User's guide
H-1000-5080-04-A

RENISHAW
apply innovation™

Machine checking gauge (MCG)

Disclaimer

Considerable effort has been made to ensure that the contents of this document are free from inaccuracies and omissions. However, Renishaw makes no warranties with respect to the contents of this document and specifically disclaims any implied warranties. Renishaw reserves the right to make changes to this document and to the product described herein without obligation to notify any person of such changes.

Trademarks

RENISHAW® and the probe emblem used in the RENISHAW logo are registered trademarks of Renishaw plc in the UK and other countries.

apply innovation is a trademark of Renishaw plc.

All other brand names and product names used in this document are trade names, service marks, trademarks, or registered trademarks of their respective owners.

Renishaw part no: H-1000-5080-04-A

Issued: 04 2007

MCG

machine checking gauge

user's guide

Care of equipment

Renishaw probes and associated systems are precision tools used for obtaining precise measurements and must therefore be treated with care.

The Renishaw recommended recalibration period for MCG is 12 months.

Recalibration periods are purely a recommendation, under normal service conditions. However, there are several factors that may generate the need for more or less frequent recalibrations including:-

- Environmental conditions
- Frequency and duration of use
- Harsh treatment of the MCG system, during storage, transportation or use
- Level of accuracy required by the user
- The requirements of company QA procedures an / or national / local regulations

Ultimately it is for the user to determine the appropriate calibration period given his operational environment and performance requirements.

Changes to Renishaw products

Renishaw plc reserves the right to improve, change or modify its hardware or software without incurring any obligations to make changes to Renishaw equipment previously sold.

Warranty

Renishaw plc warrants its equipment provided that it is installed exactly as defined in associated Renishaw documentation.

Consent must be obtained from Renishaw if non-Renishaw equipment (e.g. interfaces and/or cabling) is used or substituted. Failure to comply with this will invalidate the Renishaw warranty.

Claims under warranty must be made from authorised services centres only, which may be advised by the supplier or distributor.

Patents

Features of the machine checking gauge are subject to the following patents and patent applications:

US 4777818

Contents

1 Introduction

Figure 1 - Renishaw's machine checking gauge

Renishaw's machine checking gauge (MCG) (as shown in figure 1 above) provides an easy way to monitor the volumetric measurement performance of your co-ordinate measuring machine (CMM). The MCG is an effective complement to existing standards for CMM verification and can be used as an interim checking gauge in accordance with international standards BS EN ISO 10360-2.

Based on a simple alternative to the 'ballbar principle', the MCG provides fast, automatic machine evaluation (Go/No go checks) on a regular basis. The MCG can also be used for machine characterisation and, in some instances, software compensation of errors found.

2 Principle of operation

The counterbalanced arm, as shown in figure 2, has a kinematic seat which sits on a precision ruby ball located on an adjustable tower. The kinematic seat allows very accurate arm pivoting, both horizontally through 360° and vertically through ±45° (please see note on page 10). At the end of the counterbalanced arm is a second kinematic location which is formed by two rods, the tungsten carbide ball of the arm, and the probe stylus ball. The arm is able to sweep a truncated spherical outline of radius R about the kinematic pivot location.

The counterbalanced arm is balanced to provide a downforce of 2 gm at the measuring end to allow arm movement without false triggering.

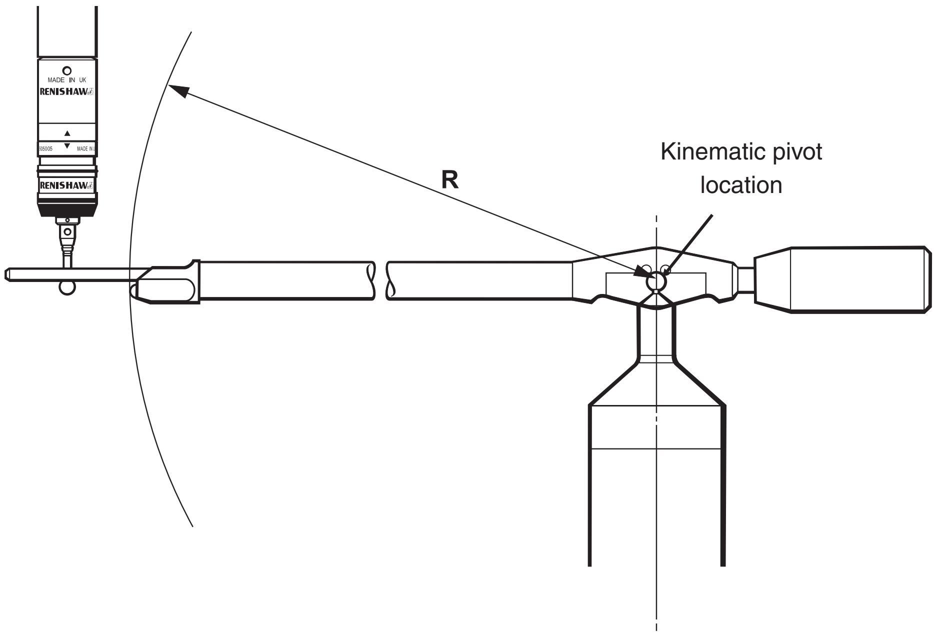


Figure 2 - Counterbalanced arm

The probe is moved to its required position (position A, figure 3) and then towards the pivot position (B) where it will trigger at the kinematic location (C) and the radius is measured.

