Machine Checking Gauge Users Guide

Table of Contents

Introduction

The *Machine Checking Gauge* utility is software that compliments the Renishaw MCG test artifact. The primary purpose of the *Machine Checking Gauge* utility is to interpret and report data collected by the Renishaw MCG artifact but it can also be used to create a part program necessary for the measurement of the gauge.

Interim checks are necessary to ensure that a coordinate measuring machine is measuring properly and commonly used to verify that changes to the machine, such as a software upgrade or machine repair, have not adversely affected the accuracy of the CMM. Performing a regular check of the coordinate measuring machine allows tracking of changes in the machine over time and should be done regularly to ensure everything is working properly.

Overview

The *Machine Checking Gauge* utility consists of a main window showing a graphical view of measurements or program path, a detailed analysis view, and a report view. Two additional options for the measurement path and tolerance are included on the left side of the main view in dockable widgets.

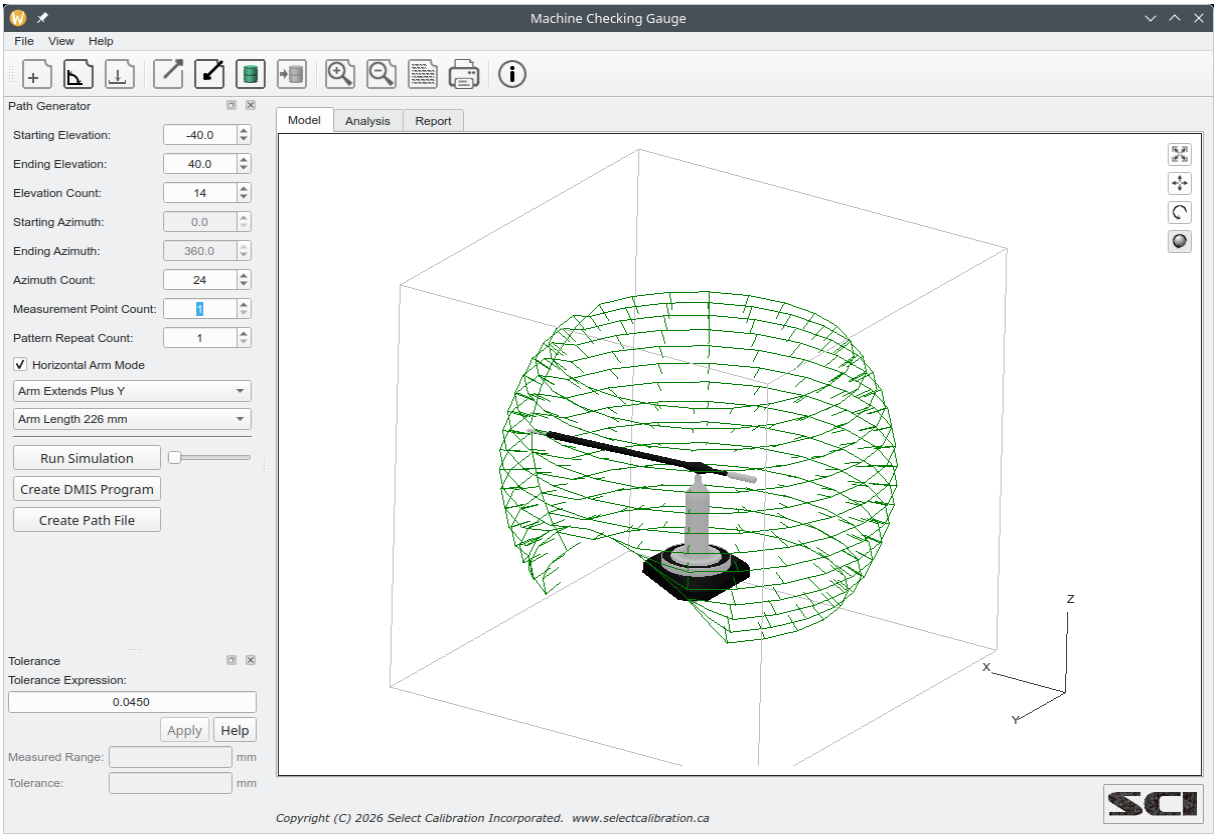


Illustration 1: Main view of the Machine Checking Gauge utility.

Model View

This view shows a 3D representation of the measurement or measurement path. The measurement path is shown when no measurement data is loaded otherwise a representation of the measurement is displayed in the model view. Illustration 2 shows an example of a loaded measurement where each arm position of the measured data is displayed.

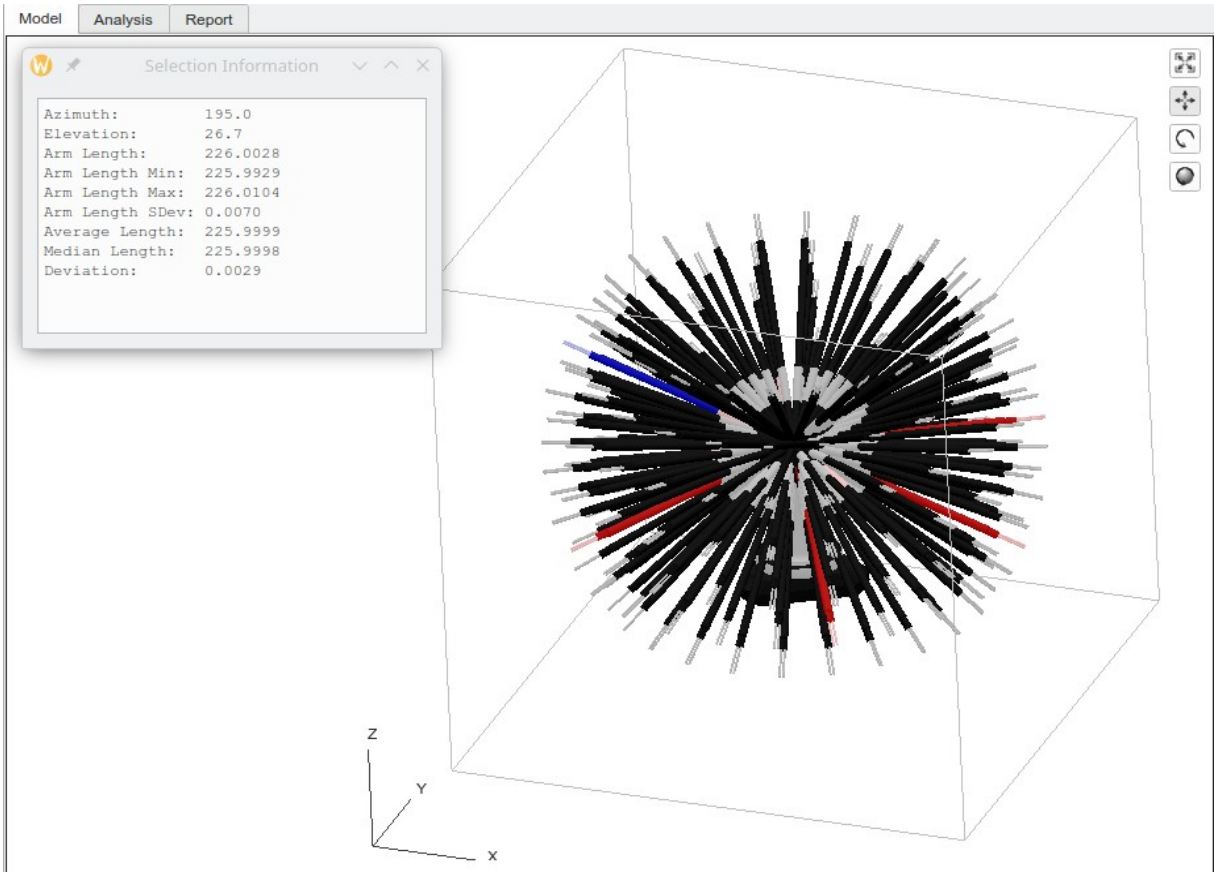


Illustration 2: Display of measurement data showing selection and out of tolerance positions.

