SCI Calibration Reports

Table of Contents

Purpose

This document describes the calibration reports generated by Select Calibration Incorporated when testing the performance of coordinate measuring machines. Performance testing of CMM's follows the recommendations from either the ASME B89.4.10360-2:2008 or ISO/IEC 10360-2:2009 standard.

The ASME B89.4.10360-2 and ISO/IEC 10360-2 standards are virtually identical and subsequently described as simply 10360-2. Differences that do exist will be indicated if the difference is applicable to the calibration report generated by SCI.

Report Sections

The calibration report is broken down into different sections:

- Title
- Repeatability
- E0 Length Measurements
- E150 Length Measurements
- Summary (optional).

The calibration report is a minimum of five pages in length. The number of pages is based on the number of measurement tests performed and has no practical upper limit. The summary page is optional and is used to consolidate all the measurement results to a single location.

Title Section

The title page is the first page of the report and is the page that is signed by the person of authority when the report is approved. The title page includes a remarks section containing a description of the limits of the report, traceability conditions, description of the uncertainty confidence level, decision rules for compliance statements, and other information related to the calibration report.

Conditions

The conditions section appears on the title page of the calibration report and contains two subsections; *Environmental Conditions* and *Adjustment and Reporting Conditions*.

Environmental Condition

The environmental condition indicator shows if the temperature of the machine's scales stayed within the temperature specifications when running the performance tests. For typical CMM's the temperature specification is usually 20°C +/- 2°C.

Environmental:

X	Manufacturer recommended requirements as described in the system User's Manual.
	Custom requirements. *

* Machines in poor thermal environments are likely to have errors which may not be completely revealed by testing in the same environment. Temperature measurements are from a subset of the entire machine volume.

Figure 1: Section showing the environmental conditions that existed when testing the CMM.

The environmental conditions are reported based on a subset of temperature measurements from the machine scales and artifacts used for the performance test. The environmental conditions are not based on the entire machine measurement volume as suggested by the standard.

When the environment exceeds the manufacturers specification for temperature the machine tolerance is increased (derated) as described in ASME B89.4.10360-2:2008.

Adjustments and Reporting Conditions

These indicators show if there were changes to the machine during the course of calibration. A change is anything that alters the machines compensation error map data or from mechanical changes of the CMM that have an impact on the machines measuring performance.

Calibrations performed by SCI involve measuring and updating all compensation parameters in a semi-automated procedure. Due to the nature of CMM calibration and the data collection process this option will always indicate that changes were made to improve performance even if all changes are at the level considered to be measurement noise (limits of the equipment).

Comparison of the original and updated compensation error map data can be used to attach a value to the amount of change in the machine in some cases.

Adjustments and Reporting:

	No adjustment was necessary to meet specifications.
X	Adjustments were done to improve performance.
X	Compliance statements included on report.
X	Measurement uncertainty included on report.

Figure 2: Section showing the Adjustment and Reporting options.

Showing the compliance statements and the measurement uncertainty on the report is optional and can be independently disabled if requested by the customer. If the compliance statements or measurement uncertainty is reported it will be shown by these two indicators.

Reference Standards and Unit Under Test

The reference standards and Unit Under Test section describe the artifacts used for testing and some details of the CMM that has influence on the testing results.

Reference Standards

This section describes the equipment used for the performance test of the CMM. This list does not extend to the equipment used to collect compensation error map data unless this equipment was also used as part of the performance test of the CMM.

All equipment has a description, serial number, calibration date, and calibration due date. Equipment that has a physical length will show the nominal length under the length column. The expansion coefficient for artifacts will only be shown for suitable equipment.

Reference Standards and Unit Under Test

Description	Standard ID	CTE	Length	Cal. Date	Due Date
Laser	**L-4975**			**Apr 17 2017**	**Apr 17 2019**
Gauge Block	**GB-131417**	**10.8**	**12.7**	**Apr 16 2018**	**Apr 16 2020**
Step Gauge	**SG-1520007**	**10.8**	**1010.0**	**Apr 20 2018**	**Apr 20 2019**
Thermometer	**T-75014120711-141732**			**Oct 4 2018**	**Oct 4 2019**

Figure 3: Section showing the reference standards used for testing the CMM.

