

# SCI Calibration Reports

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# SCI Calibration Reports

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## Purpose

This article describes the contents of calibration reports produced by Select Calibration Incorporated.

## Report Sections

The calibration report is broken down into different sections:

- Title Page
- Repeatability Tests
- E0 Length Measurement Tests
- E150 Length Measurement Tests
- Summary Page (optional).

At a minimum the calibration report produced by Select Calibration Incorporated will consist of five pages. The maximum number of pages is practically unlimited and is based on the number of measurements performed.

*The summary page is optional and shows a summary of measurement results from other parts of the calibration report.*

## Report Units

The reported data can be in either metric or imperial. Data that is reported as a deviation from a nominal value can be shown in fractional units of the base unit for the report. Each page of the report has an information bar at the bottom indicating the reported units.

Unless specified measurements are in mm, expansion coefficient in  $(\mu\text{m}/\text{m})/^\circ\text{C}$ , measurement deviation in 0.001 mm

*Illustration 1: Report units description line shown at bottom of each page of the report.*

In the example shown from illustration 1 the base units are in metric (mm), the expansion coefficients are in  $(\mu\text{m}/\text{m})/^\circ\text{C}$  and measurement deviations are reported in the units of 0.001 mm ( $\mu\text{m}$ ).

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## Title Page

The title page describes environmental conditions in effect at the time of the calibration along with the equipment used to perform the measurements. Additional details about the configuration of the coordinate measuring machine is also shown on the title page.

Conditions					
<b>Environmental Conditions:</b>			<b>Machine Adjustments:</b>		
<input checked="" type="checkbox"/>	Manufacturer recommended requirements as described in the system User's Manual. Custom requirements. *		<input type="checkbox"/>	No adjustment was necessary to meet published operating specifications. Adjustments were done to improve performance.	
<input type="checkbox"/>			<input checked="" type="checkbox"/>	Statement of Compliance Required	
	* Machines in poor thermal environments are likely to have errors which may not be completely revealed by testing in the same environment. It is always best to improve the environment. Temperature measurements are from a subset of the entire machine volume.		<input checked="" type="checkbox"/>	Measurement Uncertainty Reported	
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	May 13 2016	May 13 2018
Thermometer	T-75014120711-141732			Oct 5 2017	Oct 5 2018
Step Gauge	SG-1520007	10.8	1010.0	Apr 10 2017	Apr 10 2018

Effective CTE of machine scales: 10.0  
Scale Resolution: 0.000760  
Probe Type: SP25M  
Probe Stylus: 5 mm diameter, 30 mm length

Illustration 2: Title page testing details and equipment.

## Environmental Conditions

Shows a summary of the environment of the machine during the performance test relative to the manufacturers specifications for temperature. For machines that are not designed to work in shop floor environments the specification is typically between 18 °C and 22 °C.

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

*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.*

## Machine Adjustments

This indicator shows if there were changes to the machine as a result of the calibration. A change is anything that alters the machines compensation error map data or any mechanical adjustments that are deemed necessary.

Calibrations performed by SCI involve measuring and updating all compensation parameters in a semi-automated sequence. It is theoretically possible that a machine is found where changes are not required but due to the nature of the data collection process this option will always indicate that changes were made to improve performance.

*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.*

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## Compliance Statement / Uncertainty Reported

These options indicate that the compliance statements and measurement uncertainty are included on the report. This information may not be reported depending on the requirement of the customer.

The compliance statement is an opinion that describes if the measurement is inside or outside of specification. Opinions that indicate the measurement is inside or outside of specification include the expanded uncertainty. Measurements that are within the expanded uncertainty of the specification limits are always reported as unknown which means it is neither inside or outside specification. This opinion can not be stated with confidence either way.

*Measurement uncertainty and compliance opinions are always calculated even if not reported.*

## Calibration Equipment

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

All equipment has a description, serial number, calibration date, and calibration due date. Equipment that has length will also include the estimated coefficient of thermal expansion (CTE) and the nominal equipment length.

## CMM and Test Conditions

This section shows the effective expansion coefficient of the machine axis along with the scale resolution and other factors that affect the measurement results or calculated uncertainty.

The expansion coefficient of the axis is based on the conditions that are active on the machine during testing. For example, machines that have active scale temperature compensation that cannot be switched off will have an effective CTE of 0.0 (um/m)/ °C regardless of the actual expansion coefficient of the axis.

The type of probe and stylus used for performance testing is an influence on the final reported measurements and is therefore listed on the report. The measurement results are affected by the type of probe and stylus used for testing.

The reported 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 the machine was tested in.

*The probe used by SCI 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.*

## Repeatability Page

The repeatability page show two evaluations of measurement repeatability from the performance testing on the CMM. The Point Repeatability (Rpt) is the result from the classic sphere repeatability tests and the Length Repeatability (R0) is an evaluation of the repeatability from all E0 measurement tests performed on the CMM.