Positions that are outside of the tolerance are highlighted in red. Selected positions are highlighted in blue and will show a small information dialog with measurement details.

Graphical View 3D Controls

The 3D model display is not fixed and can be manipulated in a variety of ways as described in the following table:

Image	*Description*
	Scale to fit. Adjusts the scale of the OpenGL Projection matrix to fit the visible data into the display viewport.
	Pan Mode. When enabled a right mouse button click and drag will move the position of the displayed model. For systems with a single mouse button use Ctrl + Mouse.

Image	*Description*
	Rotate 2D Mode. When enabled a right mouse button click and drag will rotate the model around the center of the viewport. For systems with a single mouse button use Ctrl + Mouse.
	Rotate 3D Mode. When enabled a right mouse button click and drag will rotate the model around the click position on the displayed model. For systems with a single mouse button use Ctrl + Mouse.

OpenGL

The graphical view of the measurement data is drawn using OpenGL. The computer must support OpenGL version 2.x or higher in order to run this utility program with a functional 3D view of the measurement data.

Running the *Machine Checking Gauge* utility on computers that only support OpenGL 1.x the model view is replaced with an information window. An example of this information window is shown in illustration 3.

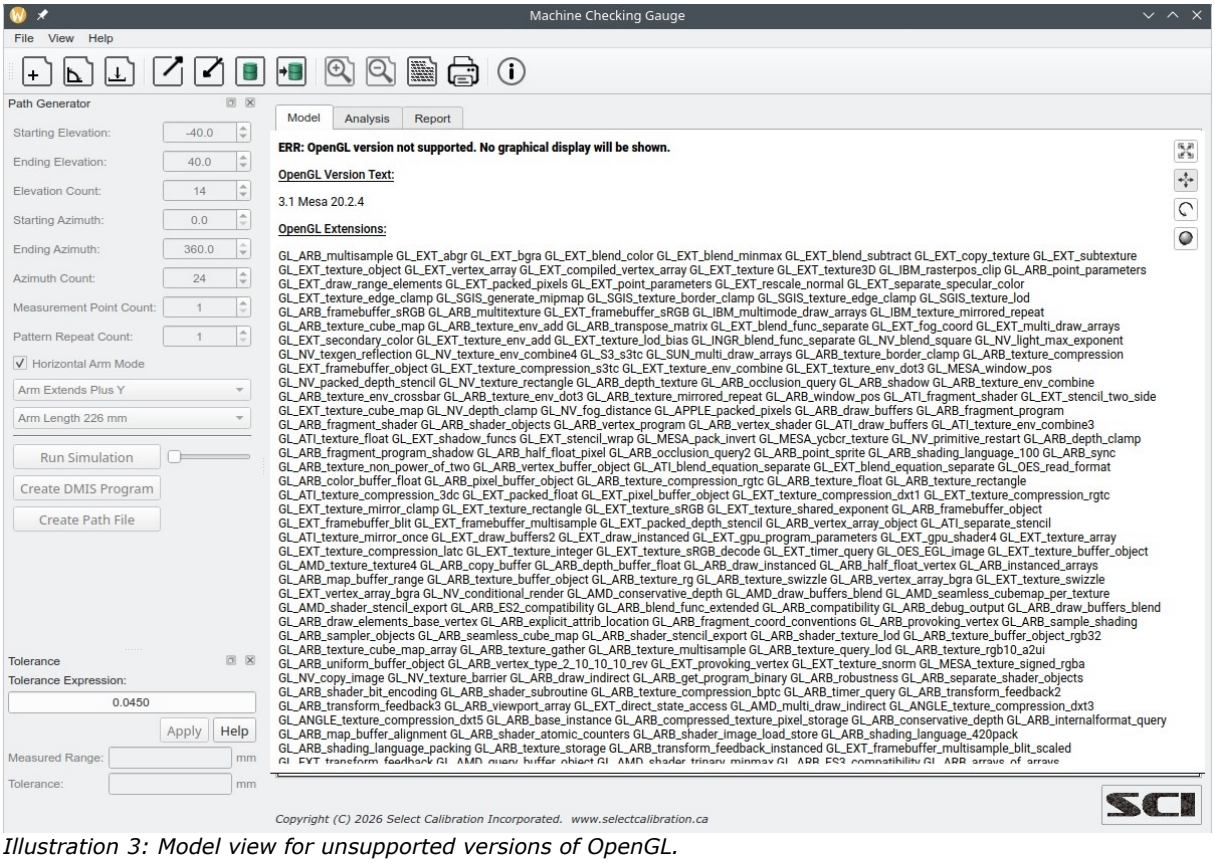


Illustration 3: Model view for unsupported versions of OpenGL.

Analysis View

The analysis view shows numerical details of the measurements and a distribution histogram graph. The analysis information is intended to help identify results which are not typical of the overall measurements such as fliers or other anomalies. Illustration 4 shows an example of a

measurement analysis from a large set of measurement data.

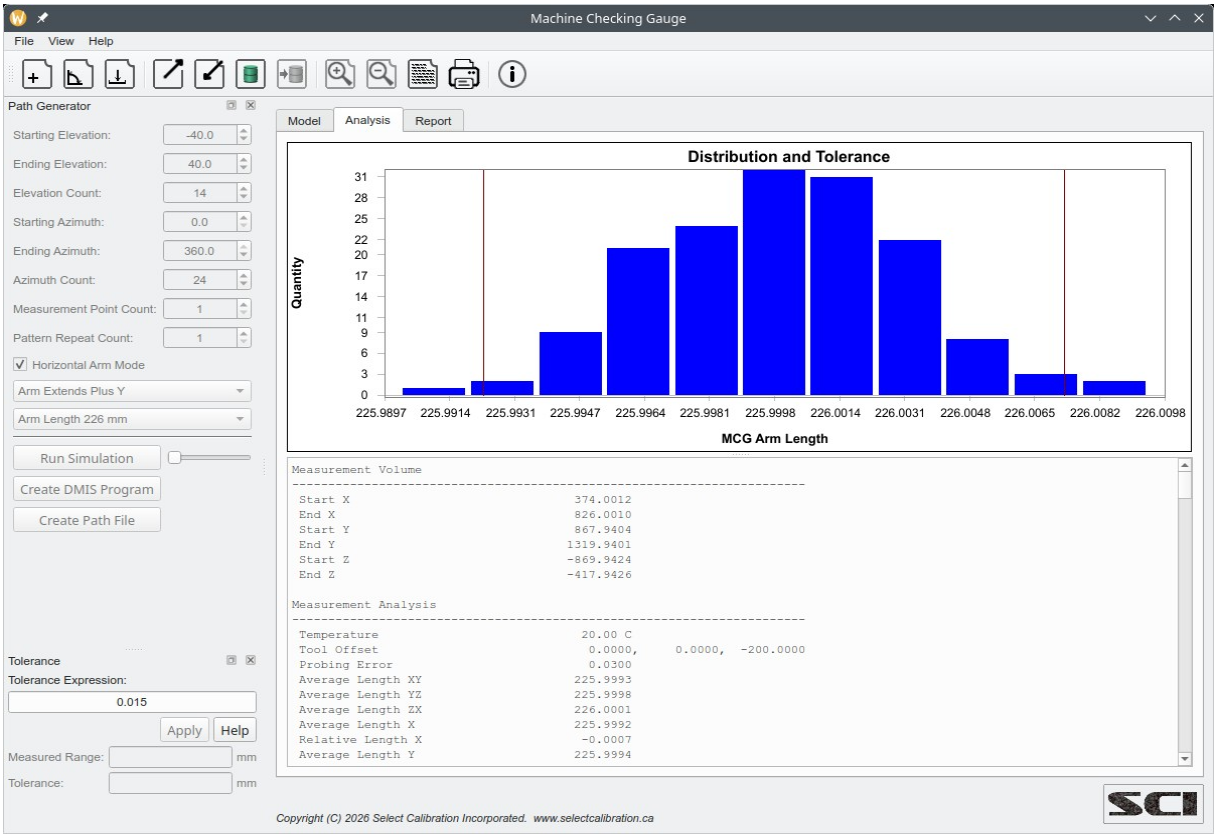


Illustration 4: Analysis view of the current measurement data.