Unit Under Test

The machine scale resolution, configuration of probe, and axis expansion coefficient can be a significant contributor to measurement error and is therefore listed in this section of the report. The calculated measurement uncertainty is partially based on the coefficient of thermal expansion of the machine axis, the resolution of the scales, the probing uncertainty, and the environmental conditions that existed during the testing of the CMM.

The expansion coefficient of the axis is based on conditions active on the machine during testing. For example, if the machine has active scale temperature compensation that cannot be switched off by the user the effective CTE will be zero.

The type of probe and stylus used for performance testing is an influence on the final reported measurement results and is therefore listed in this section of the report.

Effective CTE of machine scales: **10.0**
Scale Resolution: **0.000780**
Probe Type: **SP25M**
Probe Stylus: **5 mm diameter, 30 mm length**

Figure 4: Section showing details of the CMM that influence the measurement results and reported uncertainty.

The probe used when running the performance tests is always the one with the lowest measurement uncertainty unless specifically requested by the customer. The preferred stylus used for testing is the manufacturer recommended stylus for the probe type. The specifications for CMM's often change with different configurations of probes and probe stylus.

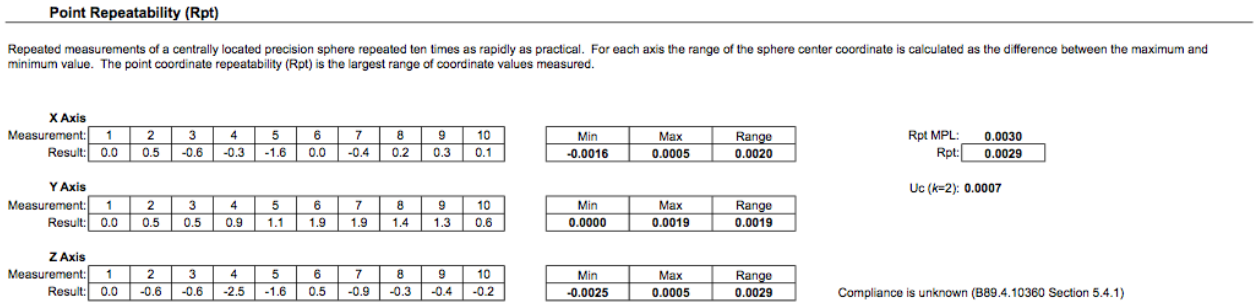
Repeatability Section

The repeatability page shows the results from both point and length repeatability tests. The point repeatability test (Rpt) is identical to the sphere repeatability tests from the legacy versions of the ASME B89.4.1 (ball bar) standard. The length repeatability test (R0) is an evaluated result from all E0 measurement tests performed on the CMM.

Point Repeatability (Rpt)

The point repeatability test is the measurement of a centrally located precision sphere repeated ten times as rapidly as practical. For each axis the range of the sphere center coordinate is calculated as the difference between the maximum and minimum value. The point coordinate repeatability (Rpt) is the largest range of coordinate values measured.

The Rpt test is not defined in ISO/IEC 10360-2:2009 but is included as a functional test for this standard.



Point Repeatability (Rpt)

Repeated measurements of a centrally located precision sphere repeated ten times as rapidly as practical. For each axis the range of the sphere center coordinate is calculated as the difference between the maximum and minimum value. The point coordinate repeatability (Rpt) is the largest range of coordinate values measured.

X Axis

Measurement:	1	2	3	4	5	6	7	8	9	10
Result:	0.0	0.5	-0.6	-0.3	-1.6	0.0	-0.4	0.2	0.3	0.1

Min	Max	Range
-0.0016	0.0005	0.0020

Rpt MPL: 0.0030
Rpt: 0.0029

Y Axis

Measurement:	1	2	3	4	5	6	7	8	9	10
Result:	0.0	0.5	0.5	0.9	1.1	1.9	1.9	1.4	1.3	0.6

Min	Max	Range
0.0000	0.0019	0.0019

Uc (*k*=2): 0.0007

Z Axis

Measurement:	1	2	3	4	5	6	7	8	9	10
Result:	0.0	-0.6	-0.6	-2.5	-1.6	0.5	-0.9	-0.3	-0.4	-0.2

Min	Max	Range
-0.0025	0.0005	0.0029

Compliance is unknown (B89.4.10360 Section 5.4.1)

Illustration 1: Point repeatability test, Rpt, measured on a sphere

The individual sphere measurement positions are reported as a deviation from the initial sphere position and shown using the deviation reporting units (typically micrometers). The summary showing the minimum, maximum, and range is displayed in the base reporting units (typically millimeters). The largest range from the X, Y, or Z axis is the value reported for Rpt.

