Machine Checking Gauge Users Guide

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Introduction

The Machine Checking Gauge utility was written to allow users the ability to display and analyze measurement data from a Renishaw Machine Checking Gauge as part of interim checks on CMM's. Interim checks are necessary to ensure that the machine is running properly and also used to verify that changes to the machine, such as a software upgrade, have not adversely affected the accuracy of the machine.

This utility is cross platform compatible and can be run on GNU/Linux, OSX, and Windows.

Overview

The Machine Checking Gauge utility is a single dialog window with tabs that have specific functions.

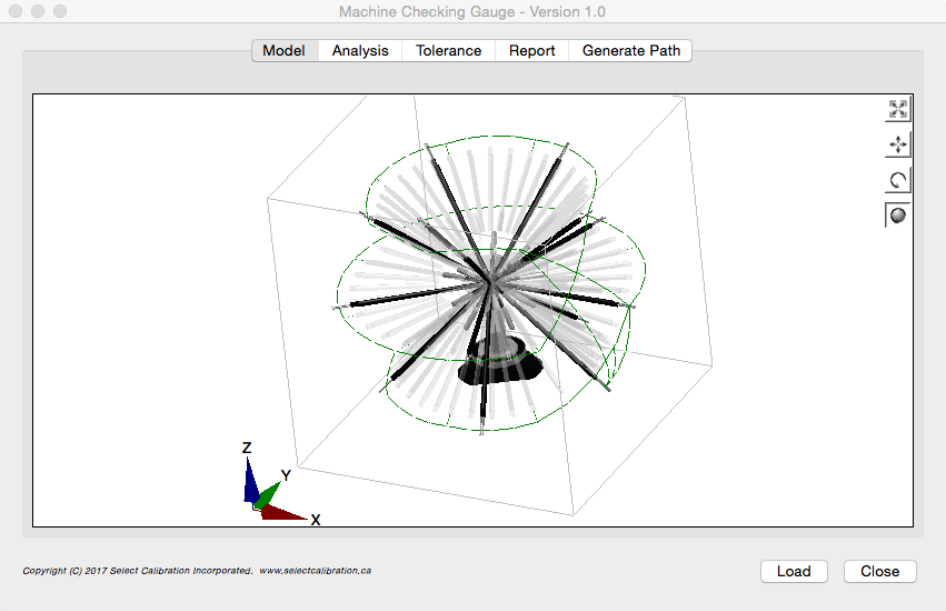

Illustration 1: View of the Machine Checking Gauge program showing a combination of measurement data and path.

Model View

The model view shows the measurement data in 3D along with an outline of the measurement volume and axis directions for reference. Measurements that are outside of tolerance are shown in red and a selected MCG position is shown in blue.

Measurement uncertainty is not considered for when deciding if a result is inside or outside of specification. The upper and lower limits are set based on a symmetrical deviation around the average (not the range of the data).

Display 3D Controls

The 3D model display is not fixed and can be manipulated in a variety of ways. The model is displayed on the idea of a projection frustum to mimic the relative size of objects based on the distance away from the viewer to provide a slightly more realistic rendering of the volume of the data.

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.
	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.

Selection Data

The individual measurements shown in the model view window can be selected with a left mouse button click. When a measurement position has been selected information about the measurement will appear at the top of the model window and the selected position will be highlighted in blue. The selection data includes the azimuth, elevation, length, and deviation from average.

Path Data

The path data is shown as a series of translucent Machine Checking Gauge positions for each move and measurement point in the generated path. The path data can be disabled by unchecking the option *Draw Path in Model* from the *Generate Path* view of the Machine Checking Gauge program.

When measurement data is imported some of this information is used for the generation of the path (position and measurement length) resulting in the two sets of information appearing to overlap.

OpenGL

The graphical view of the measurement data is drawn using OpenGL. The computer must have at least OpenGL version 2.x or higher in order to run this utility program with a visible model window.

Running the Machine Checking Gauge program on computers with only OpenGL 1.x support the

graphics window is automatically disabled and replaced with an information window.

In the event the model view of the program is disabled the rest of the program will continue to work as expected.