Since the counterbalanced arm is of a constant radius R, any deviation from R is an indication of the volumetric measuring performance of the CMM for that volume swept by the arm. Repetition of a sequence of readings checks the system for repeatability. Volumetric measuring performance is the maximum error between any two points in any plane, over any distance within the full measuring volume.

On horizontal arm machines the probe is mounted at 90° to the arm.

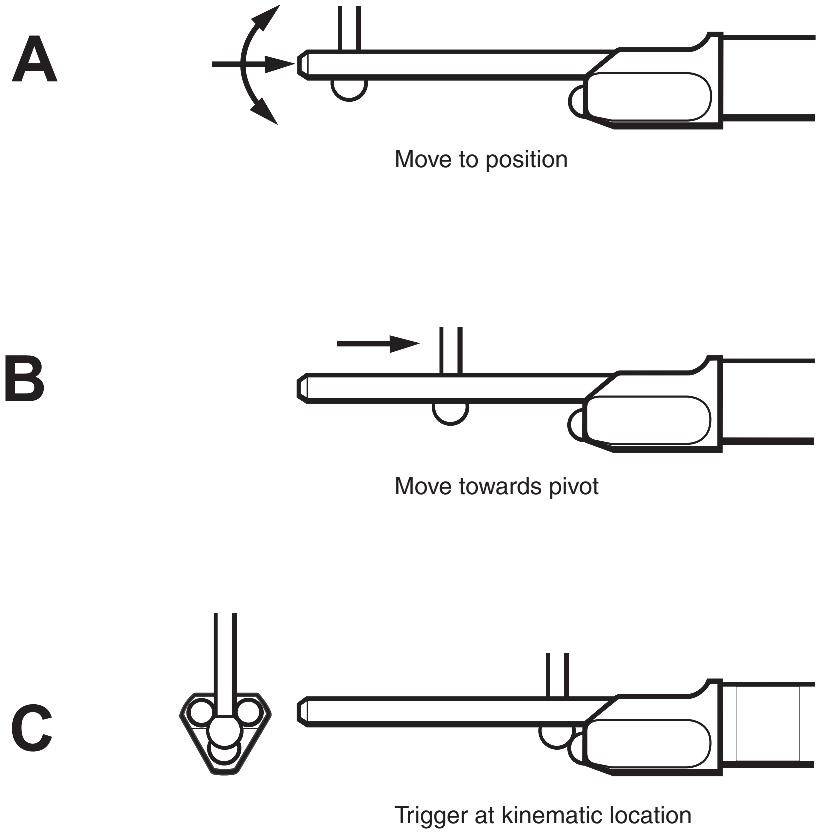


Figure 3 - Measuring sequence

3 Setting-up

Several precautions must be taken when using the machine checking gauge (MCG).

3.1 Cleanliness

The pivot ball, probe stylus and arm forks must be scrupulously cleaned before assembly as even a fingerprint can give an error of 3 microns. Use a proprietary cleaner to clean the surfaces of these components.

3.2 Temperature

The components of the MCG are subject to distortion due to changes in temperature. It is therefore important that handling of the components is kept to a minimum and that, if handled, a five-minute temperature stabilisation period is observed once any handling is complete. It is also recommended that the MCG is left in the vicinity of the CMM prior to performing any checking.

3.3 Mounting

For optimum performance, it is recommended that the MCG is clamped by its base to the table of the CMM prior to use. The recommended procedure is as follows:

NOTE: The MCG is not suitable for use with TP7M, SP600 or SP80 probes, and not recommended for use with TP200 probes. SP25M requires a TM25-20 and TP20 module.

1. Attach the special, calibrated stylus of the MCG (this can be readily identified by the two grooves cut within the stylus stem) to your touch-trigger probe. If necessary, use the extensions and adaptors supplied to allow the calibrated stylus to be fitted to the probe (see figure 4).

