Accuracy Assessment

of

DMG DMC50V

for

Thomas Keating Ltd

March 2009

C. D. Measurements Ltd

SPECIALISTS IN ENGINEERING METROLOGY

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Site Report

Customer	:	Thomas Keating Ltd Station Mills Billingshurst West Sussex RH14 9SH
Machine	:	DMG DMC50V
Serial number	:	2880-0338
Calibration type	:	Positional
Calibrated by	:	A J Gregory
Date	:	20 Mar 2009
Equipment	:	Agilent 5529 laser interferometer
Calibration ref	:	C71/09-DMG
Certificate no	:	02667

Linear Axis Positional sign convention.

The convention for determining the value and direction of error is found by the following subtraction:-

Error = Laser Reading (Reference) - Machine Reading (Command)

This convention holds true to the machine tools own sign convention with respect to the resultant direction in which the axis error lies.

For example in a positive moving axis:-

Error = (2000.147mm) - (2000.000mm) = +0.147mm Overtravel.

Error = (1999.983mm) - (2000.000mm) = -0.017mm Undertravel.

And in a negative moving axis:-

Error = (-2000.147mm) - (-2000.000mm) = -0.147mm Overtravel.

Error = (-1999.983mm) - (-2000.000mm) = +0.017mm Undertravel.

X axis positional results - As Found

Target Position	Error Averages (µm) Forward	Reverse	System	2σ Std Devn (µm) Forward	Reverse	Dead Zone
-9.000	0.142	-0.407	-0.132	0.000	0.000	0.549
24.000	1.098	1.024	1.061	0.000	0.000	0.075
57.000	1.845	1.645	1.745	0.000	0.000	0.200
90.000	2.178	2.230	2.204	0.000	0.000	-0.052
123.000	2.663	2.354	2.508	0.000	0.000	0.308
156.000	3.157	2.781	2.969	0.000	0.000	0.376
189.000	4.145	3.993	4.069	0.000	0.000	0.153
222.000	4.975	4.700	4.838	0.000	0.000	0.274
255.000	4.621	4.550	4.586	0.000	0.000	0.071
288.000	5.473	5.438	5.455	0.000	0.000	0.035
321.000	5.979	5.861	5.920	0.000	0.000	0.118
354.000	5.527	5.454	5.491	0.000	0.000	0.073
387.000	6.811	6.905	6.858	0.000	0.000	-0.094
420.000	8.344	8.346	8.345	0.000	0.000	-0.002
453.000	8.226	8.339	8.283	0.000	0.000	-0.113
486.000	8.408	8.549	8.479	0.000	0.000	-0.141

Analysis to ISO 230:Part 2:2006 Linear Positioning

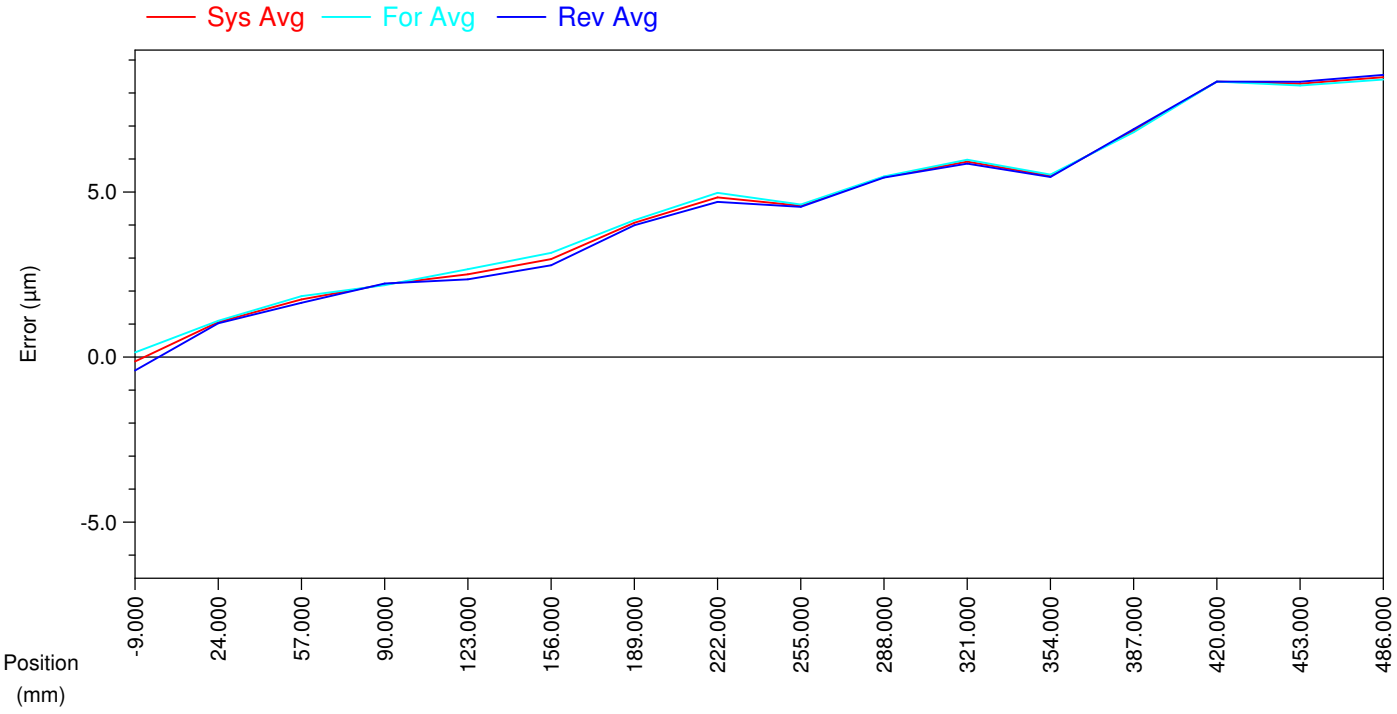
Mean reversal value = 0.11 µm
Mean bidir positional devn = 8.61 µm

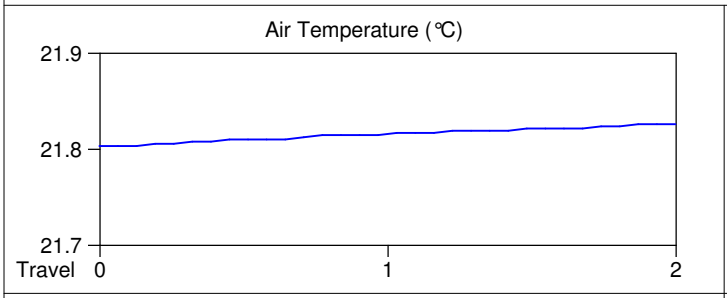
Air pressure = 772.58/772.72 mm Hg
Air humidity = 50/50 % rel
Air temperature = 21.799/21.826 ℃
M/C temperature = 19.095/19.104 ℃
Exp coefficient (Scale) = 8.0 ppm/℃
Air compensation = 725.87/725.93 ppm
Total compensation = 733.07/736.46 ppm
Traceability reference = NPL LL0101/0709

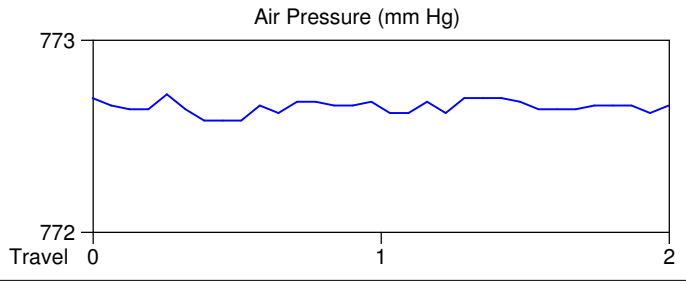
X AXIS POSITIONAL ERROR (ISO 230)

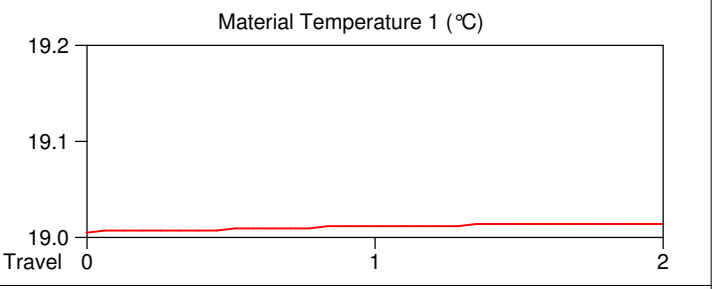
Machine : DMG DMC50V
Serial No : 2880-0338
Date : 20 Mar 2009 at 13:00
Inspector : A J Gregory
Customer : Thomas Keating Ltd

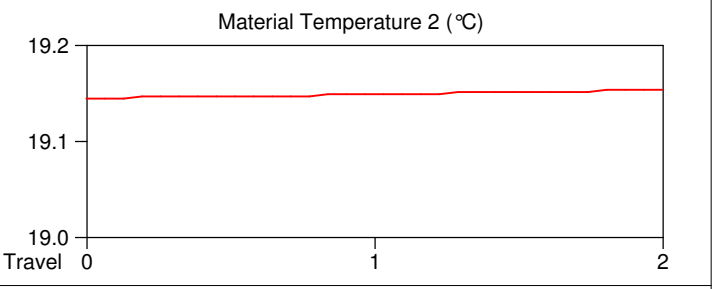
Mean bidir positional devn = 8.61 µm
Mean Reversal Value = 0.11 µm
As Found