The analysis text includes details of the measurement and may be useful for troubleshooting unexpected results:

```
Measurement Volume
-------------------------------------------------------------------------
 Start X                                374.0012
 End X                                  826.0010
 Start Y                                867.9404
 End Y                                 1319.9401
 Start Z                               -869.9424
 End Z                                 -417.9426

Measurement Analysis
-------------------------------------------------------------------------
 Temperature                             20.00 C
 Tool Offset                              0.0000,     0.0000,  -200.0000
 Probing Error                            0.0300
 Average Length XY                      225.9993
 Average Length YZ                      225.9998
 Average Length ZX                      226.0001
 Average Length X                       225.9992
 Relative Length X                       -0.0007
 Average Length Y                       225.9994
 Relative Length Y                       -0.0005
 Average Length Z                       226.0037
 Relative Length Z                        0.0038
 Squareness XY                           -0.0010 mm/m
```

Squareness YZ	-0.0113 mm/m
Squareness ZX	-0.0202 mm/m

Measurement Statistics

Measurement Count	155
Minimum Length	225.9910
Maximum Length	226.0085
Average Length	225.9999
Median Length	225.9998
StdDev Length	0.0033
Range Length	0.0176
Tolerance	0.0150
Estimated Range for 95%	0.0130
Number Outside of Estimated Range	6

Measurement Center

Pivot Sphere Start	600.0010,	1093.9400,	-643.9420
Pivot Sphere End	599.9990,	1093.9360,	-643.9340
MCG Sphere Center	600.0011,	1093.9402,	-643.9425

Individual Measurement Results

Azimuth	Elevation	Length	Min	Max	Std Dev	Dev	
-0.0	-40.0	226.0024	225.9946	226.0060	0.0040	0.0026	
15.0	-40.0	225.9992	225.9867	226.0090	0.0103	-0.0007	
30.0	-40.0	225.9966	225.9845	226.0092	0.0094	-0.0033	
45.0	-40.0	225.9947	225.9872	226.0058	0.0081	-0.0052	
135.0	-40.0	226.0036	225.9949	226.0093	0.0058	0.0038	
150.0	-40.0	226.0024	225.9899	226.0140	0.0108	0.0025	
165.0	-40.0	226.0034	225.9946	226.0107	0.0063	0.0035	
180.0	-40.0	225.9989	225.9855	226.0104	0.0096	-0.0010	
195.0	-40.0	225.9968	225.9890	226.0071	0.0078	-0.0031	
210.0	-40.0	226.0034	225.9888	226.0125	0.0087	0.0035	
225.0	-40.0	226.0044	225.9910	226.0113	0.0089	0.0045	
240.0	-40.0	226.0043	225.9902	226.0139	0.0111	0.0045	
255.0	-40.0	225.9971	225.9891	226.0050	0.0056	-0.0028	
270.0	-40.0	225.9992	225.9856	226.0113	0.0106	-0.0007	
285.0	-40.0	226.0024	225.9904	226.0136	0.0102	0.0025	
300.0	-40.0	225.9968	225.9871	226.0031	0.0070	-0.0031	
315.0	-40.0	226.0018	225.9916	226.0101	0.0080	0.0019	
330.0	-40.0	225.9964	225.9870	226.0077	0.0072	-0.0035	
345.0	-40.0	225.9953	225.9918	225.9983	0.0029	-0.0046	
-0.0	-26.7	226.0017	225.9883	226.0133	0.0109	0.0018	
15.0	-26.7	226.0084	226.0041	226.0143	0.0035	0.0085	<-Out of tolerance.
30.0	-26.7	226.0027	225.9858	226.0120	0.0119	0.0028	
45.0	-26.7	226.0027	225.9917	226.0139	0.0094	0.0028	
135.0	-26.7	226.0042	225.9871	226.0140	0.0107	0.0043	
150.0	-26.7	226.0064	226.0023	226.0138	0.0040	0.0065	
165.0	-26.7	225.9991	225.9937	226.0066	0.0058	-0.0007	
180.0	-26.7	226.0039	225.9853	226.0144	0.0103	0.0040	
195.0	-26.7	225.9951	225.9877	226.0113	0.0094	-0.0048	
210.0	-26.7	225.9964	225.9878	226.0099	0.0076	-0.0035	
225.0	-26.7	226.0012	225.9951	226.0143	0.0071	0.0013	
240.0	-26.7	226.0059	225.9919	226.0140	0.0092	0.0060	
255.0	-26.7	226.0023	225.9939	226.0147	0.0077	0.0024	
270.0	-26.7	225.9995	225.9922	226.0136	0.0083	-0.0004	
285.0	-26.7	226.0001	225.9893	226.0135	0.0104	0.0002	
300.0	-26.7	225.9910	225.9853	226.0021	0.0067	-0.0089	<-Out of tolerance.
315.0	-26.7	226.0012	225.9873	226.0142	0.0106	0.0013	
330.0	-26.7	225.9965	225.9869	226.0139	0.0100	-0.0034	
345.0	-26.7	226.0002	225.9900	226.0144	0.0095	0.0004	

```
    -0.0   -13.3   225.9974   225.9873   226.0130   0.0104  -0.0025
...
    75.0    40.0   225.9945   225.9858   226.0095   0.0084  -0.0054
    90.0    40.0   226.0026   225.9923   226.0107   0.0076   0.0027
   105.0    40.0   225.9952   225.9866   226.0074   0.0082  -0.0047
   120.0    40.0   226.0000   225.9915   226.0141   0.0105   0.0001
   135.0    40.0   225.9943   225.9862   226.0024   0.0068  -0.0056
   150.0    40.0   226.0038   225.9899   226.0159   0.0108   0.0039
   165.0    40.0   225.9959   225.9858   226.0127   0.0107  -0.0040
   180.0    40.0   226.0063   225.9925   226.0152   0.0090   0.0065
   195.0    40.0   226.0040   225.9896   226.0156   0.0120   0.0042
   210.0    40.0   225.9976   225.9901   226.0084   0.0066  -0.0023
   225.0    40.0   226.0005   225.9865   226.0136   0.0093   0.0007
   240.0    40.0   225.9964   225.9877   226.0148   0.0095  -0.0035
   255.0    40.0   226.0033   225.9940   226.0150   0.0075   0.0034
   270.0    40.0   226.0034   225.9876   226.0083   0.0078   0.0035
   285.0    40.0   226.0010   225.9869   226.0113   0.0100   0.0011
   300.0    40.0   226.0019   225.9913   226.0131   0.0075   0.0020
   315.0    40.0   226.0002   225.9881   226.0142   0.0106   0.0003
   330.0    40.0   226.0002   225.9953   226.0066   0.0052   0.0003
   345.0    40.0   226.0004   225.9908   226.0090   0.0067   0.0005
```