X Axis

Measurement:	1	2	3	4	5	6	7	8	9	10
Result:	0.0	0.5	-0.6	-0.3	-1.6	0.0	-0.4	0.2	0.3	0.1

Min	Max	Range
-0.0016	**0.0005**	**0.0020**

Illustration 2: Example showing extraction of values to represent the repeatability range for the data along the X axis. The largest range of the three axis is the reported Rpt value.

The Rpt measurement is not separated into As Found and As Left results. This kind of repeatability is considered to be a characteristic of the machine and is not influenced by typical changes from calibration.

Rpt MPL

Tolerance limit for the repeatability test Rpt *(maximum permissible limit*).

Rpt

Largest repeatability range from the three machine axis.

Uc

Shows the calculated measurement uncertainty expanded to a coverage level of 95%.

Length Repeatability (R0)

This section shows the repeatability of all measurements of length from the E0 test positions. This measurement of repeatability is evaluated from the E0 measurements and not from a separate measurement test.

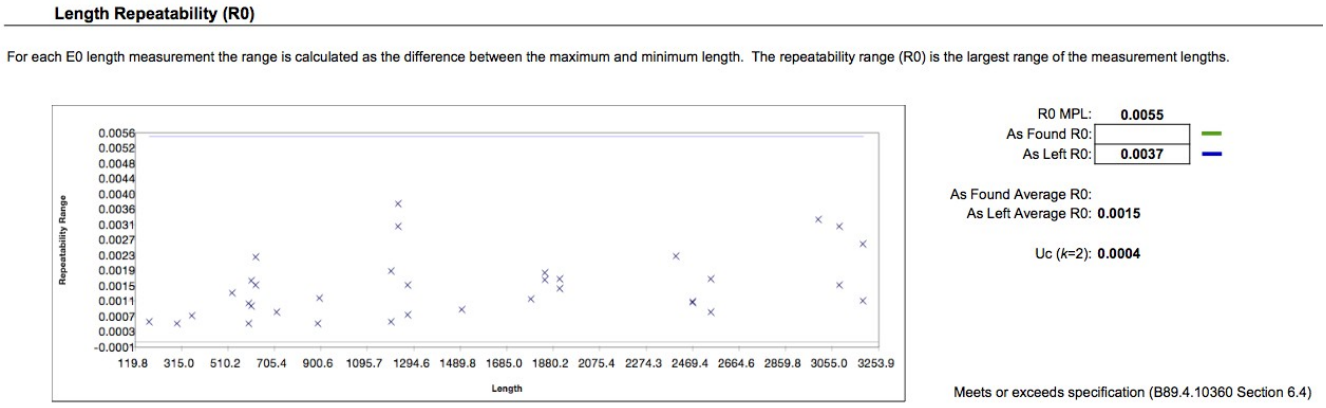


Figure 5: Evaluation of length repeatability from the E0 measurement positions.

Each E0 measurement line consists of five lengths measured three times. The range of the three measured lengths is calculated for each of the five measurement lengths. The length range is shown on the R0 graph with the largest range in length reported for R0.

The length repeatability R0 is separated into *As Found* and *As Left* results. It is expected that the results are comparable between the two sets of data as this kind of repeatability is considered to be a characteristic of the machine and is not influenced by typical changes from calibration.

R0 MPL

Tolerance limit for the repeatability test (*maximum permissible limit*).

R0

Largest repeatability range from all the E0 measurement lengths.

Average R0

Average repeatability of all the E0 measurement lengths.

This average R0 is reported to provide an indication of the average repeatability of length. The maximum R0 value is the result of the measurement test.

