the ISO 14405-2 standard on dimensions other than linear sizes.

ASME Y14.5-2018

Figure 5-24 Specifying a Radius

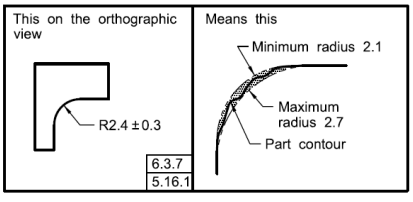
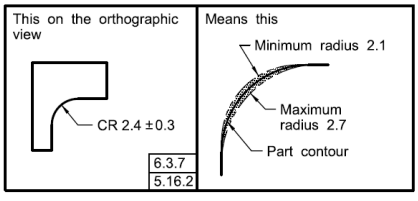


Figure 5-25 Specifying a Controlled Radius



- Basic idea of radius and controlled radius have not changed in 2018 revision.
- One massive change for 2018: “When the center of the radius is located via dimension(s), the arcs are concentric.”

Located vs Unlocated Center

Fig. 1-23 Radius With Located Center

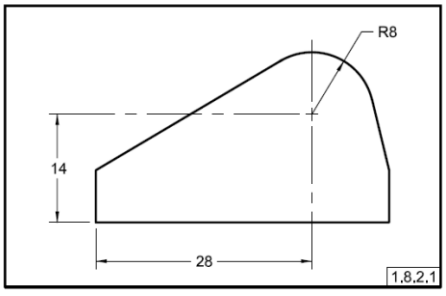
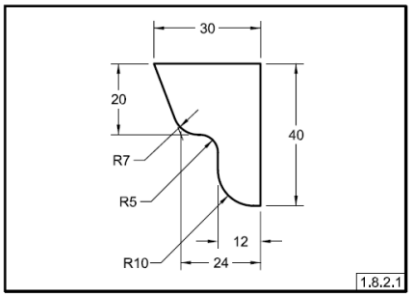


Fig. 1-24 Radii With Unlocated Centers



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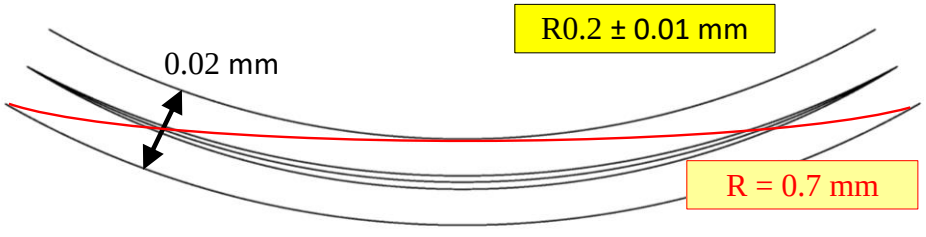
Tangent located or center located



If the center is dimensioned, the radius tolerance creates an entirely different profile tolerance zone.

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Good Practice to Eliminate Ambiguity

Only use plus/minus tolerances for size on features that you can grab with the outside or inside jaws of a caliper

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Influence of Surface Texture

- New Fundamental Rule in ASME Y14.5-2018
- Section 4.1 (s): “Unless otherwise stated, elements of a surface include surface texture and flaws (e.g. burrs and scratches). All elements of a surface shall be within the applicable specified tolerance zone boundaries.”

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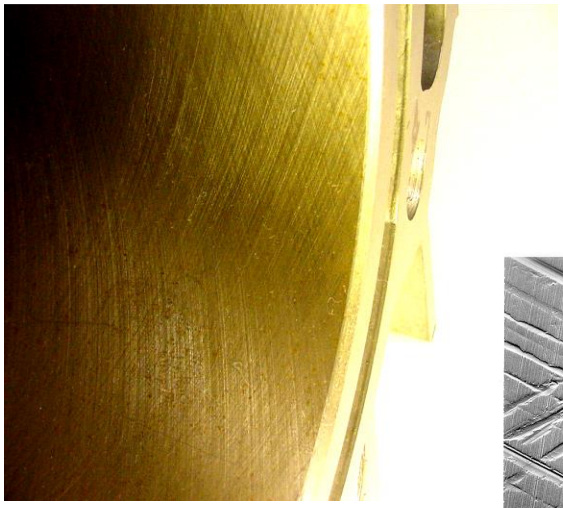

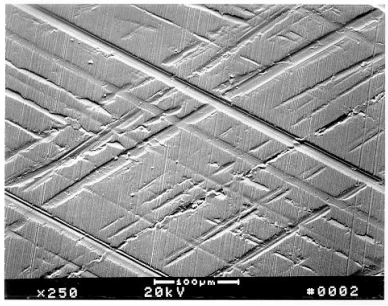

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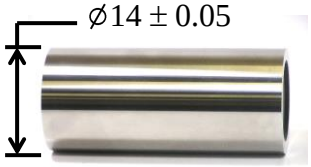
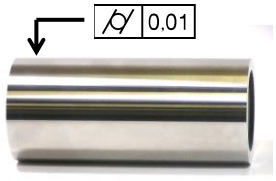