### Point Repeatability (Rpt)

This is the results of running the point repeatability test defined in ASME B89.4.10360-2:2008. The test conditions and evaluation of the results are identical to the method used by ASME B89.4.1:1997.

*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.														
<b>X Axis</b>														
Measurement:	1	2	3	4	5	6	7	8	9	10	Min	Max	Range	Rpt MPL: 0.0030
Result:	0.0	0.5	-0.6	-0.3	-1.6	0.0	-0.4	0.2	0.3	0.1	-0.0016	0.0005	0.0020	Rpt: 0.0029
<b>Y Axis</b>														
Measurement:	1	2	3	4	5	6	7	8	9	10	Min	Max	Range	Uc (k=2): 0.0007
Result:	0.0	0.5	0.5	0.9	1.1	1.9	1.9	1.4	1.3	0.6	0.0000	0.0019	0.0019	
<b>Z Axis</b>														
Measurement:	1	2	3	4	5	6	7	8	9	10	Min	Max	Range	Compliance is unknown (B89.4.10360 Section 5.4.1)
Result:	0.0	-0.6	-0.6	-2.5	-1.6	0.5	-0.9	-0.3	-0.4	-0.2	-0.0025	0.0005	0.0029	

Illustration 3: Point repeatability test, Rpt, measured on a sphere

### Test Method

The point repeatability test is a measurement of a sphere with four points repeated ten times. The measurements are done as rapidly as practical.

The deviation in the X, Y, and Z axis of the sphere position is recorded in the result section of the measurement table for each axis.

The summary of the results for each axis is reported at the end of the measurement table. The summary shows the minimum, maximum, and range for the ten sphere measurements performed.

The reported value for Rpt is the largest measurement range from the three machine axis.

X Axis													
Measurement:	1	2	3	4	5	6	7	8	9	10	Min	Max	Range
Result:	0.0	0.5	-0.6	-0.3	-1.6	0.0	-0.4	0.2	0.3	0.1	-0.0016	0.0005	0.0020

Illustration 4: 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 test not separated into As Found or As Left results. This repeatability is considered to be a characteristic of the machine and is not influenced by typical changes from calibration.*

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## Rpt MPL

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

## Rpt

Largest repeatability range from the three machine axis (*repeatability of a point*).

## Uc

Shows the calculated measurement uncertainty. All reported uncertainty values are expanded to an approximate coverage level of 95%.

## Length Repeatability (R0)

This is the results of analyzing all E0 measurements and reporting the maximum length repeatability range found from the E0 data.

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### 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.

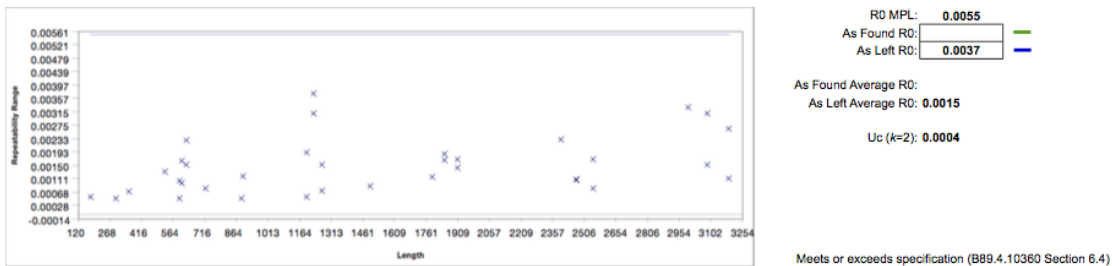


Illustration 5: Graph showing length repeatability evaluation of E0 measurements.

## Test Method

Each E0 measurement line consists of five lengths measured three times. For each of the five measurement lengths the range of the three repeated results is calculated and reported on the R0 graph at the position of the average length. The largest range from the length repeatability results is reported as the measurement of R0.

The length repeatability R0 results are separated by *As Found* and *As Left* measurements. It is expected that the results are comparable between the two sets of data but since there can be separate *As Found* and *As Left* E0 measurements there are also separate R0 results.

## R0 MPL

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

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### R0

Largest repeatability range of all the E0 measurement lengths (*repeatability of E0 measurements*).

### Average R0

Average repeatability range of all the E0 measurement lengths.

*This value is reported to provide an indication of the average length repeatability and does not represent the measured R0 value.*

### Uc

Shows the calculated measurement uncertainty for the R0 measurement. All reported uncertainty values are expanded to an approximate coverage level of 95%.



# SCI Calibration Reports

## El Measurement Page

The El measurement pages show detailed results from the E0 and E150 measurement tests. The number of measurements required by ISO/IEC 10360-2:2009 or ASME B89.4.10360-2:2008 is seven sets of measurements for E0 and two sets of measurements for E150.