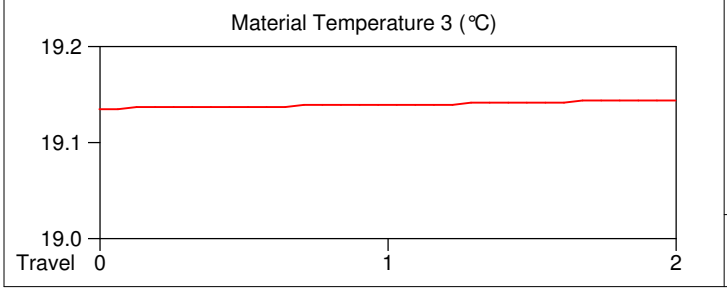












Test Details

Forward travels	: 1
Reverse travels	: 1
Targets	: 16
Target window	: 0.5000 mm
Samples	: 120
Bandwidth	: 0.0010 mm
Steptype	: Linear
Pitch	: 0.0000 mm
Instrument	: Agilent 5529 Laser
Radius/Dia	: Radial
Control	: Closed loop (CNC)
Static/Fly	: Static
Sample delay	: 0.00 seconds

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X axis positional results - No Compensation

Target Position	Error Averages (µm) Forward	Reverse	System	2σ Std Devn (µm) Forward	Reverse	Dead Zone
-9.000	-0.071	-0.191	-0.131	0.231	0.200	0.120
24.000	2.859	2.685	2.772	0.518	0.186	0.174
57.000	4.383	4.173	4.278	0.539	0.364	0.210
90.000	5.034	4.614	4.824	0.311	0.360	0.420
123.000	4.775	4.308	4.542	0.448	0.360	0.467
156.000	4.879	4.448	4.663	0.358	0.255	0.431
189.000	5.814	5.359	5.587	0.520	0.269	0.455
222.000	6.737	6.461	6.599	0.775	0.454	0.275
255.000	7.792	7.438	7.615	0.416	0.478	0.354
288.000	9.052	8.659	8.855	0.479	0.303	0.393
321.000	9.852	9.354	9.603	0.516	0.366	0.498
354.000	8.633	8.177	8.405	0.532	0.217	0.456
387.000	8.282	7.882	8.082	0.604	0.397	0.400
420.000	7.820	7.505	7.662	0.695	0.475	0.315
453.000	6.470	6.415	6.442	0.487	0.377	0.055
486.000	5.961	5.913	5.937	0.699	0.528	0.048

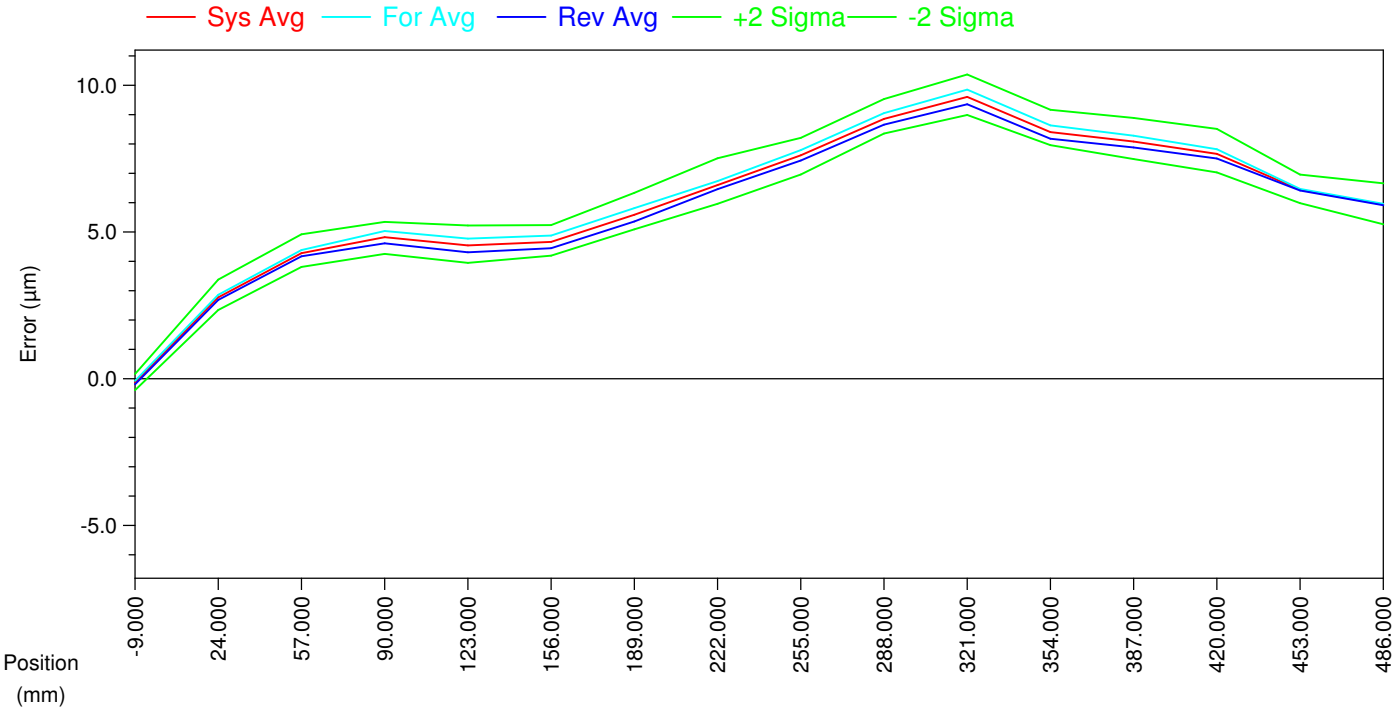
Analysis to ISO 230:Part 2:2006 Linear Positioning

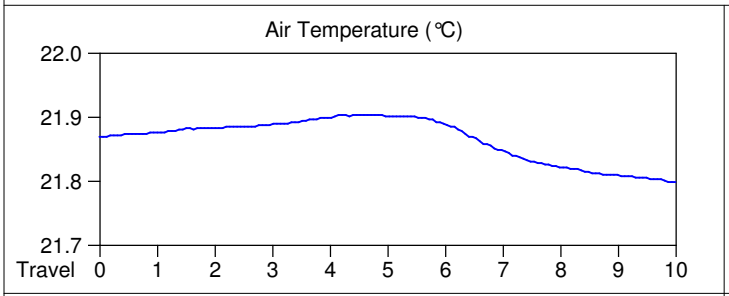
Accuracy	= 10.76 µm
Unidirectional repeatability	= 1.55 µm at 222.000 mm, forward direction
Bidirectional Repeatability	= 1.55 µm at 222.000 mm
Mean reversal value	= 0.32 µm
Mean bidir positional devn	= 9.73 µm

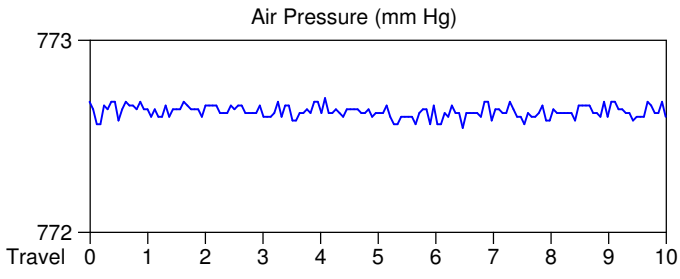
Air pressure	= 772.54/772.70 mm Hg
Air humidity	= 50/50 % rel
Air temperature	= 21.799/21.904 ℃
M/C temperature	= 19.124/19.161 ℃
Exp coefficient (Scale)	= 8.0 ppm/℃
Air compensation	= 725.88/726.02 ppm
Total compensation	= 732.59/736.19 ppm
Traceability reference	= NPL LL0101/0709

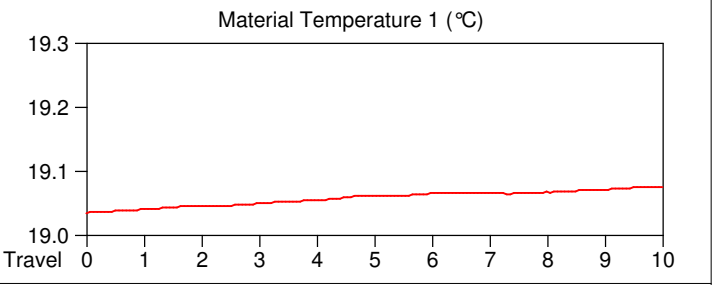
X AXIS POSITIONAL ERROR (ISO 230)

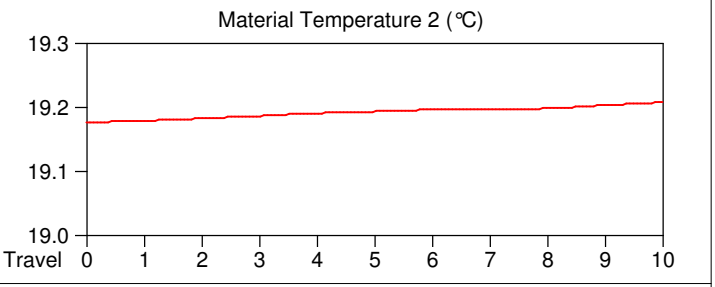
Machine	: DMG DMC50V	Accuracy	= 10.76 µm
Serial No	: 2880-0338	Uni-Direction Repeat	= 1.55 µm
Date	: 20 Mar 2009 at 13:32	Bi-Direction Repeat	= 1.55 µm
Inspector	: A J Gregory	Mean Reversal Value	= 0.32 µm
Customer	: Thomas Keating Ltd	No Compensation	