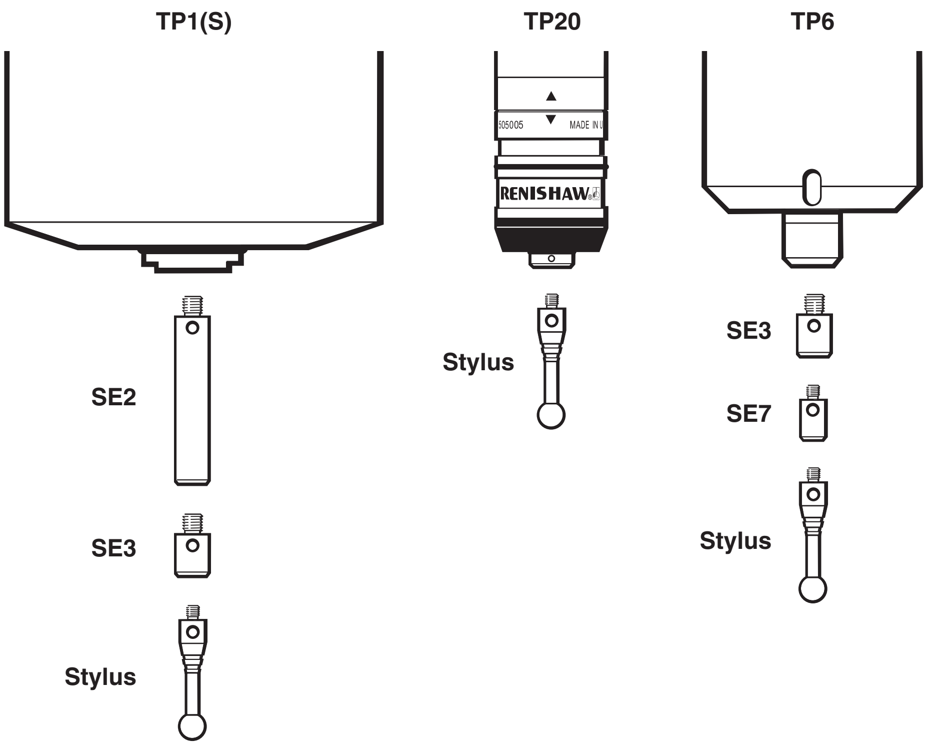


Figure 4 - Adaptors and extensions

2. Visually inspect the stylus ball of the calibrated stylus for contamination and clean if required.

3. Inspect the probe head to ensure that it is securely located in the machine quill.

4. Construct a tower using the base, pillars and pivot. When building the tower, ensure that the pivot ball height will be approximately half the height of the component to be measured. If the component is mounted on a fixture, take any added height into account (see figure 5). Tighten the pillars by hand.

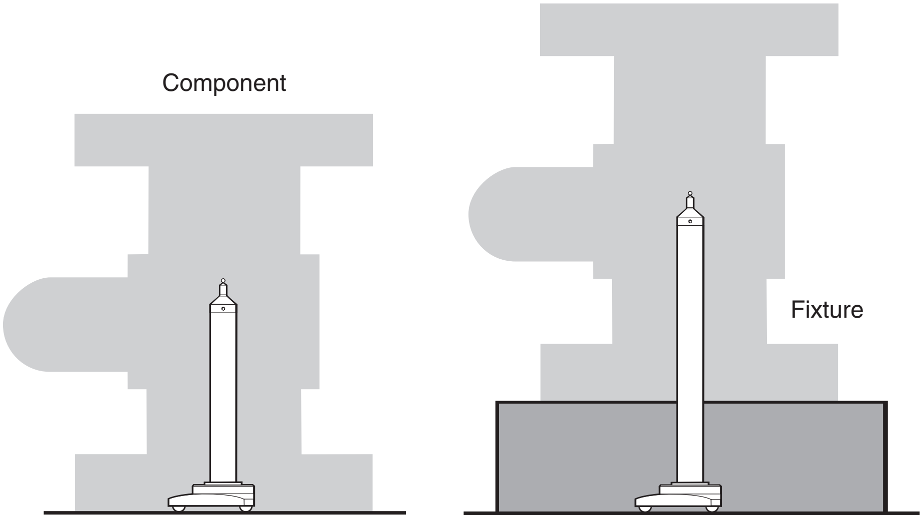


Figure 5 - Building a tower

5. Towers of varying heights are possible by using the pillars in combinations as required (see figure 6).

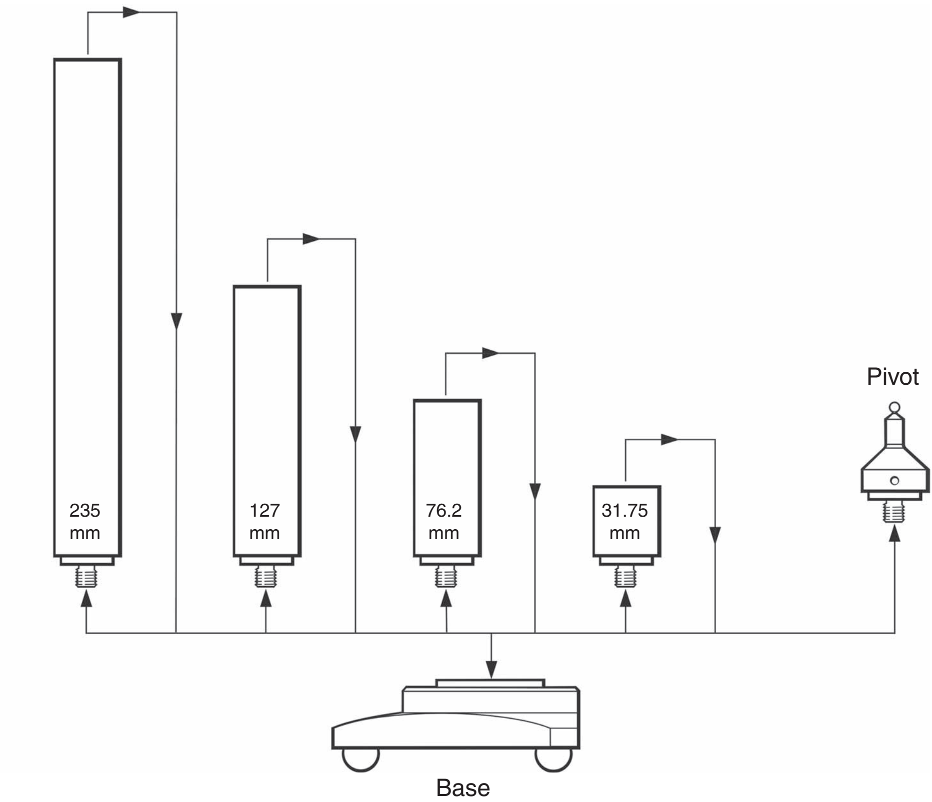


Figure 6 - Available pillar extensions

NOTE: It is recommended that when mounting the tower to the CMM table that the base of the tower is clamped on the central steel clamping ring.