Parameter	*Description*
Measurement Volume	The area of the machine containing the Machine Checking Gauge measurement.
Temperature	Temperature recorded during the test.
Tool Offset	XYZ offset of the tool used during the test.
Probing Error	Form error of the measured MCG pivot sphere.
Average Length XY, YZ, ZX	The average of all measurements in these three planes.
Average Length X, Y, Z	The average length of all measurements parallel to the X, Y, and Z axis.
Relative Length X, Y, Z	The error of the measurements along the X, Y, and Z axis relative to the average length of all measurements.
Squareness XY, YZ, ZX	Measurement of the squareness error of the three projection planes of the machines volume.
Measurement Count	Total number of MCG arm measurements.
Minimum Length	The length of the shortest MCG arm measurement. This is the average of any position and not the absolute shortest length.
Maximum Length	The length of the longest MCG arm measurement. This is the average of any position and not the absolute longest length.
Range Length	Difference in length between the shortest and longest MCG arm measurements.
Average Length	The average length of all MCG arm measurements.
Median Length	The middle length between the shortest and longest measurement. The median length is used when considering the tolerance.
StdDev Length	The standard deviation of the length measurements.
Tolerance	The current working tolerance. This value is defined by entering a

Parameter	*Description*
	tolerance value or expression. Comparison to tolerance uses the median MCG arm length.
Estimated Range for 95%	The range covering two standard deviations of the data.
Number Outside Estimated	The total number of length measurements that fall outside the estimated range of the length data.
Pivot Sphere Start	XYZ position of the measured pivot sphere before the MCG arm is mounted on the gauge.
Pivot Sphere End	XYZ position of the measured pivot sphere after the MCG arm has been removed from the gauge.
MCG Sphere Center	XYZ position of the best fit sphere from of all the measurement point data. Ideally this position is identical to that of the pivot sphere. *All reported data is calculated from the center of a best fit sphere and does not rely on the mechanical center of the MCG gauge.*
Individual Measurements	A list of all the individual measurements that were used for the calculations.

The starting and ending pivot positions are important when reviewing the data. Most often, if there is a change in the pivot sphere position, the change happened when the MCG arm is either installed or removed but it could also happen during the course of measurement. If the measured results look reasonable even though there is a relatively large shift in the pivot sphere position the shift likely happened when the arm was installed or removed but, either way, the test should be repeated to be certain.

Report View

The report view of the *Machine Checking Gauge* utility shows a preview of how the data will appear when output as PDF file or sent to a printer. An example of the report view is shown in illustration 5.

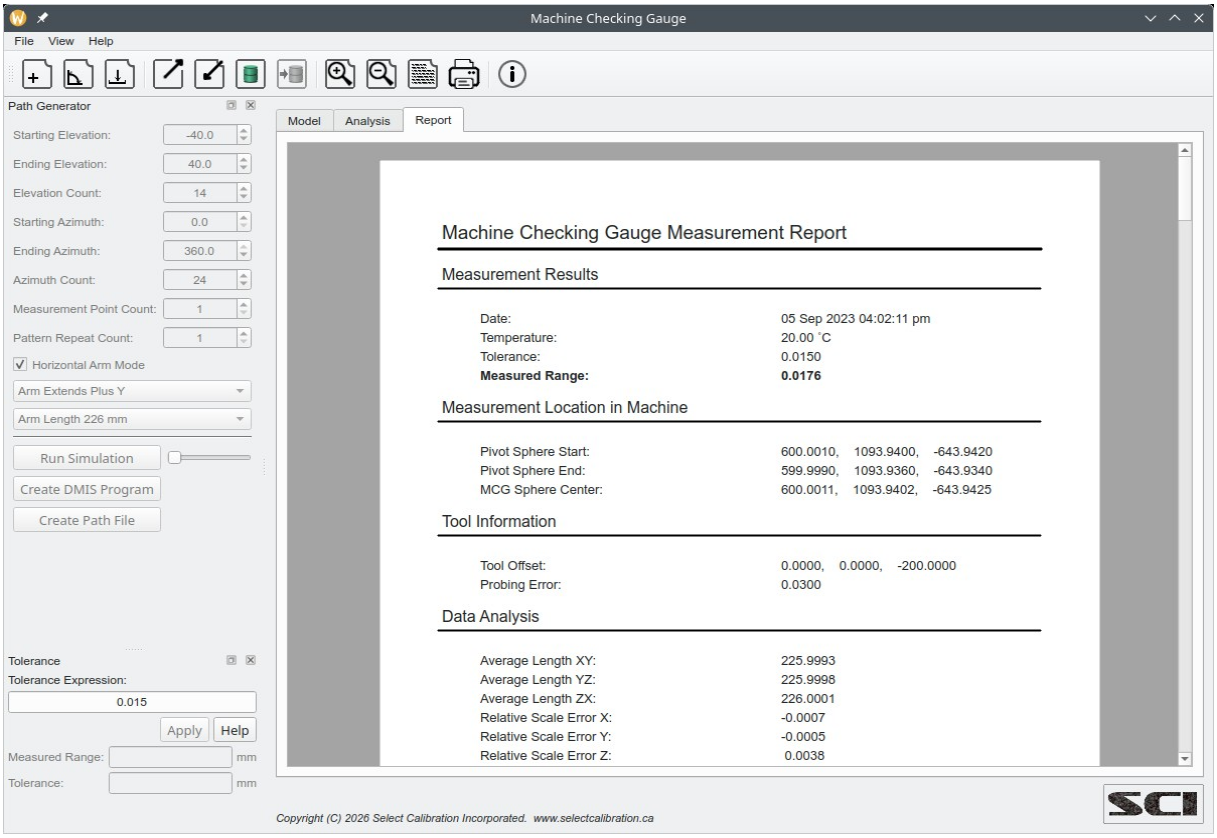


Illustration 5: Report view of the measurement.

The reported date and time is generated when the raw measurement data is processed by the Machine Checking Gauge utility.

Path Generator

This option allows the user to create a measurement path file or DMIS part program that can be used to simplify the measurement of the MCG artifact. Use of the path file can be used to create a simple part program that imports and executes the commands contained within the file. The DMIS program is generic enough that it should be usable on almost any system that supports DMIS programs. If the inspection software cannot create a DMIS output file then it will be necessary to modify the program in order to add a supported output. Most inspect software that translate the DMIS program into a native format will not generate a DMIS output file. Inspection software that uses DMIS as the native language should have the option to create a DMIS output file.