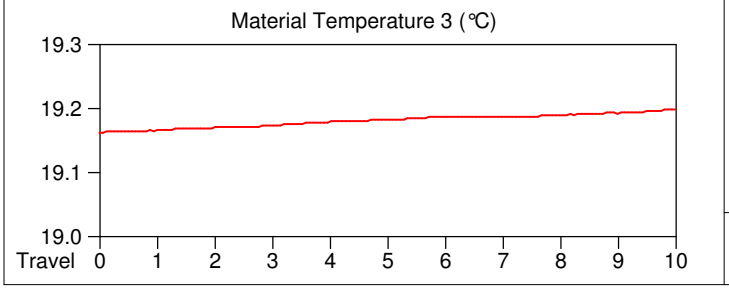












Test Details

Forward travels	: 5
Reverse travels	: 5
Targets	: 16
Target window	: 0.5000 mm
Samples	: 120
Bandwidth	: 0.0010 mm
Steptype	: Linear
Pitch	: 0.0000 mm
Instrument	: Agilent 5529 Laser
Radius/Dia	: Radial
Control	: Open loop (NC)
Static/Fly	: Static
Sample delay	: 0.00 seconds

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X axis positional results - With Compensation

Target Position	Error Averages (µm) Forward	Reverse	System	2σ Std Devn (µm) Forward	Reverse	Dead Zone
-9.000	0.136	-0.061	0.038	0.276	0.221	0.197
24.000	0.011	-0.255	-0.122	0.122	0.099	0.267
57.000	0.124	-0.274	-0.075	0.148	0.052	0.399
90.000	0.284	-0.227	0.029	0.069	0.125	0.511
123.000	0.157	-0.528	-0.185	0.174	0.185	0.684
156.000	0.189	-0.357	-0.084	0.117	0.144	0.546
189.000	0.060	-0.368	-0.154	0.206	0.325	0.428
222.000	0.186	-0.364	-0.089	0.184	0.298	0.550
255.000	0.116	-0.319	-0.101	0.217	0.123	0.435
288.000	0.110	-0.304	-0.097	0.198	0.301	0.414
321.000	0.178	-0.371	-0.096	0.118	0.155	0.549
354.000	-0.051	-0.565	-0.308	0.135	0.291	0.514
387.000	0.364	0.052	0.208	0.239	0.111	0.313
420.000	0.180	-0.045	0.067	0.158	0.310	0.225
453.000	-0.128	-0.044	-0.086	0.212	0.216	-0.084
486.000	-0.200	-0.235	-0.217	0.183	0.278	0.035

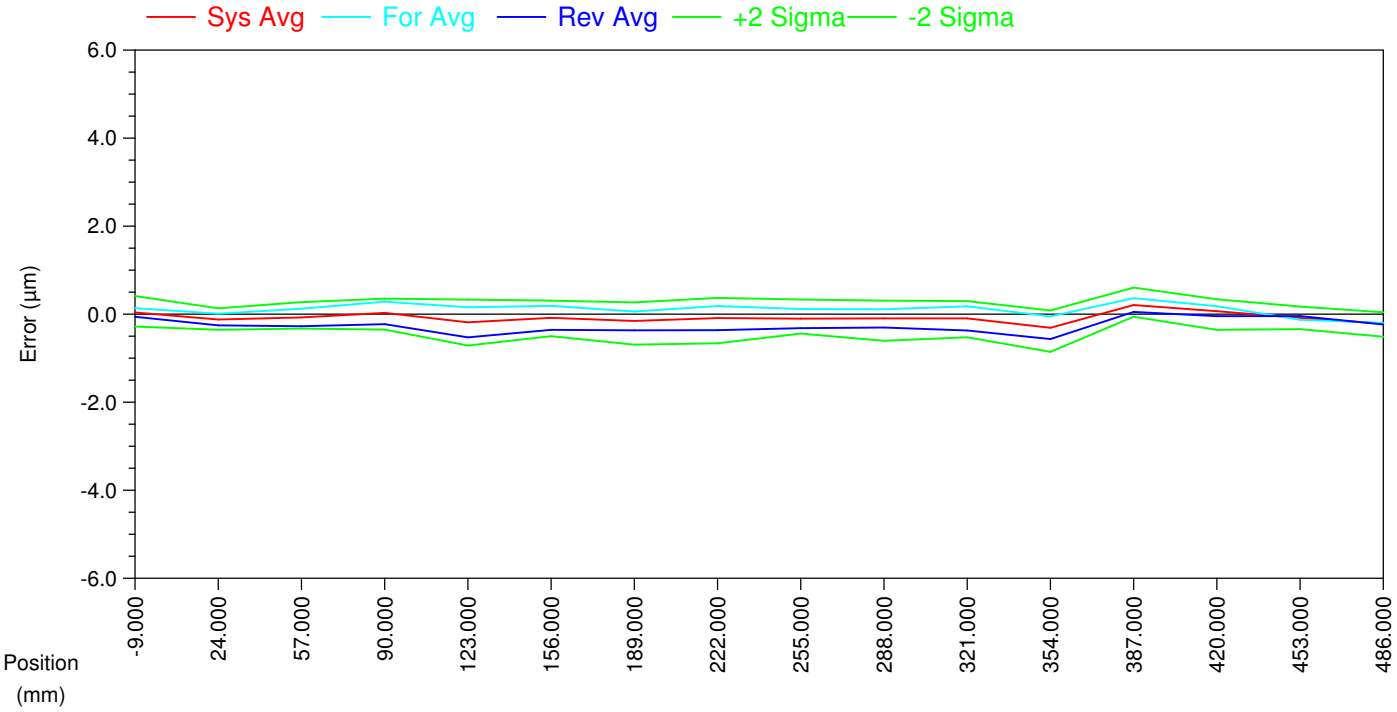
Analysis to ISO 230:Part 2:2006 Linear Positioning

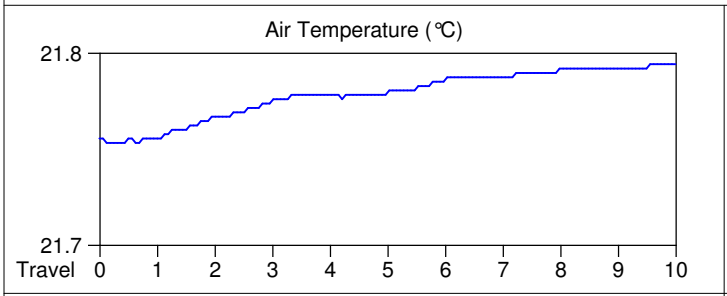
Accuracy	= 1.46 µm
Unidirectional repeatability	= 0.65 µm at 189.000 mm, reverse direction
Bidirectional Repeatability	= 1.04 µm at 123.000 mm
Mean reversal value	= 0.37 µm
Mean bidir positional devn	= 0.52 µm

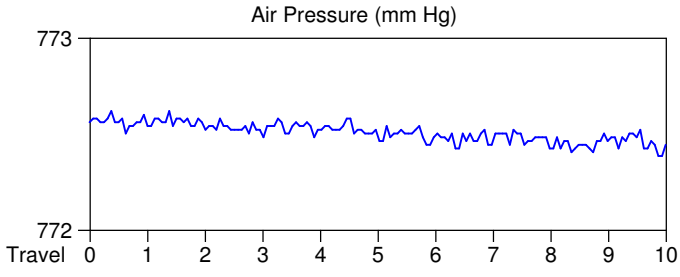
Air pressure	= 772.39/772.62 mm Hg
Air humidity	= 50/50 % rel
Air temperature	= 21.753/21.794 ℃
M/C temperature	= 19.177/19.221 ℃
Exp coefficient (Scale)	= 8.0 ppm/℃
Air compensation	= 725.86/725.98 ppm
Total compensation	= 732.17/735.51 ppm
Traceability reference	= NPL LL0101/0709

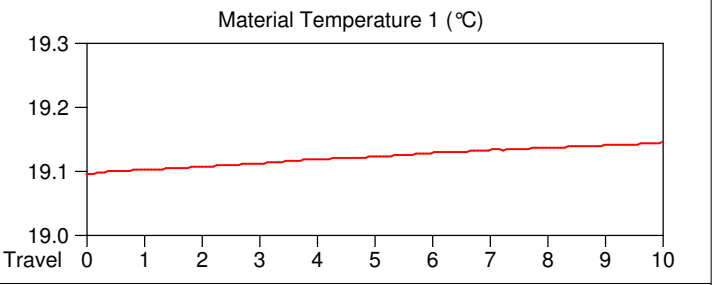
X AXIS POSITIONAL ERROR (ISO 230)