Analysis View

The analysis view of the data shows the measurements in a distribution histogram and all the numerical results in a text window. The analysis is intended to help identify results which are not typical of the overall measurements. The analysis text view summarizes the measurement data with the following information:

```
Measurement Volume
------------------------------------------------------------------------
          Start X:  -183.2772
            End X:  1183.2826
          Range X:  1366.5598
          Start Y:    66.7235
            End Y:  1433.2833
          Range Y:  1366.5598
          Start Z: -1283.2885
            End Z:    83.2712
          Range Z:  1366.5598

Measurement Analysis
------------------------------------------------------------------------
      Temperature:    21.00 C
     Probe Offset:     0.0000,     0.0000,  -195.0700
      Probe Error:     0.0000
Average Length XY:   683.2796
Average Length YZ:   683.2712
Average Length ZX:   683.2821
 Average Length X:   683.2833
Relative Length X:     0.0035
 Average Length Y:   683.2668
Relative Length Y:    -0.0131
 Average Length Z:   683.2808
Relative Length Z:     0.0009
    Squareness XY:     0.0038 mm/m
    Squareness YZ:    -0.0037 mm/m
    Squareness ZX:     0.0026 mm/m

Measurement Statistics
------------------------------------------------------------------------
Measurement Count:         24
   Minimum Length:   683.2582
   Maximum Length:   683.2913
     Range Length:     0.0331
   Average Length:   683.2799
    Median Length:   683.2748
    StdDev Length:     0.0080
        Tolerance:     0.0081

Estimated Range for 99% of Measurements: 0.02385
Number Outside of Estimated Range: 2

Measurement Center
------------------------------------------------------------------------
      Pivot Start:   500.0000,   750.0000,  -600.0000
        Pivot End:   500.0000,   750.0000,  -600.0000
      Data Center:   500.0027,   750.0034,  -600.0087

Individual Measurement Results
```

```
-------------------------------------------------------------------------

Azimuth Elevation  Length      Min         Max      Std Dev   Dev
-------------------------------------------------------------------------
   -0.0   -40.0   683.2808   683.2786   683.2828   0.0014   0.0009
   45.0   -40.0   683.2886   683.2869   683.2899   0.0010   0.0087
   90.0   -40.0   683.2674   683.2659   683.2684   0.0008  -0.0125
  135.0   -40.0   683.2871   683.2851   683.2895   0.0017   0.0072
...
```

Parameter	*Description*
Measurement Volume	Describes the area of the machine as a cube with values that contain the machine checking gauge measurement.
Temperature	Temperature recorded during the test.
Probe Offset	XYZ offset of the probe used during the test.
Probe 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 along 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 fork measurements.
Minimum Length	The length of the shortest MCG fork measurement.
Maximum Length	The length of the longest MCG fork measurement.
Range Length	Difference in length between the shortest and longest MCG fork measurements.
Average Length	The average length of all MCG fork measurements.
Median Length	The middle length between the shortest and longest measurement. If fliers exist in the measurements this will often be very different from the average length.
StdDev Length	The standard deviation of the length measurements.
Tolerance	The current working tolerance. This value is defined by entering a tolerance expression in the tolerance tab and calculated from the average MCG fork length.
Estimated Range for 99%	The range of three 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 Start	XYZ position of the measured pivot sphere before the MCG arm is mounted on the gauge.
Pivot End	XYZ position of the measured pivot sphere after the MCG arm has been removed from the gauge.

Parameter	*Description*
Data Center	XYZ position of the best fit center of all the measurement 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.

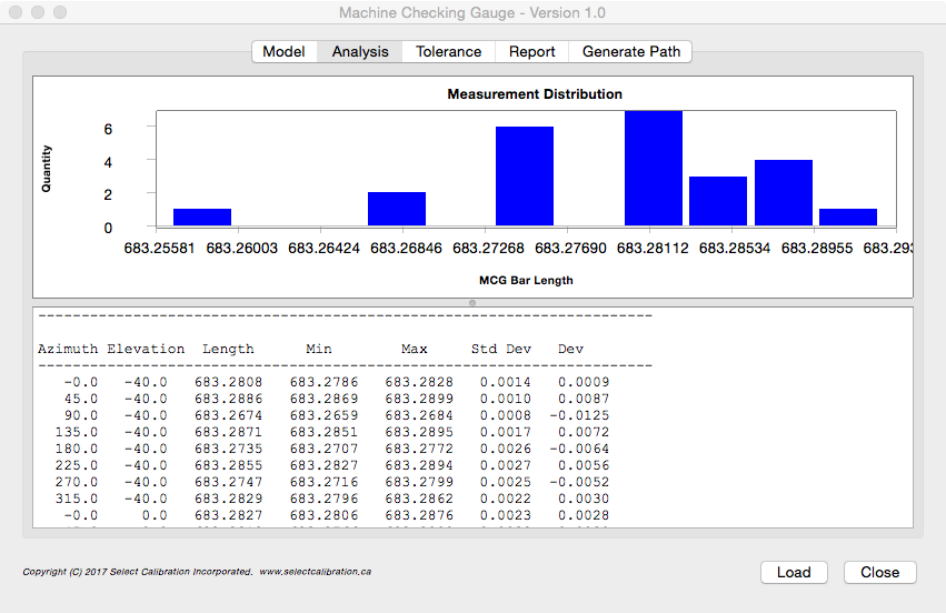

Illustration 2: Example of how the MCG data is reported in the analysis view.