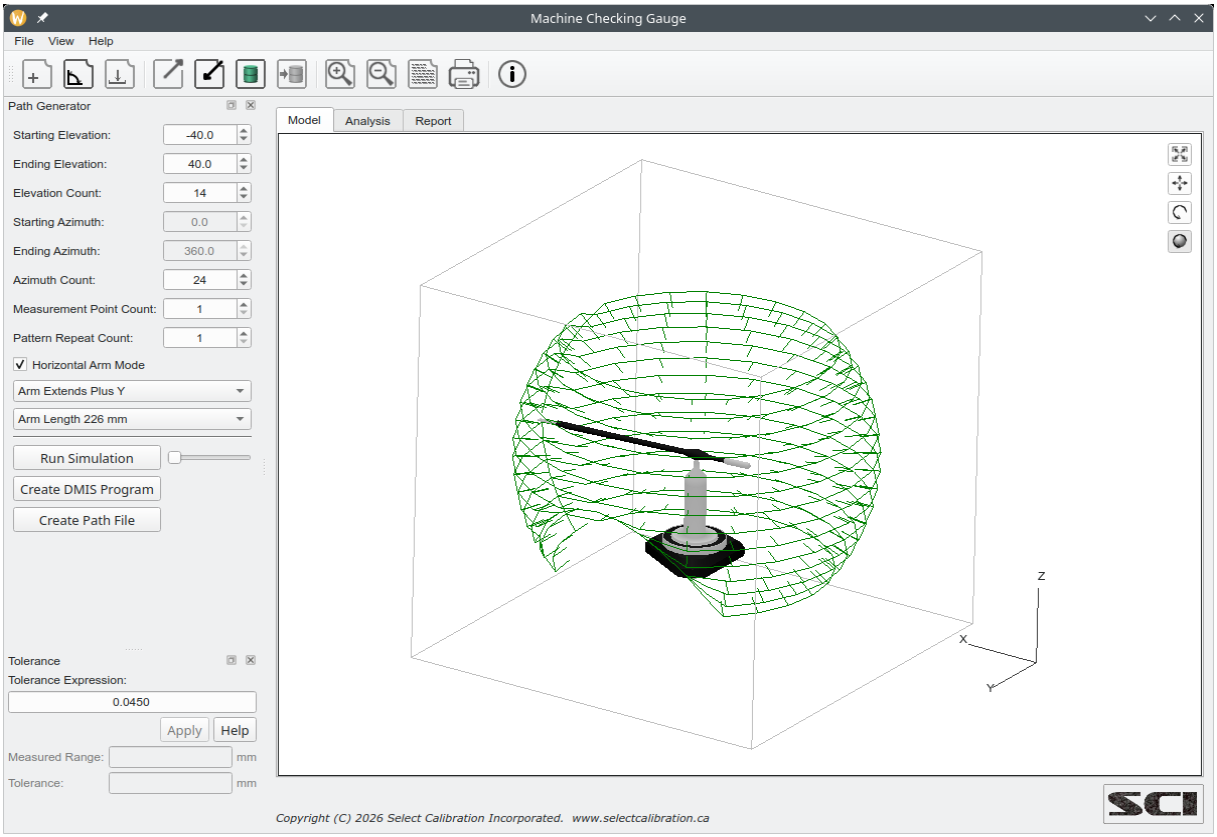


Illustration 6: Path Generator options and end result in the model view.

Options:

Parameter	*Description*
Starting Elevation	Angle in degrees for the starting level of the measurement path.
Ending Elevation	Angle in degrees for the ending level of the measurement path.
Elevation Count	Number of measurement levels between the elevation start and end angles.
Starting Azimuth	Angle in degrees for the starting rotation of the measurement path.
Ending Azimuth	Angle in degrees for the ending rotation of the measurement path.
Azimuth Count	Number of measurement positions between the starting and ending azimuth angles.
Measurement Point Count	Number of times to measure individual points.
Pattern Repeat Count	Number of times to measure the entire pattern of points.
Horizontal Arm Mode	When enabled a circular area of the path is avoided allowing the gauge to be run on horizontal arm CMM's. This area can be defined as +/- X or +/- Y depending on the axis configuration of the machine with the most common being +Y. See Arm Axis section for details.

Parameter	*Description*
Run Simulation	Run a simulation of the measurement pattern in the machine. The simulation will continue endlessly until stopped.
Create DMIS Program	Create a DMIS part program for the inspection of the MCG artifact.
Create Path File	Create the measurement path file.

Arm Axis

When using a horizontal arm there is a section of the gauge that cannot be measured since the arm will collide with the pivot sphere of the MCG artifact. When generating a path in *Horizontal Arm Mode* all moves that are in the shadow of the arm will be avoided.

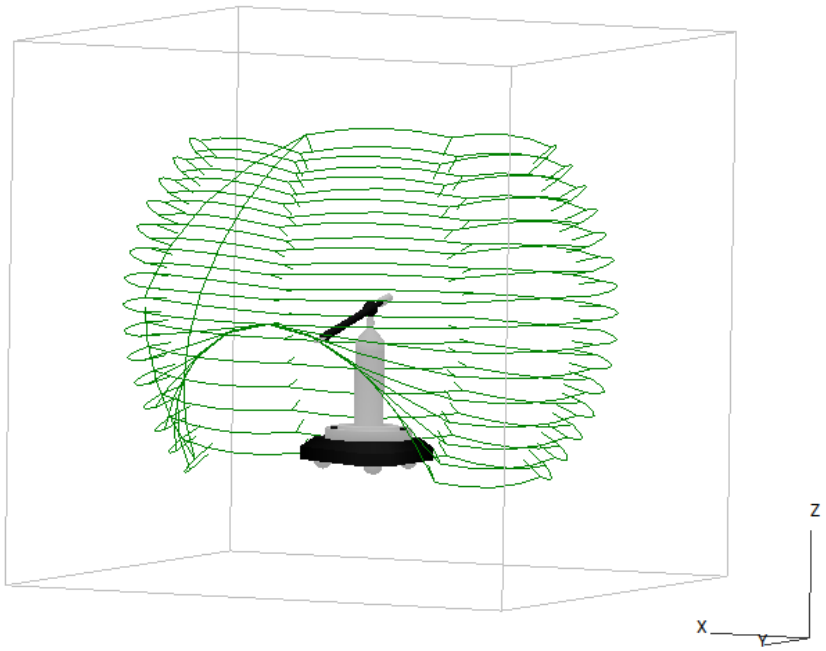


Illustration 7: Example of a section of the measurement sphere avoided on a horizontal arm CMM.

The example shown in illustration 7 was created using many measurement levels in order to clearly show the area that is avoided with the horizontal arm option enabled.

Path File Format

The path file format generated by the Machine Checking Gauge program is intended to be easy to read by any inspection software. An example of a path file is shown below.

```
MCG_PATH_FILE_V1
P 1.000000000 0.000000000 0.000000000
P 0.984807753 0.000000000 -0.173648178
P 0.939692621 0.000000000 -0.342020143
P 0.866025404 0.000000000 -0.500000000
P 0.766044443 0.000000000 -0.642787610
M 0.766044443 0.000000000 -0.642787610
M 0.766044443 0.000000000 -0.642787610
P 0.766044443 0.000000000 -0.642787610
```

```
P 0.733072090 0.143223580 -0.664900231
P 0.683906806 0.283283474 -0.672325780
P 0.619634610 0.417085881 -0.664900231
P 0.541675220 0.541675220 -0.642787610
M 0.541675220 0.541675220 -0.642787610
M 0.541675220 0.541675220 -0.642787610
P 0.541675220 0.541675220 -0.642787610
P 0.417085881 0.619634610 -0.664900231
…
```

The path file has three different types of entries; one is used for validation and the other two are used to define the move and measure points for the measurement sequence.

Line	*Sample*	*Description*
1	MCG_PATH_FILE_V1	Error checking line. If this file is read and this is not the first line then the wrong file has been selected.
2 or higher	P 1.00 0.00 0.00	Move point following by the IJK vector
2 or higher	M 1.00 0.00 0.00	Measurement point followed by the IJK vector

It was decided to have only an IJK direction for all move and measurement points in order to separate the actual length of the MCG arm from the path file. The result is that a single path file can be used to measure any length of MCG arm.