Uc

Shows the calculated measurement uncertainty for the R0 measurement expanded to a coverage level of 95%.

Length Measurement Sections

The length measurement pages show detailed results from the individual E0 and E150 measurement tests. The minimum number of measurement lines is seven E0 and two E150.

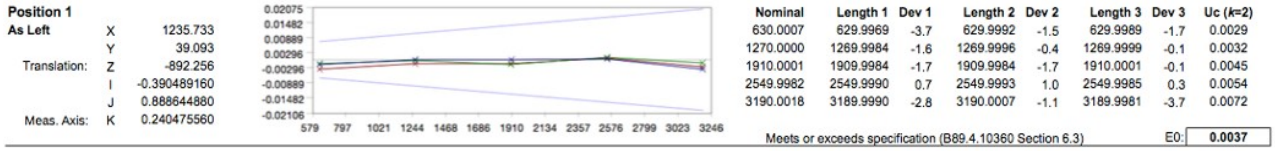


Illustration 3: Report section for a single measurement line consisting of fifteen measurement lengths.

The E0 measurement tests are performed with a zero (or minimal) probe offset perpendicular to the third axis of the CMM. The E150 measurement tests are performed with a probe offset of approximately 150 mm perpendicular to the third axis of the CMM. The E0 and E150 tests are virtually identically other than the probe offset. Collectively these two categories of measurements are referenced as E_L.

Test Method

Each measurement line through the volume of the CMM is broken down into five proportional lengths (rounded to the nearest 10 mm). The measurement line for E0 positions 1 to 4 is along the XYZ diagonals of the machine while E0 positions 5 to 7 are parallel to the X,Y, and Z axis of the machine. The E150 positions are measurements in the YZ or ZX planes of the CMM using an offset probe with a nominal length of approximately 150 mm.

The reported measurement value is the distance between two bidirectional and unique points measured for each length. When using a laser as the certified length standard the measurement is supplemented with a short gauge block to re-create the bidirectional measurement component that would only exist when using a physical artifact.

Nominal	Length 1	Dev 1	Length 2	Dev 2	Length 3	Dev 3	Uc (*k*=2)
629.9976	629.9999	2.3	629.9991	1.5	629.9984	0.8	0.0014
1269.9979	1269.9989	1.0	1269.9982	0.3	1269.9984	0.6	0.0025
1909.9966	1909.9986	2.0	1909.9989	2.3	1909.9975	0.9	0.0036
2550.0003	2549.9989	-1.4	2550.0000	-0.3	2550.0006	0.3	0.0048
3190.0037	3189.9999	-3.8	3189.9988	-4.9	3189.9989	-4.8	0.0059

Meets or exceeds specification (ISO 10360-2 Section 6.3) E0: **0.0049**

Figure 6: Extraction of measurement from measurement position.

The nominal lengths, actual lengths, and measurement uncertainty estimates are reported using

the base reporting units (typically millimeters). The deviations between the nominal and actual lengths are reported using the deviation reporting units (typically micrometers).

The largest deviation from any of the individual measurement lengths from a single measurement line is the reported E_L value. Figure 6 shows an example of an E_L measurement and how the final result is extracted from the data.

Translation

The starting position in the machine volume for the measurement line. This position is the zero location of all the five measurement lengths performed along the measurement line.

Meas. Axis

Direction within the machine volume of the measurement line.

Nominal

Nominal length for all measurements.

Length N

Actual measured length from a pair of the six measurement points. There are three sets of length measurements calculated from the six measurement points.

Dev N

Deviation of the measurement length from the nominal length. The deviation is the difference from the nominal and actual length.

Uc

Shows the calculated measurement uncertainty expanded to a coverage level of 95%.

E0 or E150

Value that represents the largest measurement deviation from a single measurement line. This value is the largest absolute deviation from the nominal length.

As Found or As Left Max E0 or E150

Value that represents the largest measurement deviation from all the E0 or E150 positions. When the report contains a combination of *As Found* and *As Left* measurement positions there will be four separate values (*As Found* Max E0, *As Left* Max E0, *As Found* Max E150, and *As Left* Max E150).