Size



Form

Roughness

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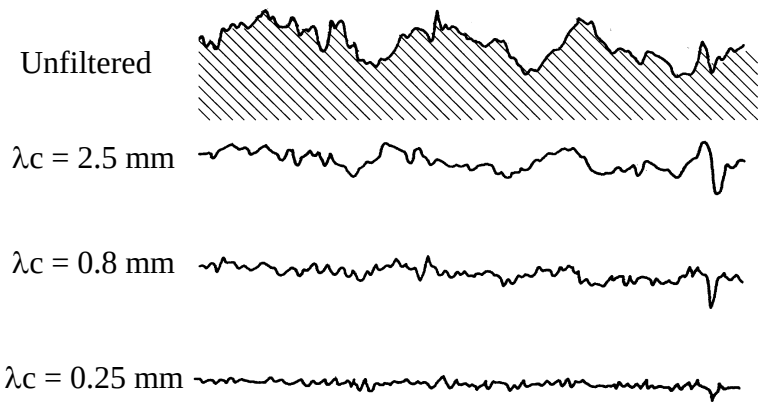
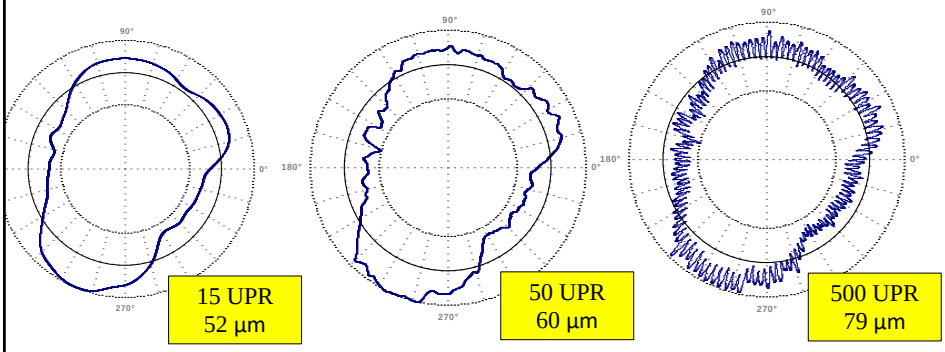
Surface Roughness



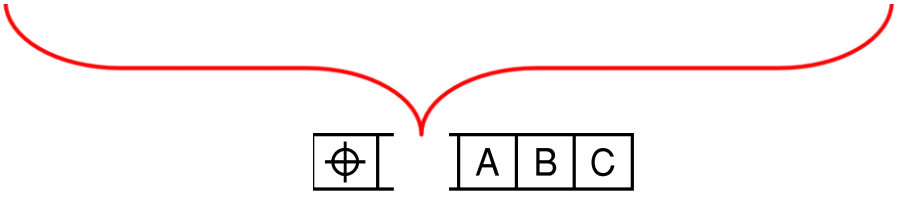
50 years of filtering in roundness measurement

- Form measurement is heavily influenced by filtering.
- Does Y14.5 give the designer the necessary tools?



Brave New World of ISO 1101:2017

Tolerance zone					Toleranced feature				Characteristic		Material condition	State
Shape	Width and extent	Comb.	Specified offset	Con-straint	Filter[a]		Ass. tol. feature	Derived feature	Association[b]	Parameter[c]		
					Type	Indices						
⌀ S⌀	0,02 0,02–0,01 0,1/75 0,1/75×75 0,2/⌀4 0,2/75×30° 0,3/10°×30°	CZ SZ	UZ+0,2 UZ-0,3 UZ+0,1:+0,2 UZ+0,2:–0,3 UZ-0,2:–0,3	OZ VA ><	G S etc.	0,8 –250 0,8–250 500 –15 500–15 etc.	Ⓒ Ⓖ Ⓝ Ⓣ Ⓧ	Ⓐ Ⓟ Ⓟ25 Ⓟ32–7	C CE CI G GE GI X N	P V T Q	Ⓜ Ⓛ Ⓡ	Ⓕ
1a	1b	2[d]	3	4[d]	5a	5b	6	7[d]	8	9	10[d]	11
8.2.2.1					8.2.2.2				8.2.2.3		8.2.2.4	8.2.2.5



Use GD&T Wisely

- GD&T is deeply complex and can be very tricky at times.
- Use the available tools in whatever manner best serves your organization.
- No measurement method is “correct”, but some are better than others.
- If you don’t like what the standard says, redefine it for your own purposes.

Thank You

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