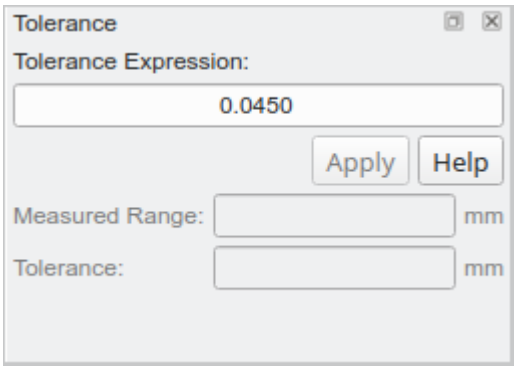
The following is an example of a loop used to read this path file in PC-DMIS. The alignment at this point in the program has the XYZ origin set to the center of the MCG pivot sphere:

```
             ASSIGN/POINT_TYPE=0
             ASSIGN/POINT_I=0
             ASSIGN/POINT_J=0
             ASSIGN/POINT_K=0

             DO/
READ_LINE_RESULT=FILE/READLINE,INPUT_FILE_PNTR,{POINT_TYPE}+" "+{POINT_I}+" "+{POINT_J}+" "+{POINT_K}

             IF/READ_LINE_RESULT == "OK"
             ASSIGN/PNT_VECTOR=MPOINT(POINT_I,POINT_J,POINT_K)

             IF/POINT_TYPE == "M"
             ASSIGN/MEAS_PNT=PNT_VECTOR * MCG_LENGTH
PT1         =FEAT/POINT,CARTESIAN
             [measure point at MEAS_PNT.XYZ with surface normal of PNT_VECTOR.IJK]
             ENDMEAS/
             END_IF/

             ELSE_IF/POINT_TYPE == "P"
             ASSIGN/MOVE_PNT=PNT_VECTOR * (MCG_LENGTH + CLEARANCE)
             MOVE/POINT,NORMAL,<MOVE_PNT.X,MOVE_PNT.Y,MOVE_PNT.Z>
             END_ELSEIF/

             END_IF/

             UNTIL/READ_LINE_RESULT == "EOF"
             FILE/CLOSE,INPUT_FILE_PNTR,KEEP
```

This program should be easy to recreate in almost any inspection software which is the main reason this method exists.

Tolerance

The tolerance option of the *Machine Checking Gauge* utility allows the user to define the upper limit for the range of the measurement lengths. The result from a MCG measurement is comparable to the length repeatability tolerance as defined in the ASME B89.4.1:1997 ball bar test.



The tolerance expression can be in one of the three formats:

- A single value such as 0.010
- An expression based on the length such as 0.010 + 0.005L/1000
- An expression based on the length with a hard limit such as 0.010 + 0.005L/1000 | 0.015

Entries that do not make sense will change the background color of the input field to red.

The tolerance value used for the analysis of the measurement data is treated as a bandwidth from the input tolerance expression. For example, if the input expression is 0.010 mm then the range of the input measurement lengths is expected to be 0.010 mm or less (or +/- 0.005 mm from the median length).

Importing Measurement Data

Data can be imported into the *Machine Checking Gauge* utility by using the import toolbar icon, the import option from the file menu, or by dragging and dropping a measurement file onto the utility.

The imported measurement data has no specific requirements other than to contain a minimum of four unique measurement positions that can be used to calculate a sphere. The order of the imported data is not important. There is no practical upper limit for the number of measurement positions that can be imported.

Data that includes repeated measurement positions are automatically grouped together and reported as a single measurement along with a range and standard deviation. The grouping is done at one degree increments therefore the maximum number of measurement positions that can be theoretically reported is 32,400 (360 x 90).

The analysis of the data is done using all samples that fit within a given measurement range. For example, when calculating the average length along a given axis then all data that is within a reasonable angle to that axis is used. If there are no suitable positions in the data the report will indicate that that particular value cannot be calculated.

XML File Format

The measurement data collected from the inspection software written to an XML file is expected to appear as shown below.

```
<!DOCTYPE MCG_Measurement>
<MCG_Measurement_Data File_Version="1" Units="MM">
    <Environment>
        <Temperature>21</Temperature>
    </Environment>
    <Probe>
        <Probe_Offset_XYZ>-0.000,-0.000,-195.070</Probe_Offset_XYZ>
        <Probe_Error>0.0000</Probe_Error>
    </Probe>
    <Pivot_Sphere_Initial>
        <Location_XYZ>500.000,750.000,-600.000</Location_XYZ>
    </Pivot_Sphere_Initial>
    <Gauge_Points>
        <Point_XYZ>524.74044,0.00000,-440.30951</Point_XYZ>
        <Point_XYZ>524.74044,0.00000,-440.30951</Point_XYZ>
        <Point_XYZ>371.04753,371.04753,-440.30951</Point_XYZ>
…
        <Point_XYZ>371.04753,-371.04753,440.30951</Point_XYZ>
        <Point_XYZ>371.04753,-371.04753,440.30951</Point_XYZ>
    </Gauge_Points>
    <Pivot_Sphere_Final>
        <Location_XYZ>500.000,750.000,-600.000</Location_XYZ>
    </Pivot_Sphere_Final>
</MCG_Measurement_Data>
```

Line	*Sample*	*Description*
1	<?xml version="1.0" encoding="utf-8"?> *or* <!DOCTYPE MCG_Measurement>	The first line of the file must identify the contents as XML. Either entry will work.
2	<MCG_Measurement_Data File_Version="1" Units="MM">	Identification of the file contents as *MCG_Measurement_Data.* The file version must be indicated (currently 1) and the units must be specified (MM or IN).
<any>	<Environment> <Temperature>20.0</Temperature> </Environment>	Input temperature measurement. Temperature is always assumed to be Celsius.
<any>	<Probe> <Probe_Offset_XYZ>0.0,0.0,-195.0</Probe_Offset_XYZ> <Probe_Error>0.0000</Probe_Error> </Probe>	Probe information. This includes the tool offset and probing error.
<any>	<Pivot_Sphere_Initial> <Location_XYZ>500.0,750.0,-600.0</Location_XYZ> </Pivot_Sphere_Initial>	Location of the MCG pivot sphere at the start of the measurement test.
<any>	<Gauge_Points>	Points measured on the

Line	*Sample*	*Description*
	<Point_XYZ>524.7,0.0,-440.3</Point_XYZ> <Point_XYZ>524.7,0.0,-440.3</Point_XYZ> <Point_XYZ>371.0,371.0,-440.3</Point_XYZ> ... </Gauge_Points>	MCG arm. The order of the points is not important. The number of measurement points is not limited.
<any>	<Pivot_Sphere_Final> <Location_XYZ>500.0,750.0,-600.0</Location_XYZ> </Pivot_Sphere_Final>	Location of the MCG pivot sphere at the end of the measurement test.
<last>	</MCG_Measurement_Data>	Last line in the measurement file.

Aside from the requirements of a valid XML file the layout of the file is not important.

All measurement point data should be written with a minimum of five decimal precision (in metric). All other values such as the pivot sphere position or probe offset should show at least three decimal place precision (in metric). Using more decimal places is not a problem.

Simple Text Format

The measurement data collected from the inspection software written to a text file is expected to appear as shown below.

```
temperature:21
probe_offset:0.0 0.0 -200
probe_error:0.003
pivot_sphere_start:100.125 200.246 -300.369
pivot_sphere_end:100.126 200.247 -300.370
151.72240447346 0.00364635054 -0.00407155993
107.27960747346 107.28086935054 -0.00454555993
0.00120147346 151.71238835054 -0.00490155993
-107.27420652654 107.27861435054 -0.00464955993
-151.71466952654 0.00136535054 -0.00496355993
-107.28255352654 -107.28368764946 -0.00486955993
...
-75.85836252654 -75.86013364946 107.27542744007
0.00316247346 -107.28478064946 107.27711144007
75.86362847346 -75.86158464946 107.27746844007
```

The initial description entries are all optional but can be added to provide additional information to the *Machine Checking Gauge* utility. The goal of this format was, at a minimum, to allow a file containing only XYZ coordinates of a set of measured points to be imported in the *Machine Checking Gauge* utility.