6. Ensuring that base of the tower is approximately central to the component volume, position the tower on the table of your CMM (see figure 7).

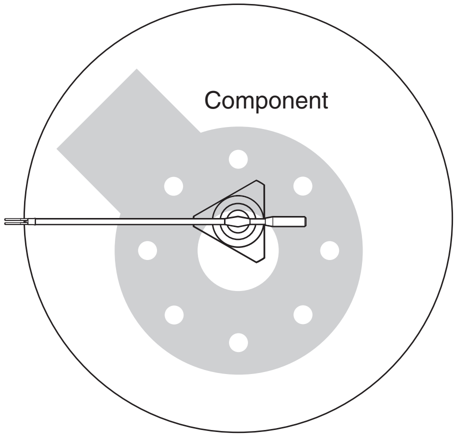


Figure 7 - Positioning the tower

7. Ensure that the ball of the kinematic pivot location is perfectly clean.

8. Allow the assembly to thermally stabilise for 2 minutes.

9. Datum the ball of the kinematic pivot location using a minimum of (10) ten readings (see figure 8). Set the centre of the pivot ball to be the origin (i.e. X=0, Y=0, Z=0).

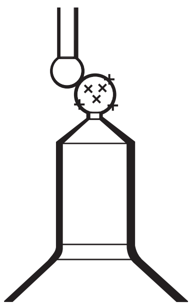


Figure 8 - Datuming the ball of the kinematic pivot location

10. Select an arm radius R to suit the component. Use the following table to choose the correct arm for your component (see figures 9 and 10).

Arm	Radius		X maximum		Z maximum	
	mm	inches	mm	inches	mm	inches
1	101	4	143	5.6	143	5.6
2	151	6	213	8.4	213	8.4
3	226	9	320	12.7	320	12.7
4	380	15	537	21.2	537	21.2
5	532	21	752	29.6	752	29.6
6	685	27	986	38.1	986	38.1

11. Visually inspect the chosen counterbalanced arm for cleanliness. Make sure that the stylus guide rods and ball of the measuring location and the three ball pivot location are perfectly clean. If necessary, clean the parts with a suitable proprietary cleaner.

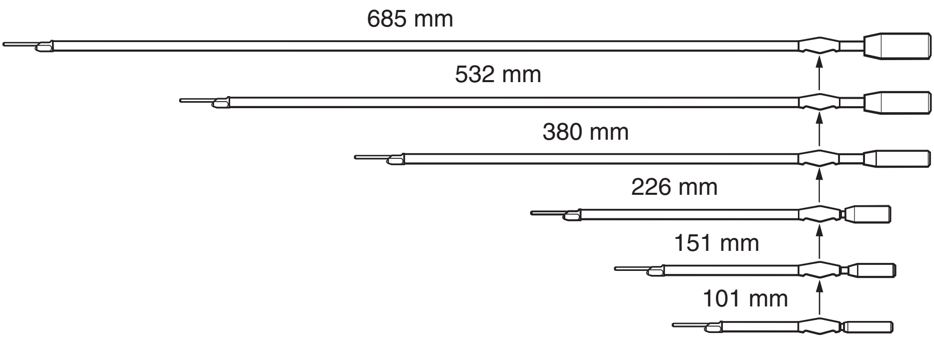


Figure 9 - Arm length selections

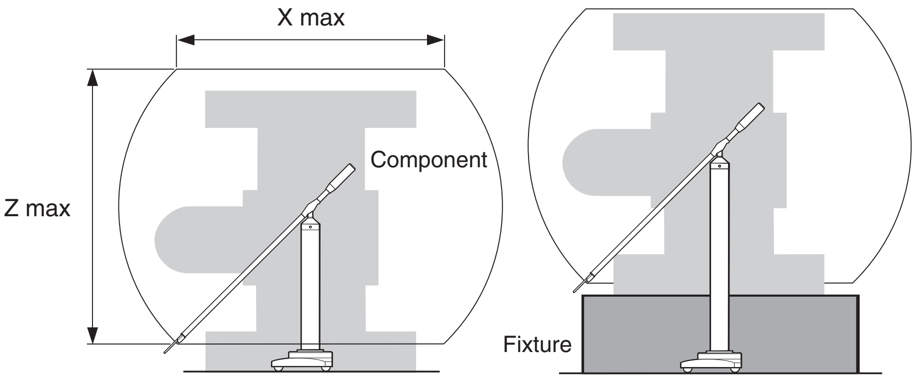


Figure 10 - Angle of rotation

NOTE: When position the counterbalanced arm on the pivot ball, it is important to ensure that handling of the arm is kept to an absolute minimum to avoid thermal distortion occurring.

