

Methods for Measurement of a Magnification Specimen

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Primary Standards Laboratory Certificates Standards for the Department of Energy Nuclear Weapons Complex



Radiation - Pulsed Neutrons



Primary Standards Lab Building

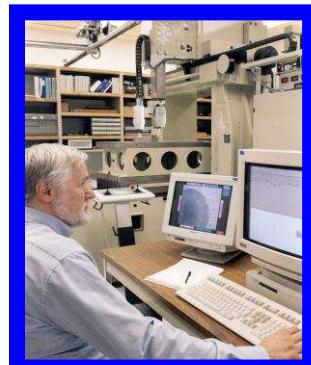


Pressure

**The PSL Mission is to
Ensure Weapon Data Integrity
for the NWC**



DC High Voltage



Dimensional



Microwave



Primary Standards Laboratory

- Operated by Sandia National Laboratories
- PSL is the highest level metrology organization for the Standards and Calibration Program in the National Nuclear Security Administration (NNSA)
- Responsibilities include technical guidance, training, certification of standards for contractors, development of new standards, proficiency testing and oversight of all NNSA calibration programs
- Support for NNSA / DOE / ERDA / AEC for more than 57 years



Sandia Metrology

Sandia Metrology provides:

- **Calibration of equipment**
- **Consultation services**
- **Management of calibration/traceability records**
- **Solutions to measurement problems**



Outline

- Magnification specimen
- Measurement methods
- Comparison of results
- Conclusions



Magnification Specimen

- Cylindrical part with a “flick” (section of removed material)
- “Flick” depth of 2-300 μm
- Used to calibrate gage head sensitivity (magnification) of a roundness machine

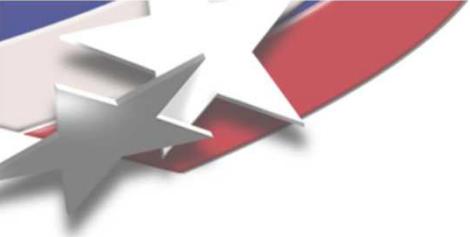




Roundness Machine

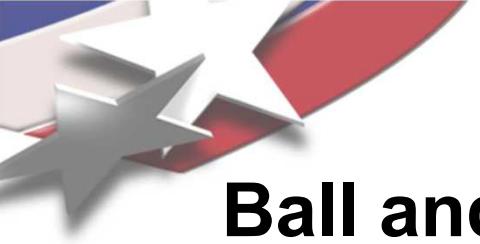


- **Talyrond 73 HPR**
- **Used to measure geometry of**
 - **ring gages**
 - **plug gages**
 - **spheres**
 - **hemispheres**



Measurement Methods

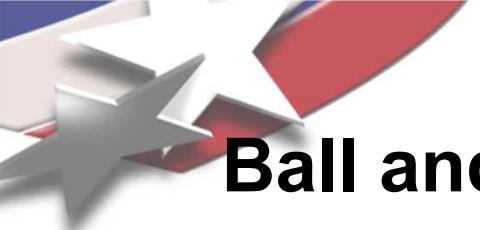
- Ball and cylinder mechanical comparator (SIP)
- Internal/external diameter comparator
- Coordinate measurement machine (CMM)
- Stylus-based measurement device (Talysurf)



Ball and Cylinder Mechanical Comparator



- SIP MI6B micro indicator comparator
- Uses a calibrated laser scale
- 1 mm range (maximum)
- 130g contact force
- Scale checked with gage blocks
- Also used to measure
 - Balls
 - Thread wires



Ball and Cylinder Mechanical Comparator Set-up

- Measurement specimen mounted in a v-block
- Positioned using
 - Spacer and magnet
 - Single axis translational stage
- Measured with round tip (0.107" spherical radius)
- Maximum outside diameter compared to minimum diameter on the flick





Internal/External Diameter Comparator



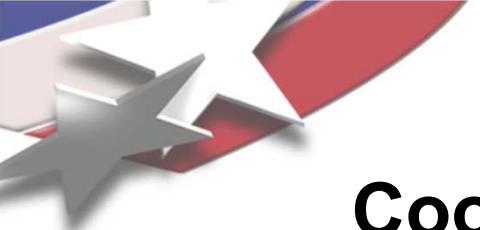
- **Federal Horizontal Master Comparator 136B-3**
- **Uses diamond-tipped feelers (elliptical, 1/8" radius)**
- **Gage blocks are used to check magnification of amplifier**
- **Analog display**
- **Also used for**
 - **Ring gage**
 - **Plug gage**



Internal/External Diameter Comparator Set-up



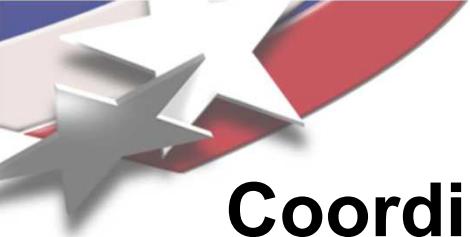
- Magnification specimen is placed on a drill blank (cylinder)
- Two single axis translational stages are used for holding and adjusting
- Comparator used to find difference between highest point on specimen cylinder and lowest point on flick