Tolerance View

The tolerance view of the Machine Checking Gauge utility program allows the user to enter an upper limit for the variation in the MCG fork measurement lengths when performing an interim test of the machine.

The method used to determine if a measurement is outside or inside the specification is to find the upper and lower measurement limits from the average based on the input specification. Any measurements that fall outside of this range are considered to be outside of tolerance. The method defined by the ASME B89.4.1:1997 standard is to compare the range of the length measurements to the specification. For this reason it is possible that measurements may appear out of tolerance but still have a measurement range that is inside specification.

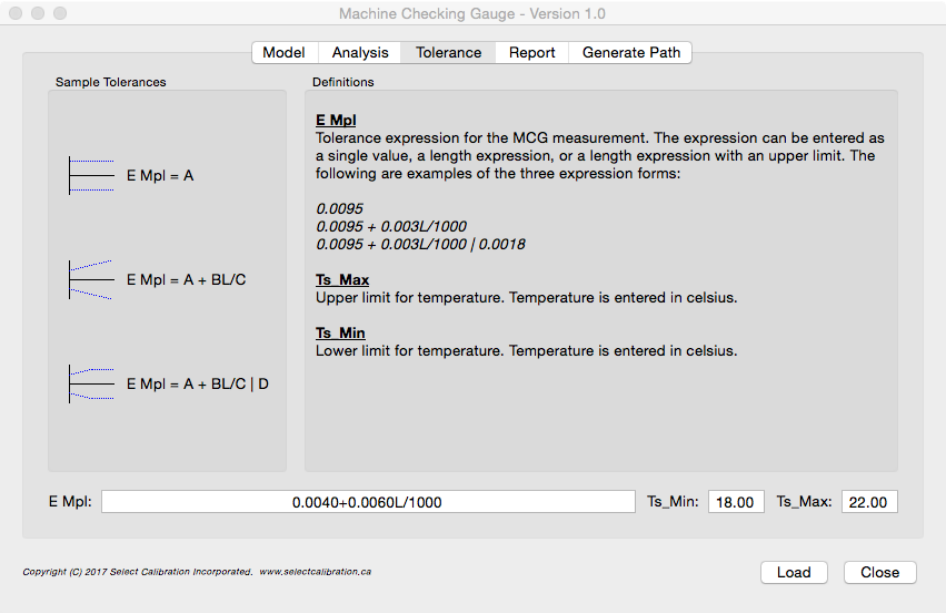

Illustration 3: Example of the tolerance view of the Machine Checking Gauge utility program.

The tolerance is input as an expression in the field *E Mpl* and can be in one of these 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

Entry errors are shown when the background color of the input field is changed to red. Entry errors can be from an unrecognized input expression or from other unrealistic input data such as swapping the upper and lower temperature limits.

The temperature tolerance fields are currently not used by the Machine Checking Gauge utility program.

Report View

The report view of the Machine Checking Gauge program presents the information in a way that is suitable for record keeping. The report data can be printed or saved as a PDF file.