12. Locate the counterbalanced arm on the pivot ball as shown in figure 11.

13. Locate the stylus ball between the stylus guide rods as shown in figure 12.

14. Allow the assembly to thermally stabilise for a minimum period of 5 minutes.

3.3.1 Additional weights

Each counterbalanced arm is set to provide a downforce on the stylus ball which is sufficient to allow the probe and the arm to be moved without causing false triggers.

If required, the downforce may be increased by attaching additional weights to the counterbalanced arm to allow greater speeds and/or acceleration to be used.

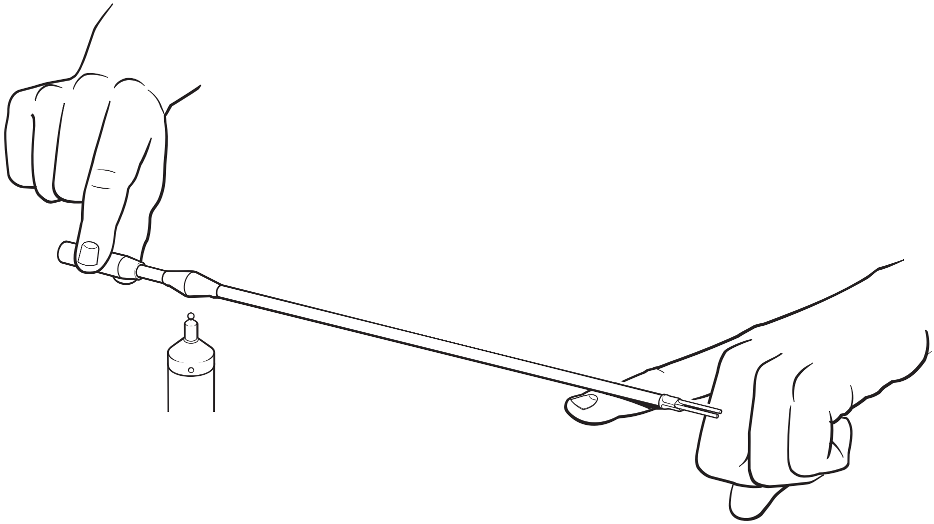


Figure 11 - Mounting the counterbalanced arm

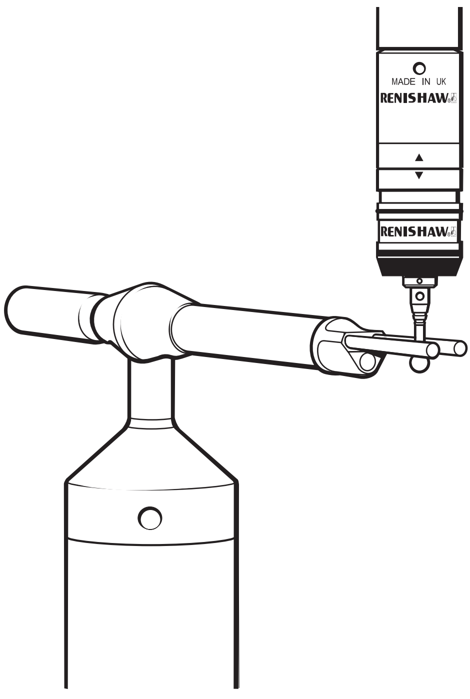


Figure 12 - Locating the stylus ball between the stylus guide rods

4 Taking measurements

4.1 Taking measurements when using the ‘On-line machine checking gauge service’

Renishaw have simplified the implementation of using a machine checking gauge by providing an on-line machine checking gauge (MCG) service at the Renishaw website at www.renishaw.com. If you wish to visit the on-line MCG service, the page can be found under Products/CMM/Accessories for your CMM - MCG online services.

Using the MCG has never been easier with Renishaw’s online MCG service. In three easy steps, we help you to measure, analyse and track the volumetric performance of your CMM:

1. **Create an MCG test program to run on your CMM -** a DMIS program is generated for you from a set of parameters that you specify. You can run this on your CMM to generate a set of measurement results.

2. **Analyse your MCG test results -** the MCG test generates a set of measurement results, again in DMIS format. You can upload these and have them analysed online. We provide guidance to help you interpret the data.

3. **Store and retrieve previous results to spot trends -** you can store your MCG test results online and retrieve them at a later date, allowing you to identify changes in the performance of your CMM over time.

4.2 Taking measurements when not using the ‘On-line machine checking gauge service’

1. **Arm elevation 0° -** measure the arm radius R at 45° intervals in the horizontal plane (a total of eight measurements) as shown in figures 13 and 14.

2. **Arm elevation -45° -** measure the arm radius R at 45° intervals in the horizontal plane (a total of eight measurements) as shown in figures 13 and 14.

3. **Arm elevation +45°** - measure the arm radius R at 45° intervals in the horizontal plane (a total of eight measurements) as shown in figures 13 and 14.

4. Repeat steps 1 to 3 twice to obtain repeatability measurements. This provides a total of 72 (3 × 24) measurements for evaluation of volumetric measuring performance and system repeatability.