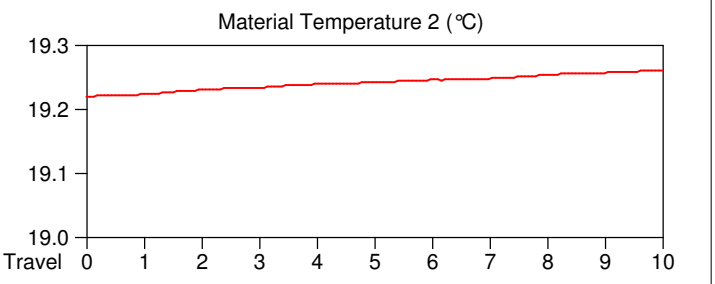
Machine	: DMG DMC50V	Accuracy	= 1.46 µm
Serial No	: 2880-0338	Uni-Direction Repeat	= 0.65 µm
Date	: 20 Mar 2009 at 13:49	Bi-Direction Repeat	= 1.04 µm
Inspector	: A J Gregory	Mean Reversal Value	= 0.37 µm
Customer	: Thomas Keating Ltd	With Compensation	

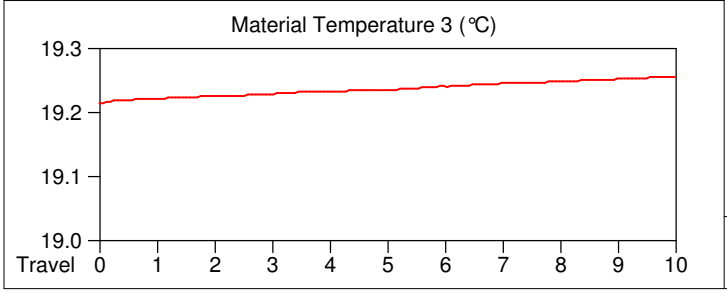












Test Details

Forward travels	: 5
Reverse travels	: 5
Targets	: 16
Target window	: 0.5000 mm
Samples	: 120
Bandwidth	: 0.0010 mm
Steptype	: Linear
Pitch	: 0.0000 mm
Instrument	: Agilent 5529 Laser
Radius/Dia	: Radial
Control	: Open loop (NC)
Static/Fly	: Static
Sample delay	: 0.00 seconds

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Y axis positional results - As Found

Target Position	Error Averages (µm) Forward	Reverse	System	2σ Std Devn (µm) Forward	Reverse	Dead Zone
-12.000	0.138	-0.071	0.033	0.000	0.000	0.209
10.000	0.330	0.247	0.289	0.000	0.000	0.084
32.000	1.007	0.891	0.949	0.000	0.000	0.116
54.000	1.231	1.108	1.170	0.000	0.000	0.123
76.000	1.355	1.301	1.328	0.000	0.000	0.053
98.000	1.702	1.346	1.524	0.000	0.000	0.356
120.000	1.479	1.326	1.403	0.000	0.000	0.153
142.000	1.260	1.069	1.165	0.000	0.000	0.191
164.000	1.007	0.648	0.828	0.000	0.000	0.359
186.000	0.462	0.055	0.258	0.000	0.000	0.407
208.000	0.285	-0.160	0.062	0.000	0.000	0.445
230.000	0.272	-0.179	0.046	0.000	0.000	0.451
252.000	0.465	0.151	0.308	0.000	0.000	0.314
274.000	0.558	0.251	0.405	0.000	0.000	0.307
296.000	0.650	0.398	0.524	0.000	0.000	0.253
318.000	0.730	0.465	0.597	0.000	0.000	0.265
340.000	0.796	0.040	0.418	0.000	0.000	0.757
362.000	0.684	0.343	0.514	0.000	0.000	0.341
384.000	0.880	0.580	0.730	0.000	0.000	0.301
406.000	0.918	0.941	0.929	0.000	0.000	-0.023

Analysis to ISO 230:Part 2:2006 Linear Positioning

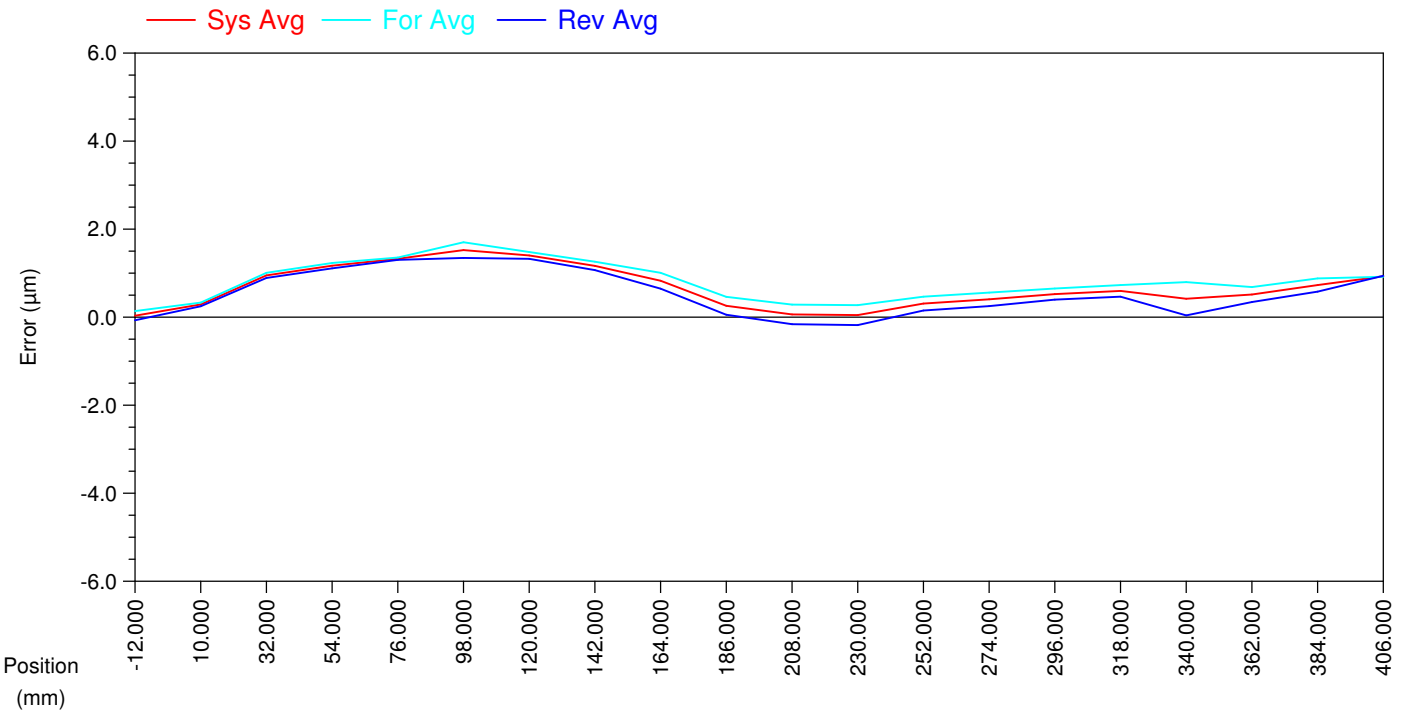
Mean reversal value = 0.27 µm
Mean bidir positional devn = 1.49 µm

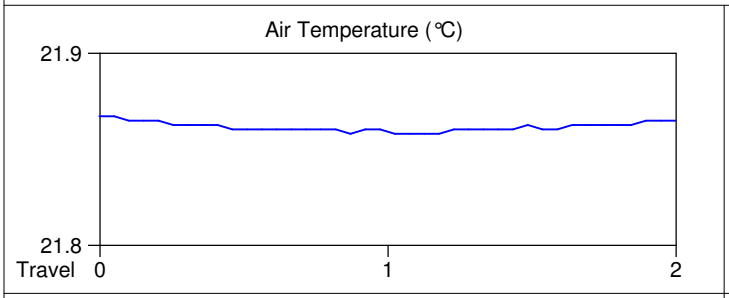
Air pressure = 772.17/772.35 mm Hg
Air humidity = 50/50 % rel
Air temperature = 21.858/21.872 °C
M/C temperature = 19.346/19.365 °C
Exp coefficient (Scale) = 8.0 ppm/°C
Air compensation = 726.06/726.12 ppm
Total compensation = 731.18/733.73 ppm
Traceability reference = NPL LL0101/0709

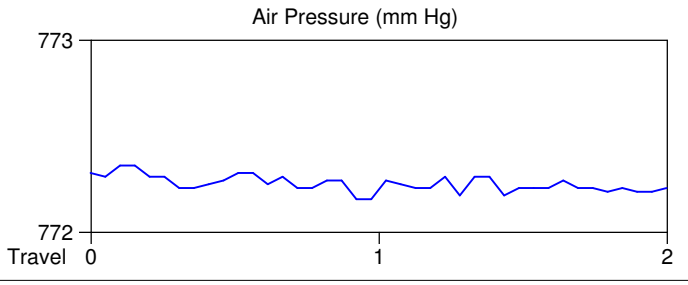
Y AXIS POSITIONAL ERROR (ISO 230)

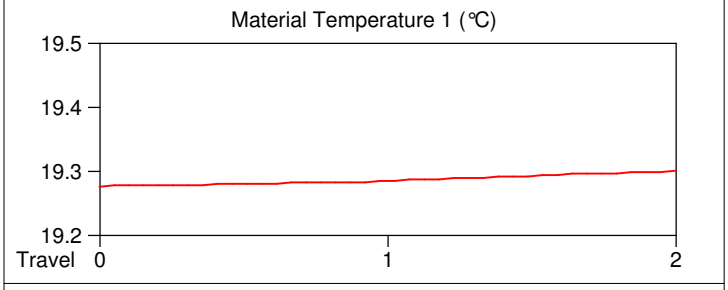
Machine : DMG DMC50V
Serial No : 2880-0338
Date : 20 Mar 2009 at 14:22
Inspector : A J Gregory
Customer : Thomas Keating Ltd