E0 or E150 MPE

Value that represents the largest measurement deviation allowed *(maximum permissible error*). This value is expressed as a formula.

Deration

Amount of adjustment of the machine specification as defined by ASME B89.4.10360-2:2008 when the temperature exceeds the manufactures limits.

Summary Section

The summary page shows the consolidation of all the measurement results in one location.

Point Repeatability (Rpt)

Position measurement of a centrally located precision sphere repeated ten times as rapidly as practical. For each axis the range of the sphere center coordinate is calculated as the difference between the maximum and minimum value. The point coordinate repeatability (Rpt) is the largest range of coordinate values measured.

Rpt MPL: 0.0030
Rpt: 0.0029 U
Uc (*k*=2): 0.0007

Length Repeatability (R0)

For each E0 length measurement the range is calculated as the difference between the maximum and minimum length. The repeatability range (R0) is the largest range of the measurement lengths.

R0 MPL: 0.0055
R0: 0.0037 I
Uc (*k*=2): 0.0004

Length Measurement Error (E0 and E150)

Five calibrated test lengths are measured three times with a zero (or minimal) tip offset for E0 and a 150 mm (5.9") tip offset for E150 . The length measurement error is the maximum length deviation from the fifteen length measurements.

Max E0: 0.0049
Max E150: 0.0020

E0 MPE: **0.0040+0.0050L/1000** Deration: Percentage of maximum error relative to out of tolerance E0: **44.0%**
E150 MPE: **0.0040+0.0050L/1000** Deration: Percentage of maximum error relative to out of tolerance E150: **24.0%**

Position 1

Nominal	Dev 1	Dev 2	Dev 3	Uc (*k*=2)
630.0007	-3.7	-1.5	-1.7	0.0014
1270.0000	-1.6	-0.4	-0.1	0.0024
1910.0001	-1.7	-1.7	-0.1	0.0036
2549.9982	0.7	1.0	0.3	0.0047
3190.0018	-2.8	-1.1	-3.7	0.0058

Position 2

Nominal	Dev 1	Dev 2	Dev 3	Uc (*k*=2)
609.9999	2.3	0.7	1.3	0.0014
1230.0001	2.5	0.8	-0.5	0.0024
1850.0001	2.8	1.0	2.0	0.0035
2470.0034	-2.3	-1.3	-1.4	0.0046
3090.0012	-1.1	0.4	0.4	0.0057

Position 3

Nominal	Dev 1	Dev 2	Dev 3	Uc (*k*=2)
609.9986	2.0	1.5	1.1	0.0014
1229.9987	2.6	1.5	-1.1	0.0024
1849.9977	2.9	1.2	1.5	0.0035
2470.0002	0.1	-1.0	-0.5	0.0046
3090.0040	-1.2	-4.3	-4.3	0.0058

Position 4

Nominal	Dev 1	Dev 2	Dev 3	Uc (*k*=2)
629.9976	2.3	1.5	0.8	0.0014
1269.9979	1.0	0.3	0.6	0.0025
1909.9966	2.0	2.3	0.9	0.0036
2550.0003	-1.4	-0.3	0.3	0.0048
3190.0037	-3.8	-4.9	-4.8	0.0059

Position 5[X]

Nominal	Dev 1	Dev 2	Dev 3	Uc (*k*=2)
299.9999	0.1	0.5	0.4	0.0009
600.0009	-1.0	-0.5	-0.7	0.0013
890.0007	-1.1	-1.3	-0.8	0.0018
1199.9990	0.8	1.0	1.3	0.0023
1499.9966	3.9	4.7	4.2	0.0028

Position 6[Y]

Nominal	Dev 1	Dev 2	Dev 3	Uc (*k*=2)
600.0004	0.2	-0.5	0.5	0.0013
1199.9972	1.2	-0.6	-0.7	0.0023
1789.9999	-0.4	0.7	0.3	0.0034
2399.9983	1.1	0.1	2.4	0.0045
2999.9998	-1.2	2.1	0.9	0.0056

Position 7[Z]