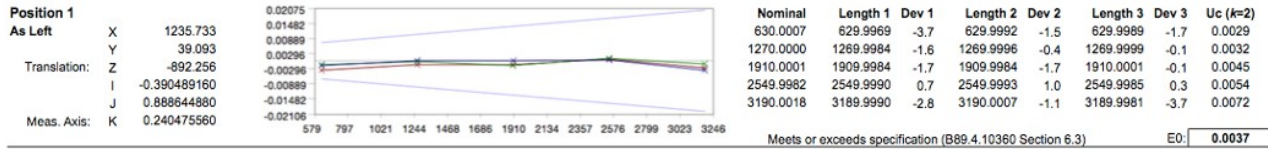


Illustration 6: Report section for a single measurement line. Fifteen length values are shown from the one measurement line.

The E0 measurements are tests performed with a zero (or minimal) probe offset perpendicular to the third axis of the coordinate measuring machine. The E150 measurements are tests performed with a probe offset of approximately 150 mm perpendicular to the third axis of the CMM. For a bridge machine the third axis is Z where a horizontal arm CMM the third axis is Y.

The E0 tests are separate from the E150 tests but otherwise handled identically.

## Test Method

Each measurement line through the volume of the CMM is broken down in 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 machine axis. E150 positions 1 and 2 are done in either 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 taken for each length. When using a laser as the certified length the measurement is supplemented with a short gauge block to re-create the bidirectional measurement component of the test.

Nominal	Length 1	Dev 1	Length 2	Dev 2	Length 3	Dev 3	Uc (k=2)
630.0007	629.9969	-3.7	629.9992	-1.5	629.9989	-1.7	0.0029
1270.0000	1269.9984	-1.6	1269.9996	-0.4	1269.9999	-0.1	0.0032
1910.0001	1909.9984	-1.7	1909.9984	-1.7	1910.0001	-0.1	0.0045
2549.9982	2549.9990	0.7	2549.9993	1.0	2549.9985	0.3	0.0054
3190.0018	3189.9990	-2.8	3190.0007	-1.1	3189.9981	-3.7	0.0072

Meets or exceeds specification (B89.4.10360 Section 6.3) E0: 0.0037

Illustration 7: Extraction of measurement from measurement position.

The largest deviation from any of the individual measurement lengths is the reported El value. Illustration 7 shows an example of an El measurement and how the final measurement value is extracted from the data.

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## Translation

Starting position in the machine volume for the measurement line. This position is the zero location of all the five measurement lengths performed along a single measurement line.

## Meas. Axis

Direction within the machine volume for the measurement line. This axis is the direction that the measurement was performed in.

## Nominal

Nominal length for all measurements.

## Length N

Actual measured length from the difference between a unique set of measurement points. There are three measurements performed for each length; Length 1, Length 2, and Length 3.

## Dev N

Deviation of each individual measurement length from the nominal length. There are three length measurements performed therefore there are three deviations reported; Dev 1, Dev 2, and Dev 3.

## Uc

Shows the calculated measurement uncertainty. All reported uncertainty values are expanded to an approximate coverage level of 95%.

## E0 or E150

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

## As Found or As Left Max E0 or E150

Value that represents the largest measurement deviation from all the E0 or E150 positions. The *As Found* and the *As Left* data are handled separately and is therefore reported separately.

## 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 in ASME B89.4.10360-2:2008 when the temperature exceeds the manufactures limits.

# SCI Calibration Reports

## Summary Page

The optional summary page is a summary of the measurement results as shown by the previous pages of the calibration report. It is not intended to be a separate calibration report but more a condensed summary of all the measurement results.