5. Remove the counterbalanced arm carefully and re-datum the pivot ball using a minimum of ten readings (refer to ‘Setting -up’, step 9). If the pivot ball centre has moved significantly more than the maximum measured repeatability, re-datum the pivot ball ensuring that:

   a. The seating faces between the pivot , pillars and baseplates are perfectly clean and that these parts are firmly tightened.

   b. The stated pillar thermal stabilising period (2 minutes minimum) is observed.

   c. The utmost care is taken when placing the counterbalanced arm of the pivot.

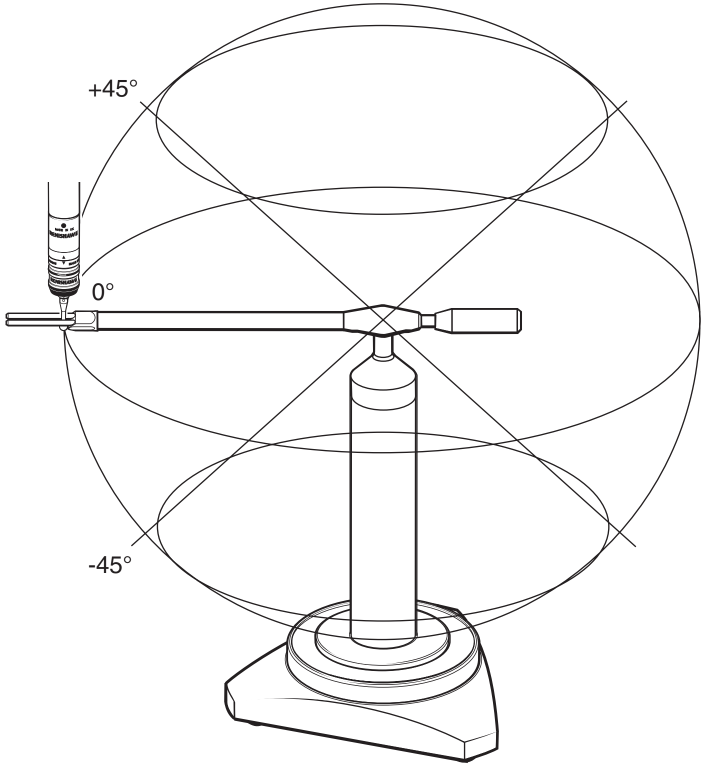


Figure 13 - Arm elevation

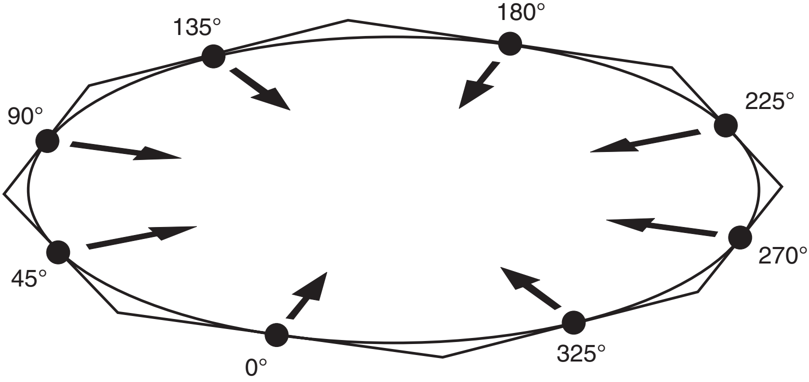


Figure 14 - Eight points of measurement

5 Evaluating the results

1. Evaluate the average measured arm radius, RAV as follows:

$$R_{AV} = \frac{\sum_{i=1}^{i=n} R_i}{n}$$

Where n = total number of readings

2. Evaluate each measured arm radius for its deviation from the average measured radius as follows:

$$\Delta R_i = R_{AV} - R_i$$

3. Evaluate the range of deviation for each run, known as the ‘span’.

4. Evaluate the range deviations over all three runs, i.e. the maximum deviation in the + and - directions. This is the VOLUMETRIC MEASURING PERFORMANCE (VMP) for the volume swept by the arm radius R as follows:

$$VMP = \Delta R_{i(max)} - \Delta R_{i(min)}$$

5. Evaluate the range of deviations for each measuring position. This is the SYSTEM REPEATABILITY at that POSITION. A suggested layout is shown overleaf.

6. When the MCG indicates an unacceptable performance of your CMM, contact the OEM to service the machine (please note that this service cannot normally be undertaken by the user).