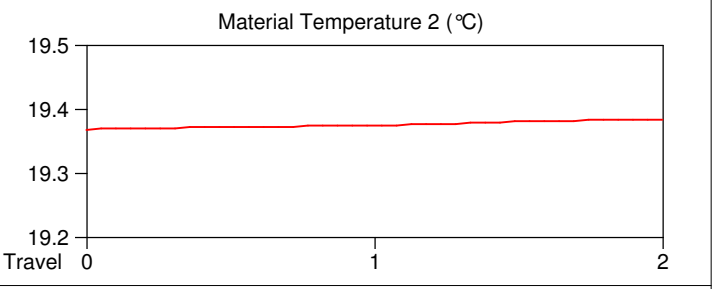
Mean bidir positional devn = 1.49 µm
Mean Reversal Value = 0.27 µm
As Found

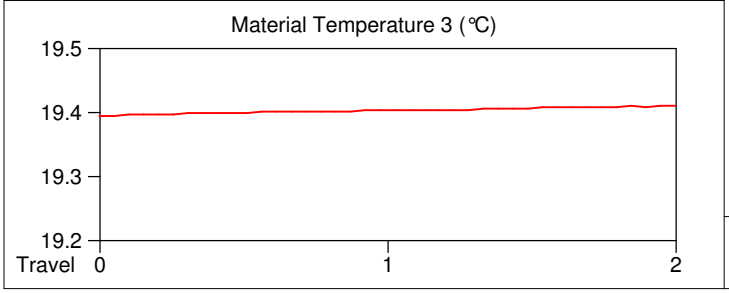












Test Details

Forward travels	: 1
Reverse travels	: 1
Targets	: 20
Target window	: 0.5000 mm
Samples	: 120
Bandwidth	: 0.0010 mm
Steptype	: Linear
Pitch	: 0.0000 mm
Instrument	: Agilent 5529 Laser
Radius/Dia	: Radial
Control	: Closed loop (CNC)
Static/Fly	: Static
Sample delay	: 0.00 seconds

C. D. Measurements Ltd

Y axis positional results - No Compensation

Target Position	Error Averages (µm) Forward	Reverse	System	2σ Std Devn (µm) Forward	Reverse	Dead Zone
-12.000	0.013	0.131	0.072	0.108	0.105	-0.118
10.000	0.384	0.523	0.453	0.108	0.089	-0.139
32.000	0.629	0.661	0.645	0.203	0.141	-0.032
54.000	0.571	0.537	0.554	0.210	0.103	0.034
76.000	1.114	0.996	1.055	0.100	0.091	0.118
98.000	1.037	0.920	0.979	0.147	0.121	0.117
120.000	0.851	0.728	0.789	0.188	0.284	0.123
142.000	0.811	0.640	0.725	0.191	0.235	0.171
164.000	0.421	0.287	0.354	0.158	0.175	0.134
186.000	-0.231	-0.469	-0.350	0.410	0.375	0.238
208.000	-0.659	-1.042	-0.851	0.248	0.213	0.383
230.000	-0.843	-1.218	-1.030	0.356	0.153	0.375
252.000	-0.634	-0.940	-0.787	0.414	0.130	0.305
274.000	-0.624	-0.989	-0.807	0.271	0.171	0.365
296.000	-0.754	-1.040	-0.897	0.216	0.165	0.286
318.000	-0.581	-1.042	-0.811	0.043	0.304	0.461
340.000	-0.956	-1.413	-1.184	0.166	0.142	0.457
362.000	-0.927	-1.328	-1.127	0.228	0.180	0.400
384.000	-1.005	-1.228	-1.116	0.196	0.321	0.223
406.000	-1.329	-1.314	-1.321	0.212	0.152	-0.015

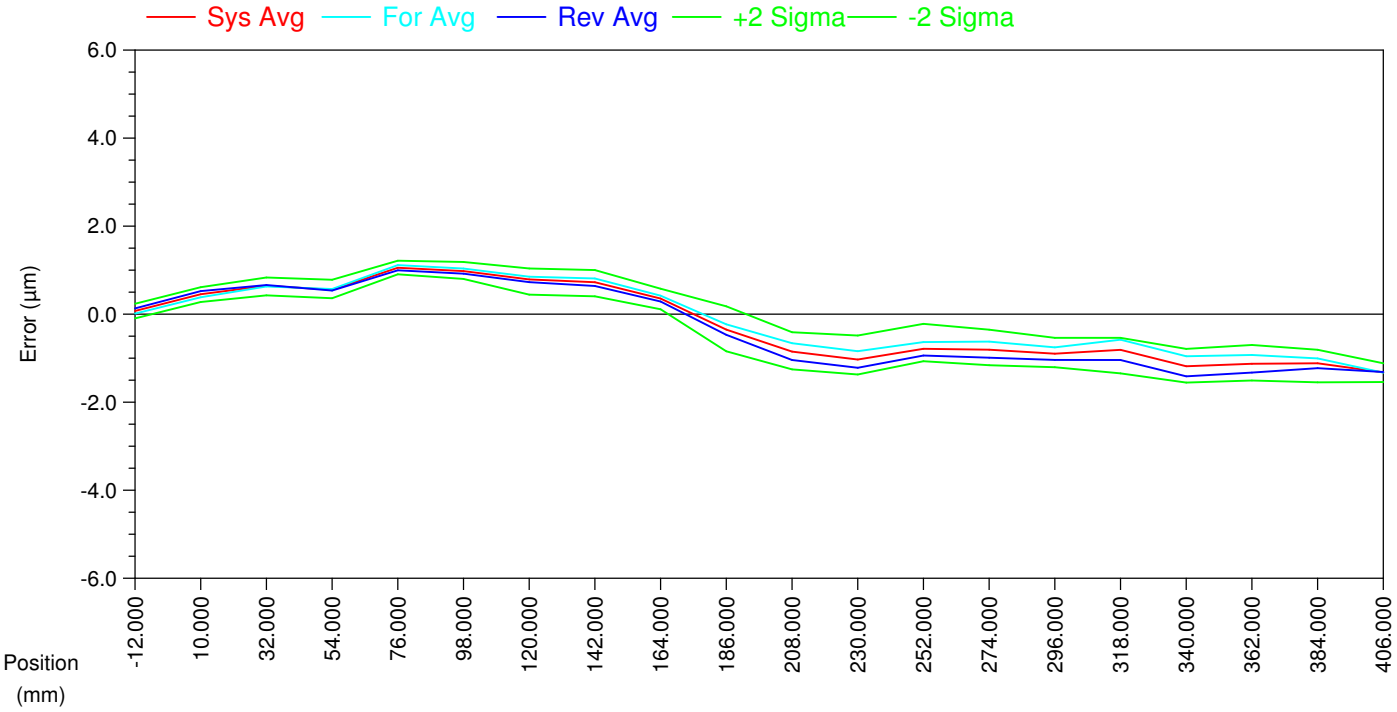
Analysis to ISO 230:Part 2:2006 Linear Positioning

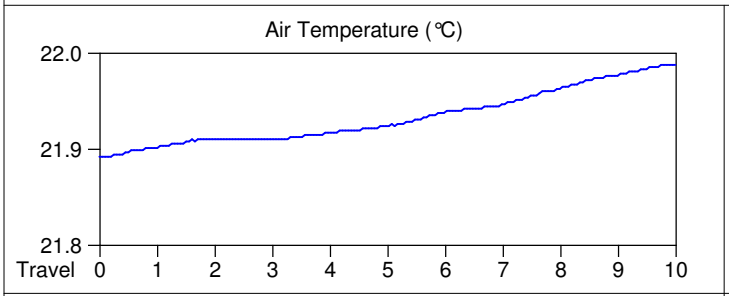
Accuracy	= 2.77 µm
Unidirectional repeatability	= 0.83 µm at 252.000 mm, forward direction
Bidirectional Repeatability	= 1.02 µm at 186.000 mm
Mean reversal value	= 0.19 µm
Mean bidir positional devn	= 2.38 µm

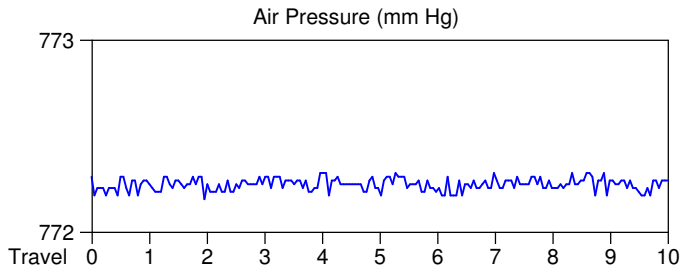
Air pressure	= 772.17/772.31 mm Hg
Air humidity	= 50/50 % rel
Air temperature	= 21.890/21.988 ℃
M/C temperature	= 19.384/19.451 ℃
Exp coefficient (Scale)	= 8.0 ppm/℃
Air compensation	= 726.10/726.23 ppm
Total compensation	= 730.60/733.31 ppm
Traceability reference	= NPL LL0101/0709