Text	*Description*
temperature:21	Input temperature measurement. Temperature is always assumed to be Celsius.
probe_error:0.003	Probing error. The form error from measuring the pivot sphere with 25 points.

Text	*Description*
probe_offset:0.0 0.0 -200	Tool offset information.
pivot_sphere_start:100.125 200.246 -300.369	Location of the MCG pivot sphere at the start of the measurement test.
pivot_sphere_end:100.126 200.247 -300.370	Location of the MCG pivot sphere at the end of the measurement test.
151.72240447346 0.00364635054 -0.00407155993 107.27960747346 107.28086935054 -0.00454555993 0.00120147346 151.71238835054 -0.00490155993 ...	XYZ points on the MCG arm.

The order of the data within the file is not important. Supplemental information including temperature, probe_error, probe_offset, pivot_sphere_start, and pivot_sphere_end are optional.

DMIS DMO Format

The measurement data collected from the inspection software written a DMIS DMO file is expected to contain DMIS formatted actual results. The feature names when the DMIS program is generated is important and should not be changed.

```
FILNAM/'C:\programs\test.dmo',04.0
DA(MAN_CSY)=DATSET/TRMATX,1.,0.,0.,0.,1.,0.,0.,0.,1.,599.998,1093.941,$
-643.949
DA(DCC_CSY)=DATSET/TRMATX,1.,0.,0.,0.,1.,0.,0.,0.,1.,600.001,1093.94,-643.942
OUTPUT/F(MCG_PNT_1),T(X_TOL),T(Y_TOL),T(Z_TOL)
F(MCG_PNT_1)=FEAT/POINT,CART,173.126,0.,-145.27,0.7660444,0.,-0.6427876
T(X_TOL)=TOL/CORTOL,XAXIS,-0.1,0.1
T(Y_TOL)=TOL/CORTOL,YAXIS,-0.1,0.1
T(Z_TOL)=TOL/CORTOL,ZAXIS,-0.1,0.1
OUTPUT/FA(MCG_PNT_1),TA(X_TOL),TA(Y_TOL),TA(Z_TOL)
...
OUTPUT/FA(MCG_SPH_1),TA(MCG_SPH_1_F)
FA(MCG_SPH_1)=FEAT/SPHERE,OUTER,CART,600.001,1093.94,-643.942,3.997,0.,0.,1.
TA(MCG_SPH_1_F)=TOL/CIRLTY,0.03,INTOL
OUTPUT/F(MCG_SPH_2),T(MCG_SPH_2_F)
F(MCG_SPH_2)=FEAT/SPHERE,OUTER,CART,0.,0.,0.,4.,0.,0.,1.
T(MCG_SPH_2_F)=TOL/CIRLTY,0.1
OUTPUT/FA(MCG_SPH_2),TA(MCG_SPH_2_F)
FA(MCG_SPH_2)=FEAT/SPHERE,OUTER,CART,599.999,1093.936,-643.934,4.,0.,0.,1.
TA(MCG_SPH_2_F)=TOL/CIRLTY,0.021,INTOL
ENDFIL
```

In cases where the inspection software does not create a DMIS output file it will be necessary to modify the DMIS program to output data in a suitable format that can be imported into the *Machine Checking Gauge* utility.

Exporting Measurement Data

The measurement data can be exported from the file menu or from the export measurement toolbar option of the *Machine Checking Gauge* utility. The format of the exported data is similar to how it appears in the *Analysis* tab of the *Machine Checking Gauge* utility.

Database

Starting with version 5 of the *Machine Checking Gauge* utility measurement data can be stored in

a SQLite database. The database allows past results to be loaded and combinations of results to be exported in a summary format in order to identify trends or other changes over time.

The database is created and initialized automatically so no special steps are needed to setup this feature. The location of the database is in a sub folder of the users home folder called `.mcg'.

The layout of the database table can be shown using the following SQLite command:

```
PRAGMA table_info('table_name');
```

where 'table_name' is the name of the database table to inspect.

Database Tables

The following shows the layout of the tables used by the *Machine Checking Gauge* utility.

Table 1: Database Table 'date'

Name	*Type*	*Primary Key*	*Comment*
date_id	INTEGER	Yes	Unique value used to cross reference date entries in other tables.
entry	TEXT	No	Date text.

Table 2: Database Table 'time'

Name	*Type*	*Primary Key*	*Comment*
time_id	INTEGER	Yes	Unique value used to cross reference time entries in other tables.
date_id	INTEGER	No	Reference value to a specific date.
entry	TEXT	No	Time text.

Table 3: Database Table 'summary'

Name	*Type*	*Primary Key*	*Comment*
date_id	INTEGER	No	Reference value to a specific date.
time_id	INTEGER	No	Reference value to a specific time.
min_length	REAL	No	Minimum measured arm length.
max_length	REAL	No	Maximum measured arm length.
mean_length	REAL	No	Average measured arm length.
median_length	REAL	No	Middle measured arm length.
stdev_length	REAL	No	Standard deviation of the variation in the measured arm length.
range	REAL	No	Actual range of the measured arm lengths
pftu	REAL	No	Form error from running a Pftu test on the pivot sphere.

Name	*Type*	*Primary Key*	*Comment*
temperature	REAL	No	Temperature at the time of measurement.

Table 4: Database Table 'entry_tool'

Name	*Type*	*Primary Key*	*Comment*
date_id	INTEGER	No	Reference value to a specific date.
time_id	INTEGER	No	Reference value to a specific time.
tool_x	REAL	No	X tool offset.
tool_y	REAL	No	Y tool offset.
tool_z	REAL	No	Z tool offset.

Table 5: Database Table 'entry_pivot_sphere'

Name	*Type*	*Primary Key*	*Comment*
date_id	INTEGER	No	Reference value to a specific date.
time_id	INTEGER	No	Reference value to a specific time.
pos_x_start	REAL	No	X pivot sphere position at start of test.
pos_y_start	REAL	No	Y pivot sphere position at start of test.
pos_z_start	REAL	No	Z pivot sphere position at start of test.
pos_x_end	REAL	No	X pivot sphere position at end of test.
pos_y_end	REAL	No	Y pivot sphere position at end of test.
pos_z_end	REAL	No	Z pivot sphere position at end of test.
pos_x	REAL	No	X sphere position from point data.
pos_y	REAL	No	Y sphere position from point data.
pos_z	REAL	No	Z sphere position from point data.

Table 6: Database Table 'entry_points'

Name	*Type*	*Primary Key*	*Comment*
date_id	INTEGER	No	Reference value to a specific date.
time_id	INTEGER	No	Reference value to a specific time.
point_x	REAL	No	X position for a measurement point.
point_y	REAL	No	Y position for a measurement point.
point_z	REAL	No	Z position for a measurement point.

Illustration 8 shows an example of using the *Qt SQLBrowser* utility to get a list of the average measured arm lengths from the data stored in the summary table outside of the *Machine*

Checking Gauge utility. It is not easier to do it this way but does demonstrate how any suitable utility can be used to query collected data.