REPEATABILITY

VOLUMETRIC MEASURING PERFORMANCE

MACHINE REFERENCE: 101-6 DATE: 27-05-85
VARIATIONS FROM MEAN RADIUS (△Ri) – MICRONS

ELEVATION	ANGLE	RUN 1	RUN 2	RUN 3	REPEATABILITY
0	0	–3.0	–3.0	–3.0	0.0
	45	0.0	–0.5	0.5	1.0
	90	2.5	2.5	2.0	0.5
	135	3.5	4.0	4.0	0.5
	180	3.5	3.5	3.5	0.0
	225	1.5	2.0	2.0	0.5
	270	–2.5	–2.0	–1.5	1.0
	315	–5.5	–5.0	–5.0	0.5
+45	0	–2.0	–2.0	–2.0	0.0
	45	–1.5	–2.0	–1.5	0.5
	90	–1.0	–1.0	–1.5	0.5
	135	1.5	1.0	0.5	1.0
	180	4.0	3.5	3.5	0.5
	225	6.0	**6.5**	5.5	1.0
	270	1.5	1.0	2.0	1.0
	315	–3.0	–4.0	–3.5	1.0
–45	0	–1.5	–1.5	–2.0	0.5
	45	–4.5	–5.0	–5.5	1.0
	90	–6.0	–6.0	**–7.0**	1.0
	135	–3.0	–3.5	–4.0	1.0
	180	1.5	1.5	1.0	0.5
	225	6.0	6.0	6.0	0.0
	270	4.0	4.5	4.5	0.5
	315	0.0	1.0	0.5	0.5
SPAN		12.0	12.5	13.0	

HIGHEST 6.5 LOWEST –7.0 SPAN (3 RUNS) 13.5

VOLUMETRIC MEASURING PERFORMANCE 13.5 MICRONS

6 Calibration procedures

A calibration report and calibration traces are supplied with each machine checking gauge kit. The traces supplied are as follows:

- Probe stylus ball roundness
- Pivot ball roundness
- Bearing runout - arm horizontal
- Bearing runout - arm at +45°.

These results are summarised on the outside of the calibration report wallet.

6.1 Probe stylus ball

A trace is made, as shown in figure 15, to simulate the action encountered during probing with a stylus.

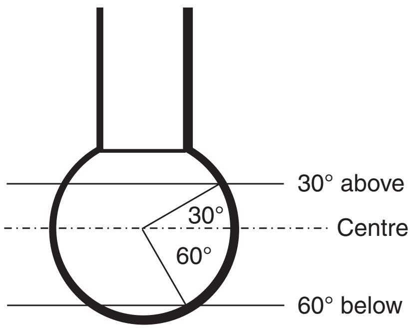


Figure 15 - Probe stylus ball trace

6.2 Pivot ball

The pivot ball roundness is a major influence on bearing runout. The trace is therefore included for reference.

The trace is made, as shown in figure 16, to simulate the action encountered when the arm revolves about the pivot.

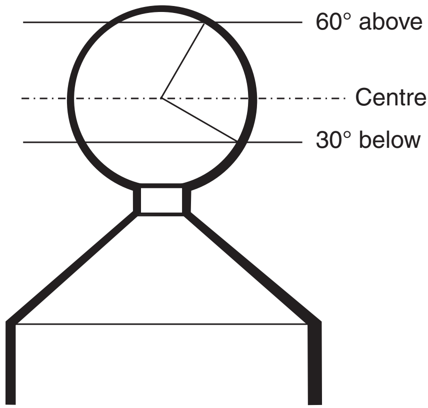


Figure 16 - Pivot ball trace

6.3 Bearing runout

Traces of bearing runout are made for all counterbalanced arms, at +45° incline and horizontally as shown in figure 17. This simulates the action encountered during measurement.