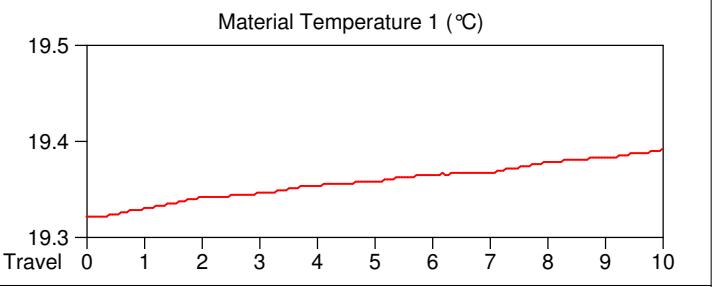
Y AXIS POSITIONAL ERROR (ISO 230)

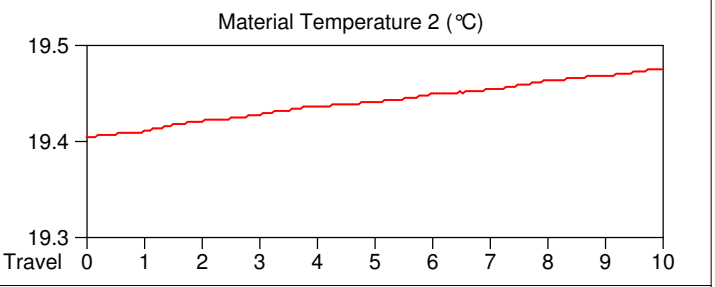
Machine	: DMG DMC50V	Accuracy	= 2.77 µm
Serial No	: 2880-0338	Uni-Direction Repeat	= 0.83 µm
Date	: 20 Mar 2009 at 14:30	Bi-Direction Repeat	= 1.02 µm
Inspector	: A J Gregory	Mean Reversal Value	= 0.19 µm
Customer	: Thomas Keating Ltd	No Compensation	

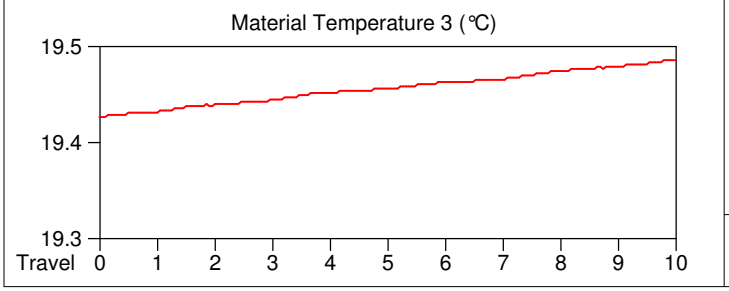












Test Details

Forward travels	: 5
Reverse travels	: 5
Targets	: 20
Target window	: 0.5000 mm
Samples	: 120
Bandwidth	: 0.0010 mm
Steptype	: Linear
Pitch	: 0.0000 mm
Instrument	: Agilent 5529 Laser
Radius/Dia	: Radial
Control	: Open loop (NC)
Static/Fly	: Static
Sample delay	: 0.00 seconds

C. D. Measurements Ltd

Y axis positional results - With Compensation

Target Position	Error Averages (µm) Forward	Reverse	System	2σ Std Devn (µm) Forward	Reverse	Dead Zone
-12.000	-0.023	0.028	0.003	0.105	0.081	-0.052
10.000	-0.101	-0.063	-0.082	0.156	0.276	-0.038
32.000	-0.032	-0.091	-0.061	0.086	0.140	0.059
54.000	-0.198	-0.229	-0.214	0.081	0.139	0.031
76.000	-0.116	-0.171	-0.144	0.163	0.180	0.054
98.000	-0.194	-0.179	-0.186	0.121	0.042	-0.015
120.000	-0.137	-0.246	-0.191	0.191	0.181	0.108
142.000	-0.166	-0.280	-0.223	0.190	0.175	0.114
164.000	0.148	-0.143	0.002	0.251	0.337	0.291
186.000	0.322	0.023	0.173	0.259	0.234	0.299
208.000	0.415	-0.030	0.193	0.190	0.164	0.445
230.000	0.270	-0.086	0.092	0.277	0.232	0.356
252.000	0.311	-0.087	0.112	0.272	0.229	0.398
274.000	0.273	0.010	0.142	0.119	0.237	0.262
296.000	0.227	-0.073	0.077	0.100	0.180	0.300
318.000	0.235	-0.036	0.099	0.243	0.170	0.271
340.000	0.370	0.007	0.189	0.408	0.289	0.363
362.000	0.301	-0.188	0.057	0.154	0.149	0.489
384.000	0.464	0.130	0.297	0.428	0.154	0.334
406.000	0.177	0.147	0.162	0.526	0.364	0.030

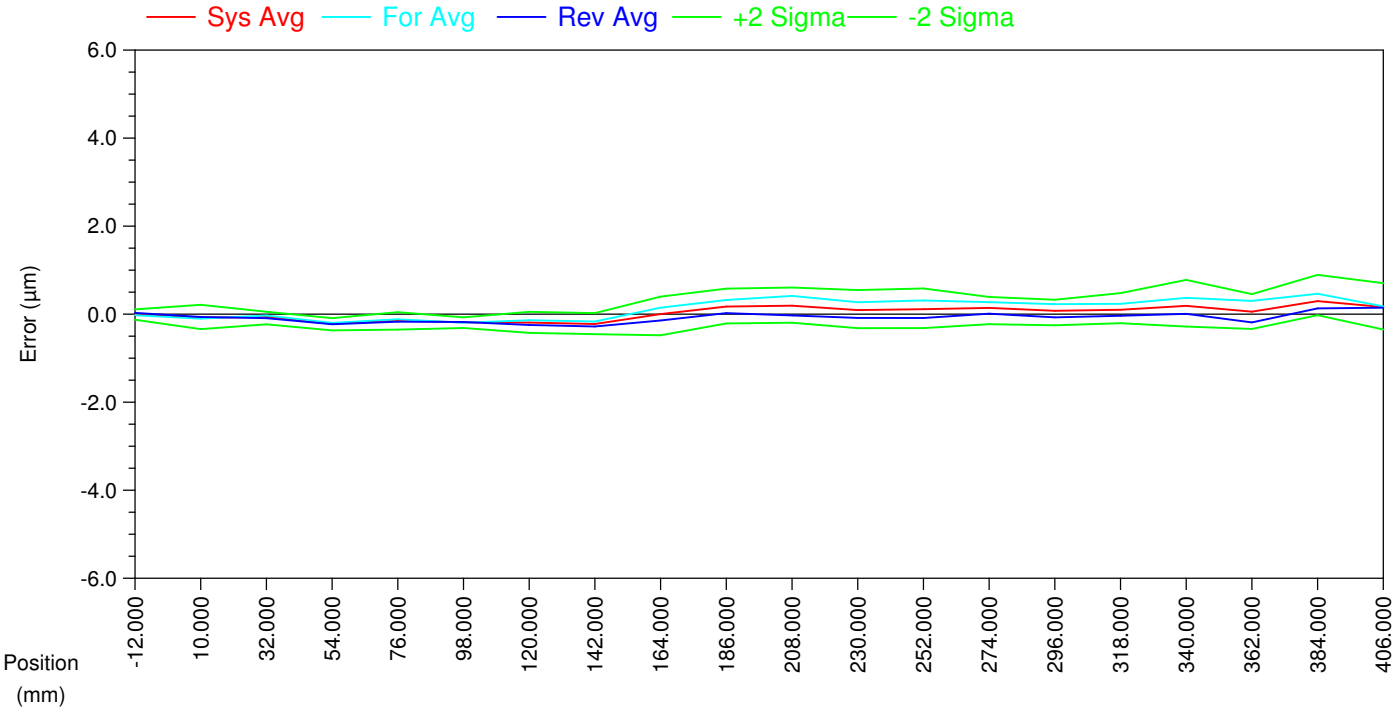
Analysis to ISO 230:Part 2:2006 Linear Positioning

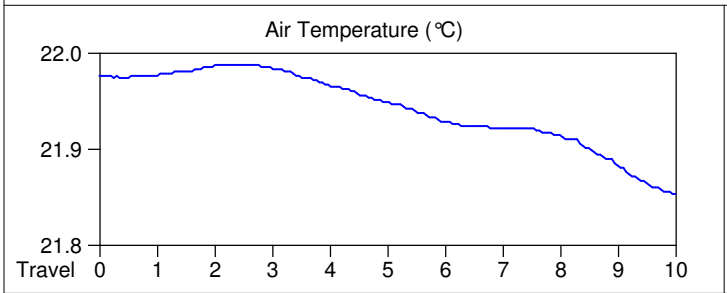
Accuracy	= 1.37 µm
Unidirectional repeatability	= 1.05 µm at 406.000 mm, forward direction
Bidirectional Repeatability	= 1.06 µm at 340.000 mm
Mean reversal value	= 0.21 µm
Mean bidir positional devn	= 0.52 µm