Coordinate Measurement Machine

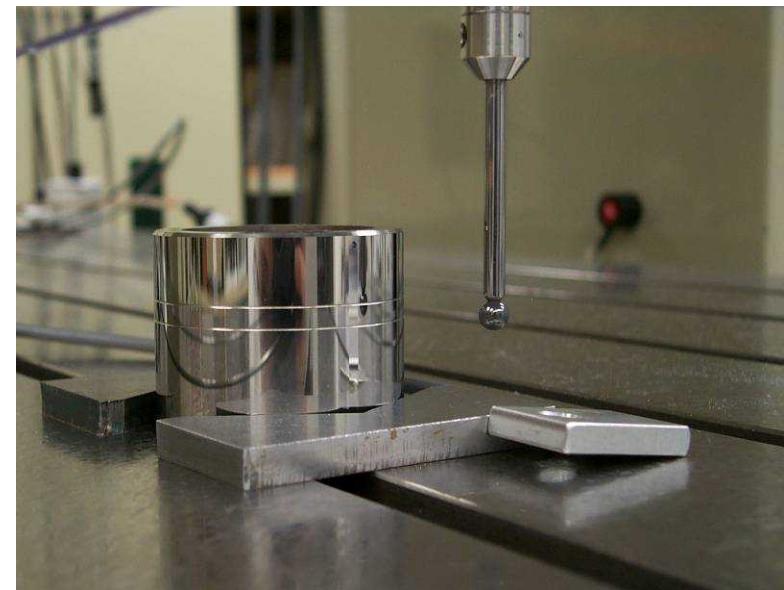


- Moore M48 CMM
- Movomatic analog probe head
- Temperature controlled environment
- Volumetric performance $0.3 \text{ um} + L/300$



Coordinate Measurement Machine Set-up

- Set up magnification specimen on CMM table
- Fixture with magnetic Vs
- Rotate so that flick is aligned as close as possible with machine x or y axis
- Collect a series of individual data points at same height from the flick and surrounding area





Stylus-based Step-height Measurement Device

- Taylor-Hobson Taylsurf
- Surface roughness and step height
- Magnification changes based on vertical displacement
- Records data on strip chart, higher displacements lead to coarser scale
- Used to examine geometry of flick





Stylus-based Step-height Measurement Device Set-up



- Set magnification specimen in v-block
- Rotate specimen to get flick at top
- Trace stylus over specimen, including cylindrical and flick areas



Example

- **Magnification Specimen
Serial Number 1741**
- **Measured by SIP,
Internal/External
comparator, and CMM**
- **Only systematic
uncertainties reported**

Method	Measured Value (μm)	Uncertainty (μm , $k=1$)
SIP	21.46	0.51
I-E	21.37	0.53
CMM	21.77	0.05



Example- SIP Calibration

- Maximum outside reading – Minimum flick reading = 21.46 um
- Sources of Uncertainty
 - Geometry error of 0.5 um
 - Scale error of 0.075 um + 0.1% of reading
- Total Uncertainty of 0.51 um (k=1)

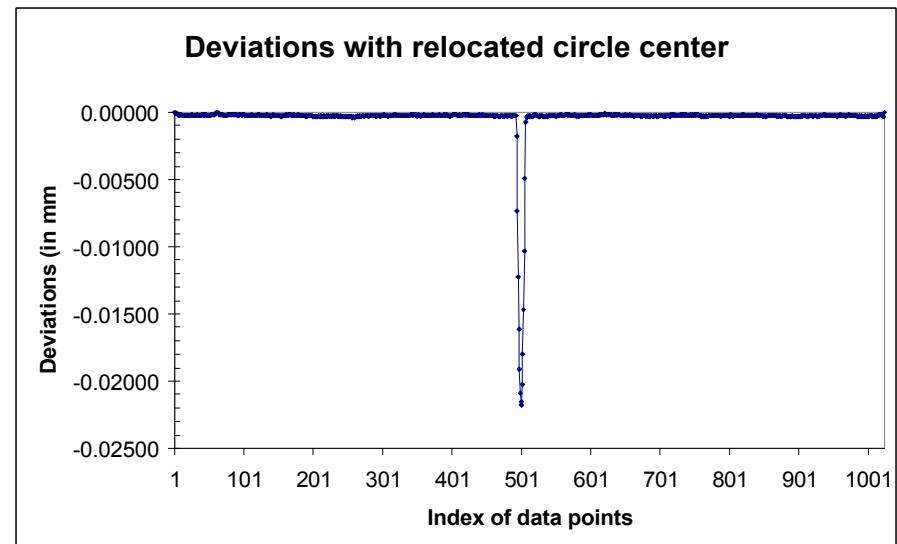


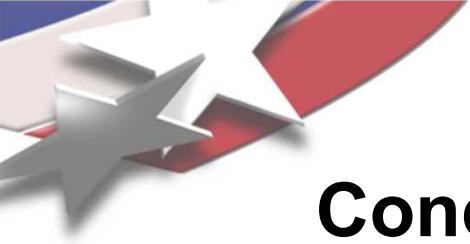
Example – Internal/External Calibration

- Maximum outside reading – Minimum flick reading = 21.37 um
- Sources of Uncertainty
 - Geometry error of 0.5 um
 - Scale error of 0.150 um + 0.5% of reading
- Total Uncertainty of 0.53 um (k=1)

Example – CMM Calibration

- **Center of circle formed by outside of specimen found**
- **Depth of flick calculated as maximum distance from outside circle = 21.77 μm**
- **Sources of Uncertainty**
 - Stylus roundness = $+\text{-} 50 \text{ nm}$ (rectangular)
 - Squareness = $+\text{-} 65 \text{ nm}$ (rectangular)
 - Scale/geometry = $+\text{-} 25 \text{ nm}$ (rectangular)
- **Total Uncertainty = 50 nm (k=1)**





Conclusions and Recommendations

- **SIP, Internal/External Comparator, and CMM all yield similar results**
- **CMM uncertainty is lowest**
- **SIP and Internal/External rely on operator ability to locate minimum point on flick**
- **CMM can fit curve to find lowest expected point**
- **All provide acceptable results**