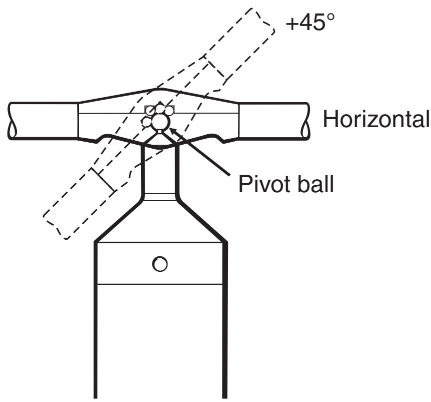


Figure 17 - Bearing runout trace

6.4 Total gauge error

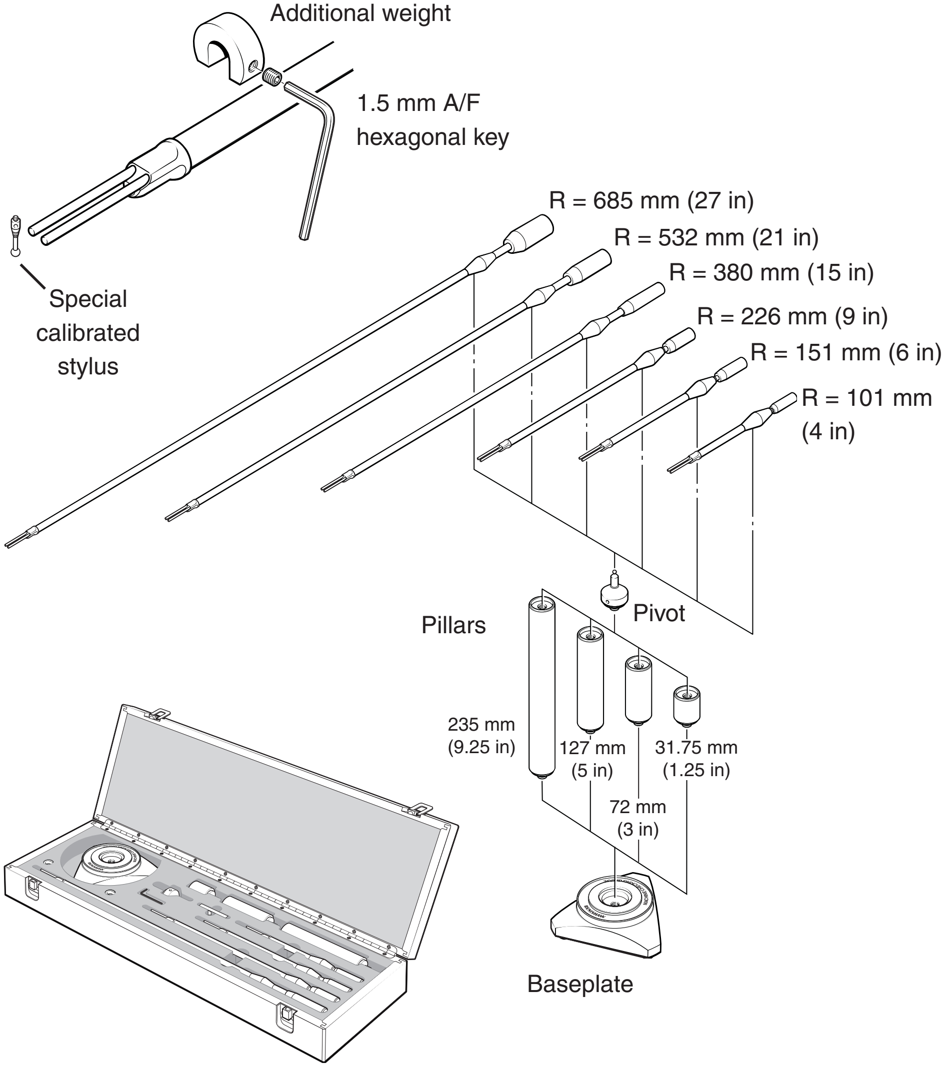
The total gauge error comprises the following components:

	Stylus ball roundness	0.25 µm maximum
Plus	Bearing runout	0.25 µm maximum
	Total gauge error	0.50 µm maximum

7 Parts list

Part	Part number (replacement only)	MCG1 (Small kit)	MCG2 (Comprehensive kit)
Baseplate	A-1007-0016	✓	✓
Pillar (31.75 mm)	M-1007-0158	✓	✗
Pillar (76.2 mm)	M-1007-0023	✓	✓
Pillar (127 mm)	M-1007-0024	✓	✓
Pillar (235 mm)	M-1007-0025	✗	✓
Pivot	A-1007-0017	✓	✓
Arm (101 mm)	A-1007-0007	✓	✓
Arm (151 mm)	A-1007-0008	✓	✓
Arm (226 mm)	A-1007-0009	✓	✓
Arm (380 mm)	A-1007-0010	✓	✓
Arm (532 mm)	A-1007-0011	✗	✓
Arm (685 mm)	A-1007-0012	✗	✓
Stylus	A-5000-7650	✓	✓
Weights (2)	A-1007-0018	✓	✓
1.5 mm AF hexagonal key	P-TL01-0150	✓	✓
Mahogany box	M-1015-7646	✓	✗
Mahogany box	M-1015-7704	✗	✓

For part identification please refer to figure 18.



Each kit includes:

- User’s guide
- Stylus and pivot ball roundness trace
- System dynamic test certificate

Figure 18 - The MCG2 kit

8 MCG online services

It is possible to create an MCG (machine checking gauge) test program online to run on your CMM and analyse the results.

NOTE: This service is only available from the Renishaw website www.renishaw.com.

This section explains both the online MCG service and the actual MCG test. Renishaw's online MCG service provides an easy way to monitor the volumetric measurement performance of your CMM. The unique MCG system enables calibration traceable to USA National Institute of Standards and Technology (Ref #731/23897-87) and British Standard BS EN ISO 10360-2.

8.1 The MCG test

The probe stylus slots into the end of what is in effect a reference "ball" bar. The probe carries the bar with it over a spherical path, and radial readings are taken at different positions. The range of these readings indicates the volumetric measuring performance of the CMM. Repetition of a sequence of readings checks the system for repeatability.

Volumetric measuring performance is the maximum error between any two points in any plane, over any distance within the full measuring volume.

A special calibrated stylus can be used with TP1, TP2, TP20, TP6 and TP6A, with suitable adaptors.

8.2 The online MCG service

Using the MCG has never been easier with Renishaw's online MCG service. In three easy steps, you can measure, analyse and track the volumetric performance of your CMM:

1. **Create an MCG test program to run on your CMM -** a DMIS program is generated for you from a set of parameters that you specify. You can run this on your CMM to generate a set of measurement results.

2. **Analyse your MCG test results -** the MCG test generates a set of measurement results, again in DMIS format. You can upload these and have them analysed online. We provide guidance to help you to interpret the data.

3. **Store and retrieve previous results to spot trends -** you can store your MCG test results online and retrieve them at a later date, allowing you to identify changes in the performance of your CMM over time.

Renishaw plc

New Mills, Wotton-under-Edge,
Gloucestershire, GL12 8JR
United Kingdom

T +44 (0)1453 524524
F +44 (0)1453 524901
E uk@renishaw.com

www.renishaw.com

apply innovation™

For worldwide contact details,
please visit our main website at
www.renishaw.com/contact

H-1000-5080-04