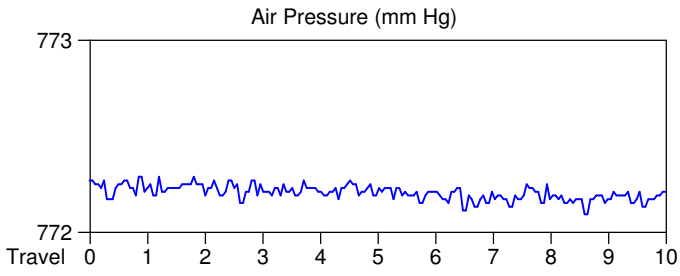
Air pressure	= 772.09/772.29 mm Hg
Air humidity	= 50/50 % rel
Air temperature	= 21.854/21.988 ℃
M/C temperature	= 19.459/19.509 ℃
Exp coefficient (Scale)	= 8.0 ppm/℃
Air compensation	= 726.10/726.25 ppm
Total compensation	= 730.03/732.53 ppm
Traceability reference	= NPL LL0101/0709

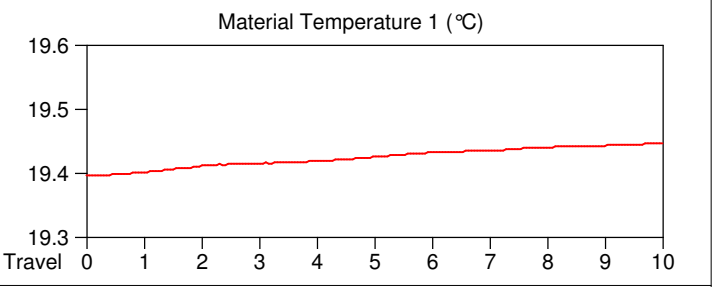
Y AXIS POSITIONAL ERROR (ISO 230)

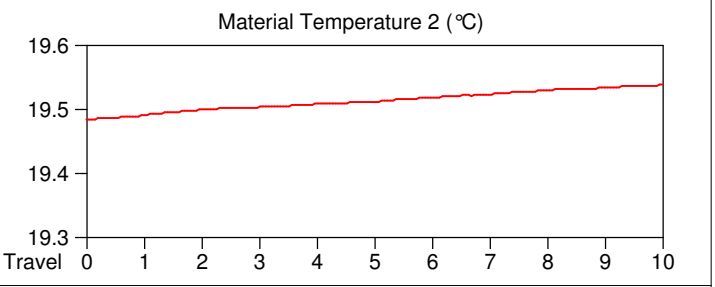
Machine	: DMG DMC50V	Accuracy	= 1.37 µm
Serial No	: 2880-0338	Uni-Direction Repeat	= 1.05 µm
Date	: 20 Mar 2009 at 14:49	Bi-Direction Repeat	= 1.06 µm
Inspector	: A J Gregory	Mean Reversal Value	= 0.21 µm
Customer	: Thomas Keating Ltd	With Compensation	

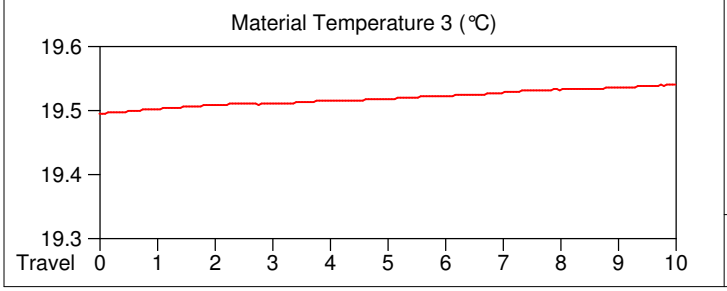












Test Details

Forward travels	: 5
Reverse travels	: 5
Targets	: 20
Target window	: 0.5000 mm
Samples	: 120
Bandwidth	: 0.0010 mm
Steptype	: Linear
Pitch	: 0.0000 mm
Instrument	: Agilent 5529 Laser
Radius/Dia	: Radial
Control	: Open loop (NC)
Static/Fly	: Static
Sample delay	: 0.00 seconds

C. D. Measurements Ltd

Z axis positional results - As Found

Target Position	Error Averages (µm) Forward	Reverse	System	2σ Std Devn (µm) Forward	Reverse	Dead Zone
-486.000	0.096	0.028	0.062	0.000	0.000	0.067
-453.000	0.813	0.658	0.735	0.000	0.000	0.155
-420.000	1.228	0.948	1.088	0.000	0.000	0.280
-387.000	1.536	1.221	1.378	0.000	0.000	0.315
-354.000	1.825	1.508	1.666	0.000	0.000	0.317
-321.000	2.556	2.202	2.379	0.000	0.000	0.354
-288.000	3.170	2.827	2.999	0.000	0.000	0.343
-255.000	4.048	3.588	3.818	0.000	0.000	0.459
-222.000	4.687	4.166	4.427	0.000	0.000	0.521
-189.000	5.324	4.980	5.152	0.000	0.000	0.344
-156.000	5.869	5.454	5.662	0.000	0.000	0.415
-123.000	6.704	6.303	6.503	0.000	0.000	0.401
-90.000	7.346	6.859	7.102	0.000	0.000	0.486
-57.000	7.846	7.395	7.621	0.000	0.000	0.451
-24.000	8.213	7.934	8.074	0.000	0.000	0.279
9.000	8.468	8.371	8.420	0.000	0.000	0.097

Analysis to ISO 230:Part 2:2006 Linear Positioning

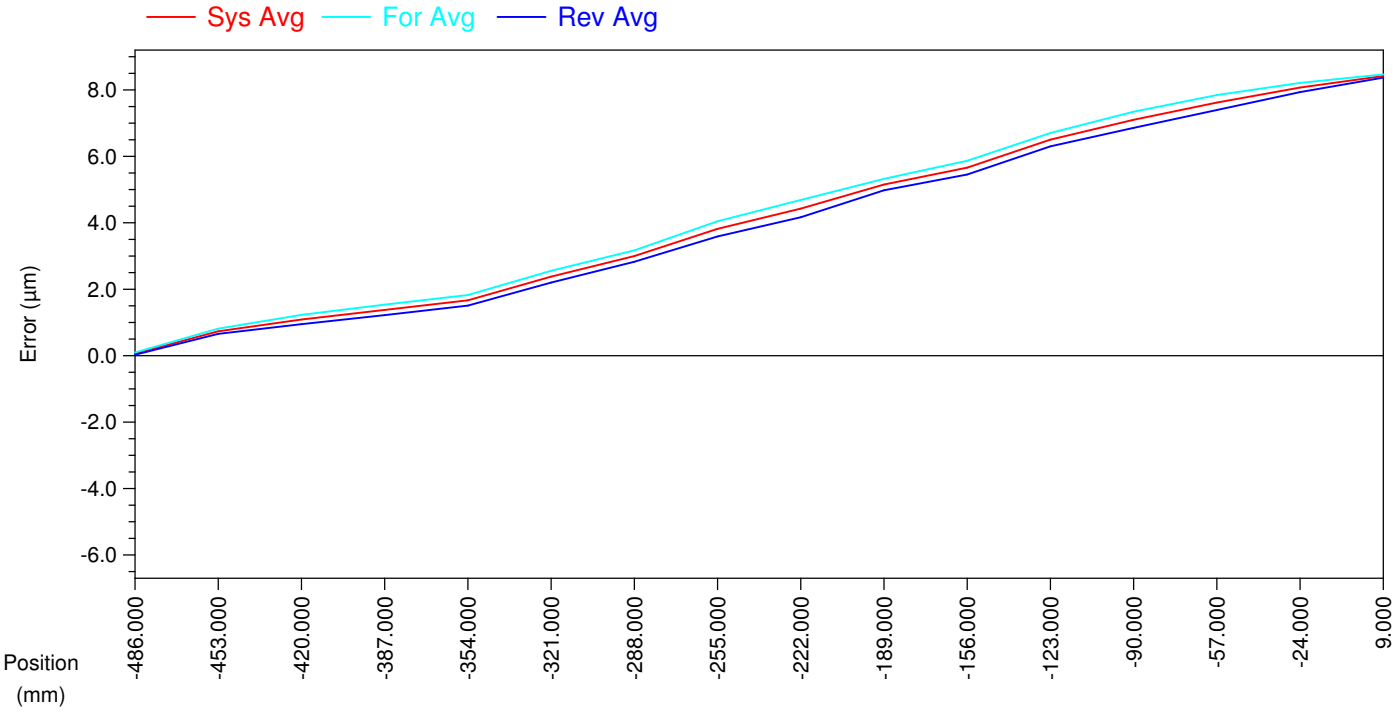
Mean reversal value = 0.33 µm
Mean bidir positional devn = 8.36 µm

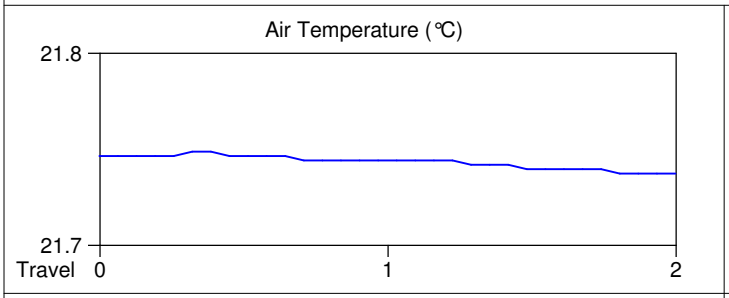
Air pressure = 772.02/772.15 mm Hg
Air humidity = 50/50 % rel
Air temperature = 21.737/21.749 ℃
M/C temperature = 19.572/19.578 ℃
Exp coefficient (Scale) = 8.0 ppm/℃
Air compensation = 726.01/726.06 ppm
Total compensation = 729.38/731.02 ppm
Traceability reference = NPL LL0101/0709