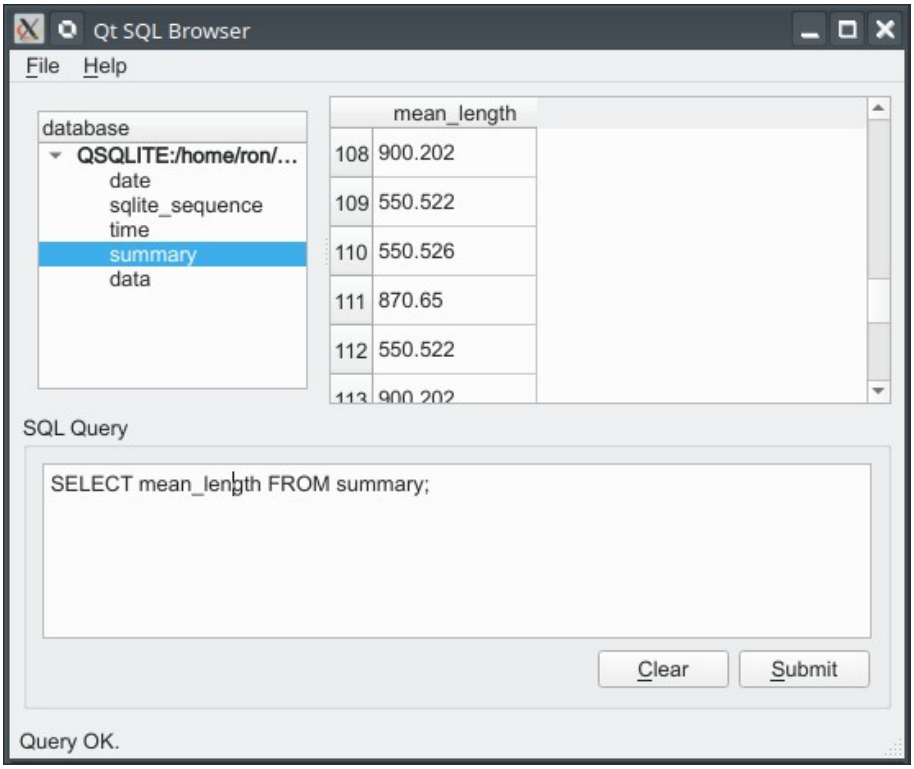


Illustration 8: Example showing the average measured arm lengths from the summary table data.

Database Dialog

Illustration 9 shows the database dialog from the *Machine Checking Gauge* utility. The data entries are shown by the year, month, and day for the first level and hour, min, and seconds for the second. It is believed that users will want to look for results from a specific date first and then consider a specific time.

Options to search for a specific date may be added in the future if the need makes sense. Using the current configuration of separating dates and times should make this unnecessary for most users.

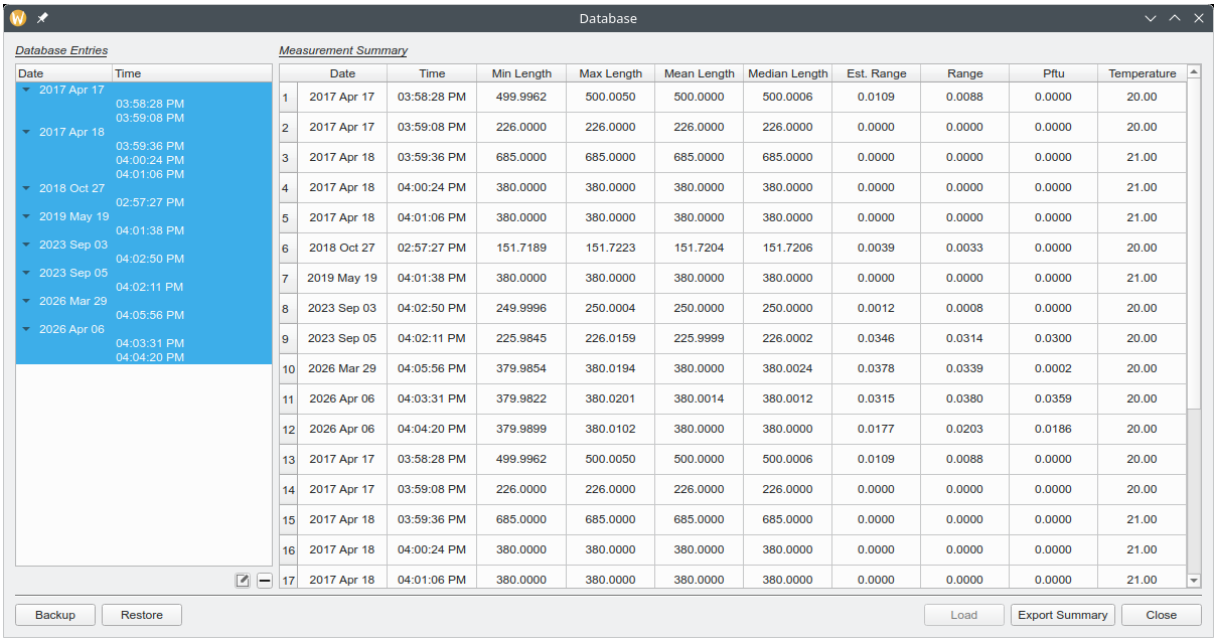


Illustration 9: Database Dialog with various selections and the summary of the selected data.

Table 7: Database Dialog Options

Option	*Description*
Backup	Create a text file backup containing the entire contents of the database. The extension of the file is '.backup'.
Restore	Import the previously created backup file.
Load	Load the selected MCG measurement data from the database and display it in the *Machine Checking Gauge* utility. This function will be disabled if more than one measurement is selected.
Export Summary	Create a CSV file from the Measurement Summary data. This file can be opened with any spreadsheet program.
Close	Close the database utility.

The database entries have limited editing options as described in table 8. Individual date and time entries can be changed and one or more entries can be removed without having to rely on an external utility. This addresses problems where an entry was added unintentionally or when importing a measurement that was done in the past (the default date and time is the current date and time).

Modification of actual measurement values cannot be done inside the Machine Checking Gauge utility.

Table 8: Database Edit Options

Option	*Description*
	Change the date and time of the selected database entry. New entries are assigned to the current date and time but, when importing older data, it is necessary to update the date and time to match when the measurement was performed.
	Delete all selected database entries.

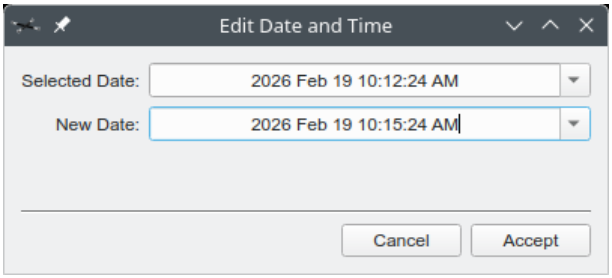


Illustration 10: Editor for the date and time for a specific measurement entry.

Adding Measurements To The Database

Measurements can be added to the database with the *Save To Database* option from the File Menu or clicking on the related toolbar button from the *Machine Checking Gauge* utility. This option is active when new data is imported and will remain active until new data is added.

The date and time associated with each measurement entry is from the date and time the data is added to the database and not the imported file date and time.

Revision History

Date	*Version*	*Changes*
Apr 18, 2017	1.0	New Program
Oct 25, 2018	2.0	Added simple text format for input data.
Oct 28, 2018	3.0	Added Data section for file management. Added ability to load and save processed MCG data. Improved readability of generated report file Added option to export measurement data. Improvements to appearance of path file. Ability to change the intensity level of the generated path data. Added ability to specify the arm axis of a horizontal arm CMM.
Sep 7, 2023	4.0	Extensive rewrite of user interface. Added option to simulate the measurement positions. Added option to create a DMIS inspection program.
Apr 11, 2026	5.0	[bug fix] Depth scaling causes items to be drawn incorrectly. Changed estimated range to 95% Updated depreciated functions. Updated reported information and formatting. Changed the tolerance widget to newer format. Added database option. Increased sensitivity to positions used for squareness.