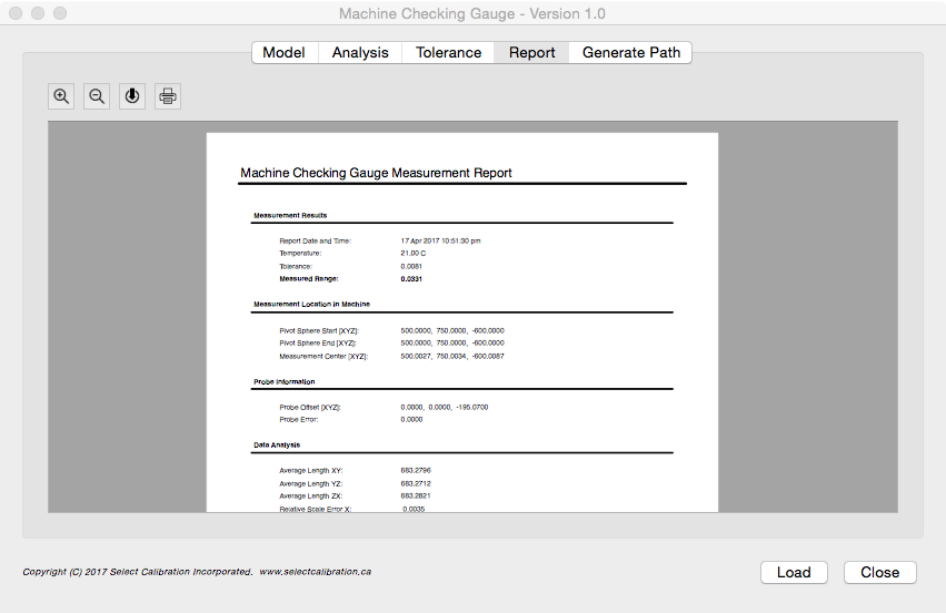

Illustration 4: Report view of the Machine Checking Gauge program.

The date and time of the report is always the current date and time when the measurement data is processed by the Machine Checking Gauge program.

Report View Options

The following options are available at the top of the report view:

Image	*Description*
	Increase the size of the displayed report.
	Decrease the size of the displayed report.
	Write the current report to a PDF file.
	Send the current report to a printer.

Generate Path View

This option allows the user to generate a generic measurement file that can be used to simplify the inspection part program for the measurement of the machine checking gauge. Use of the path file is optional but since most inspection software handle high-level programming in odd ways this option simplifies this necessary task.

The part program included with this program was written using the path file method.

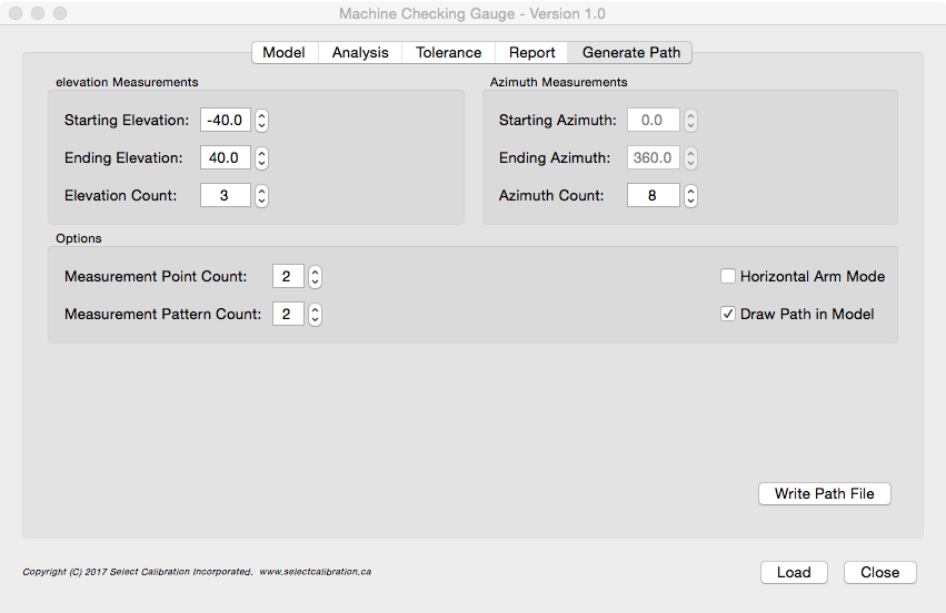

Illustration 5: Path generation option of the Machine Checking Gauge program.

The following is an explanation for the options for the generated path file:

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.
Measurement Pattern Count	Number of times to measure the entire pattern of points.
Horizontal Arm Mode	When checked a circular area on the +Y size of the path is avoided allowing the gauge to be run on horizontal arm CMM's.
Draw Path in Model	Show the path data in the model view.
Write Path File	Create the measurement path file.

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 - end	P 1.00 0.00 0.00	Move point following by the IJK vector
2 - end	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. This separates the actual length of the MCG fork from the path file (or a single path file can be used to measure any length of MCG fork).

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 was selected.

Measurement File Format

The measurement data collected from the inspection software must be written to file in an XML format defined 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.

Line	*Sample*	*Description*
<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 probe offset and probe 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> <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>	All points measured on the MCG gauge. 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.

Loading Measurement Data

The measurement data can be loaded into the Machine Checking Gauge program by one of two methods:

- Drag and drop the file onto the Machine Checking Gauge program.
- Select the option *Load* at the bottom of the Machine Checking Gauge program and select the input file using a standard file selection dialog.

Revision History

Date	*Version*	*Changes*
Apr 18, 2017	1.0	New Program