Nominal	Dev 1	Dev 2	Dev 3	Uc (*k*=2)
179.9999	1.2	1.6	1.0	0.0008
360.0003	0.4	1.0	1.1	0.0010
530.0001	0.3	1.6	0.8	0.0012
719.9999	2.0	2.4	1.6	0.0015
899.9990	1.3	1.9	2.4	0.0018

Position D1

Nominal	Dev 1	Dev 2	Dev 3	Uc (*k*=2)
209.9934	-0.5	0.4	0.9	0.0020
409.9964	2.0	1.6	1.3	0.0022
610.0008	0.4	0.8	0.8	0.0025
810.0027	-0.5	-0.8	-0.6	0.0028
1010.0028	-1.2	-1.3	-1.2	0.0032

Position D2

Nominal	Dev 1	Dev 2	Dev 3	Uc (*k*=2)
209.9934	0.3	-0.3	0.3	0.0020
409.9964	0.9	0.1	-0.4	0.0022
610.0008	1.1	0.7	0.1	0.0025
810.0027	0.7	0.2	0.8	0.0028
1010.0028	-0.1	-0.5	-0.1	0.0032

Figure 7: Data section of summary page.

The summary page has a limit of fifteen E0 and E150 measurements. When reports are generated that contain more than fifteen measurement lines then this page is not included.

Percentage of Maximum Error To Out of Tolerance

This field represents the worst result of the measured data relative to the strict rejection limit and described as a percentage. A value greater than 100% means that the compliance statement for one or more measurement positions shows that the result does not meet specification.

The worst result is the largest error relative to the specification limit and is not necessarily the

largest deviation from nominal. The specification limit is not a fixed value and increases based on the measurement length. For example, a deviation of 0.003 mm at a length of 100 mm will likely be worse than a deviation of 0.004 mm at length 1000 mm since the specification is greater at 1000 mm as compared to 100 mm.

Reporting Units

The calibration report can be generated in metric or imperial with deviations shown in units that are a fraction of the base unit. A typical report is created in metric (mm) with deviation units of 0.001 mm (micrometers) but reports can also be generated using the imperial system (Inch) with deviation units of 0.001" or 0.0001".

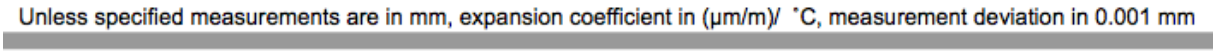


Figure 8: Description of reporting units shown at bottom of each page.

Expansion coefficients units for metric reports are um/m/°C where imperial expansion coefficients units are uIn/In/°F.

Calibration reports using the imperial units are very uncommon.

Interpretation of Measurement To Specification

Measurement uncertainty is considered when comparing a measurand to a specification. In the example shown in illustration 4, four sets of measured values are displayed relative to a tolerance. Each measurand has the expanded uncertainty drawn around the value to show the relative range for each item.

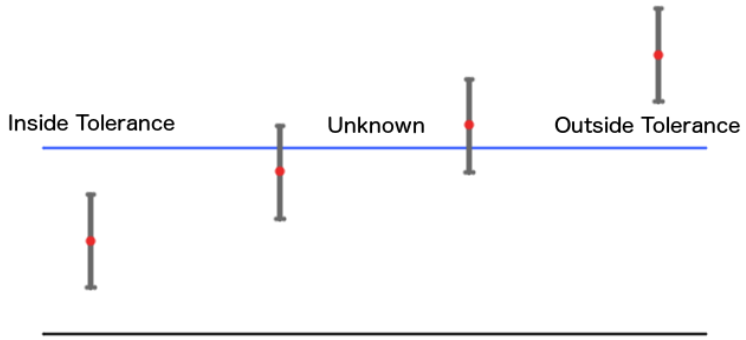


Illustration 4: Examples of measurements shown with the expanded uncertainty for each.

Based on the results shown in illustration 4 only the first and last measurement will be stated as inside or outside of tolerance. The two middle results cannot be stated with the necessary level of confidence and will be described as *compliance unknown* on the measurement report.

Revision History

Revision	*Date*	*Reason*
1	Oct 11, 2016	Initial Release
2	Nov 27, 2017	Updated information in document.
3	Feb 24, 2018	Updated with changes in the format of the calibration report.
4	Nov 7, 2018	Revision of calibration report format and content.