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.								Rpt MPL:	0.0030					
								Rpt:	0.0029					
								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					
								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:				44.6%						
E150 MPE: 0.0040+0.0050L/1000		Deration:		Percentage of maximum error relative to out of tolerance E150:				24.3%						
Position 1					Position 2					Position 3				
Nominal	Dev 1	Dev 2	Dev 3	Uc (k=2)	Nominal	Dev 1	Dev 2	Dev 3	Uc (k=2)	Nominal	Dev 1	Dev 2	Dev 3	Uc (k=2)
630.0007	-3.7	-1.5	-1.7	0.0012	609.9999	2.3	0.7	1.3	0.0012	609.9986	2.0	1.5	1.1	0.0012
1270.0000	-1.6	-0.4	-0.1	0.0021	1230.0001	2.5	0.8	-0.5	0.0021	1229.9987	2.6	1.5	-1.1	0.0021
1910.0001	-1.7	-1.7	-0.1	0.0031	1850.0001	2.8	1.0	2.0	0.0030	1849.9977	2.9	1.2	1.5	0.0030
2549.9982	0.7	1.0	0.3	0.0041	2470.0034	-2.3	-1.3	-1.4	0.0040	2470.0002	0.1	-1.0	-0.5	0.0040
3190.0018	-2.8	-1.1	-3.7	0.0051	3090.0012	-1.1	0.4	0.4	0.0049	3090.0040	-1.2	-4.3	-4.3	0.0049
Position 4					Position 5[X]					Position 6[Y]				
Nominal	Dev 1	Dev 2	Dev 3	Uc (k=2)	Nominal	Dev 1	Dev 2	Dev 3	Uc (k=2)	Nominal	Dev 1	Dev 2	Dev 3	Uc (k=2)
629.9976	2.3	1.5	0.8	0.0012	299.9999	0.1	0.5	0.4	0.0009	600.0004	0.2	-0.5	0.5	0.0012
1269.9979	1.0	0.3	0.6	0.0021	600.0009	-1.0	-0.5	-0.7	0.0012	1199.9972	1.2	-0.6	-0.7	0.0020
1909.9966	2.0	2.3	0.9	0.0031	890.0007	-1.1	-1.3	-0.8	0.0016	1789.9999	-0.4	0.7	0.3	0.0029
2550.0003	-1.4	-0.3	0.3	0.0041	1199.9990	0.8	1.0	1.3	0.0020	2399.9983	1.1	0.1	2.4	0.0039
3190.0037	-3.8	-4.9	-4.8	0.0051	1499.9966	3.9	4.7	4.2	0.0025	2999.9998	-1.2	2.1	0.9	0.0048
Position 7[Z]					Position D1					Position D2				
Nominal	Dev 1	Dev 2	Dev 3	Uc (k=2)	Nominal	Dev 1	Dev 2	Dev 3	Uc (k=2)	Nominal	Dev 1	Dev 2	Dev 3	Uc (k=2)
179.9999	1.2	1.6	1.0	0.0008	209.9934	-0.5	0.4	0.9	0.0019	209.9934	0.3	-0.3	0.3	0.0019
360.0003	0.4	1.0	1.1	0.0009	409.9964	2.0	1.6	1.3	0.0021	409.9964	0.9	0.1	-0.4	0.0021
530.0001	0.3	1.6	0.8	0.0011	610.0008	0.4	0.8	0.8	0.0024	610.0008	1.1	0.7	0.1	0.0024
719.9999	2.0	2.4	1.6	0.0014	810.0027	-0.5	-0.8	-0.6	0.0027	810.0027	0.7	0.2	0.8	0.0027
899.9990	1.3	1.9	2.4	0.0016	1010.0028	-1.2	-1.3	-1.2	0.0031	1010.0028	-0.1	-0.5	-0.1	0.0031

Illustration 8: Data section of summary page.

The summary page has a limit of fifteen E0 and E150 measurements combined. When calibrations are done that require more measurements than what would fit on this page this summary page is not included.

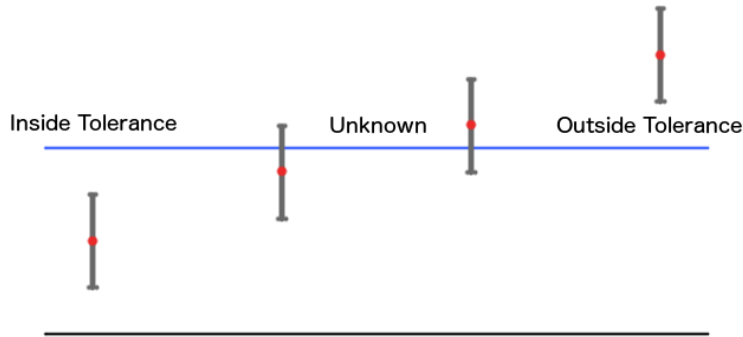
### Percentage of Maximum Error To Out of Tolerance

This field represents the worst error in the data relative to the strict rejection limit. This value describes the relative position of the worst point relative to being out of tolerance.

The worst point is the one that has the largest error relative to the specification limit and is not necessarily the point with the largest deviation from nominal.

## Interpretation of Measurement To Specification

In the example shown in illustration 9 four sets of measured values are displayed relative to a nominal and tolerance. Each measurand includes the expanded uncertainty drawn around the value to show the relative range of the expanded uncertainty for each item.



*Illustration 9: Examples of measurements shown with the expanded uncertainty for each.*

In this example only the first and last value can be described as being inside or outside of tolerance. The two middle results could be either inside or outside of tolerance but cannot be stated with confidence in either case. The two middle results can only be described as 'unknown'.

## SCI Calibration Reports

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### Revision History

<i>Revision</i>	<i>Date</i>	<i>Reason</i>
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.