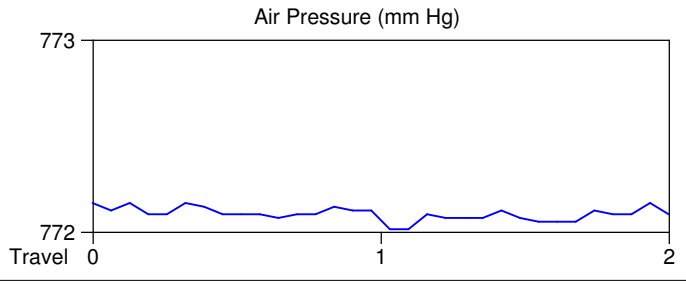
Z AXIS POSITIONAL ERROR (ISO 230)

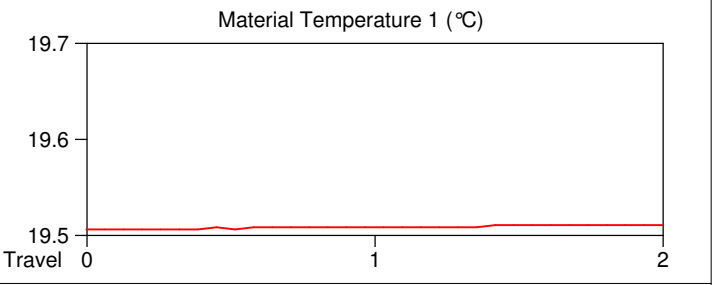
Machine : DMG DMC50V
Serial No : 2880-0338
Date : 20 Mar 2009 at 15:15
Inspector : A J Gregory
Customer : Thomas Keating Ltd

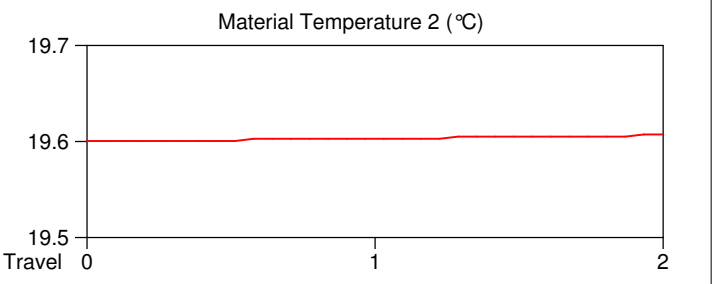
Mean bidir positional devn = 8.36 µm
Mean Reversal Value = 0.33 µm
As Found

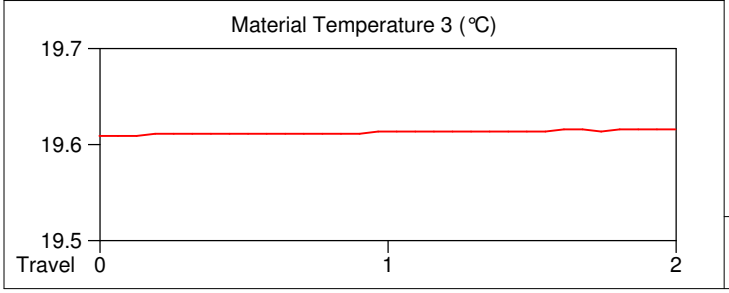












Test Details

Forward travels	: 1
Reverse travels	: 1
Targets	: 16
Target window	: 0.5000 mm
Samples	: 120
Bandwidth	: 0.0010 mm
Steptype	: Linear
Pitch	: 0.0000 mm
Instrument	: Agilent 5529 Laser
Radius/Dia	: Radial
Control	: Closed loop (CNC)
Static/Fly	: Static
Sample delay	: 0.00 seconds

C. D. Measurements Ltd

Z axis positional results - No Compensation

Target Position	Error Averages (µm) Forward	Reverse	System	2σ Std Devn (µm) Forward	Reverse	Dead Zone
-486.000	-0.057	-0.039	-0.048	0.244	0.159	-0.018
-453.000	2.113	2.061	2.087	0.277	0.152	0.052
-420.000	3.864	3.733	3.798	0.208	0.110	0.131
-387.000	5.292	5.056	5.174	0.315	0.186	0.236
-354.000	6.779	6.454	6.616	0.336	0.183	0.325
-321.000	8.520	8.144	8.332	0.399	0.171	0.376
-288.000	10.026	9.715	9.870	0.318	0.186	0.311
-255.000	11.818	11.413	11.616	0.388	0.219	0.406
-222.000	13.427	13.001	13.214	0.338	0.325	0.426
-189.000	14.947	14.548	14.748	0.271	0.339	0.400
-156.000	16.338	15.967	16.152	0.451	0.394	0.372
-123.000	17.891	17.579	17.735	0.474	0.342	0.312
-90.000	19.750	19.482	19.616	0.334	0.316	0.268
-57.000	21.764	21.497	21.631	0.250	0.376	0.267
-24.000	24.066	23.783	23.924	0.517	0.468	0.283
9.000	25.344	25.250	25.297	0.738	0.658	0.094

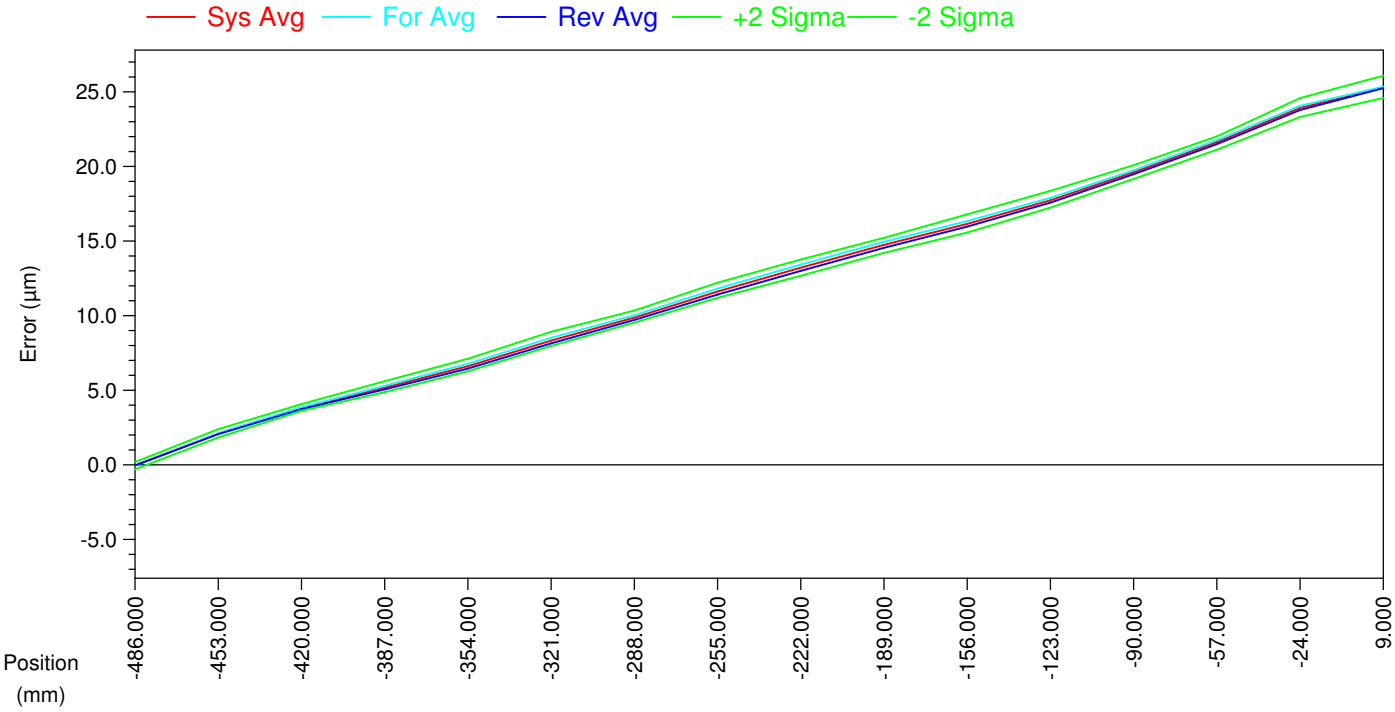
Analysis to ISO 230:Part 2:2006 Linear Positioning

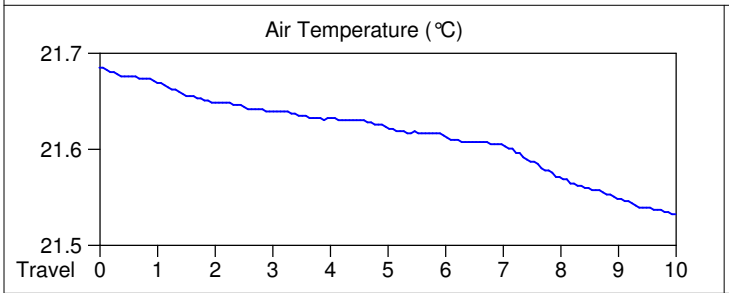
Accuracy	= 26.38 µm
Unidirectional repeatability	= 1.48 µm at 9.000 mm, forward direction
Bidirectional Repeatability	= 1.49 µm at 9.000 mm
Mean reversal value	= 0.27 µm
Mean bidir positional devn	= 25.35 µm

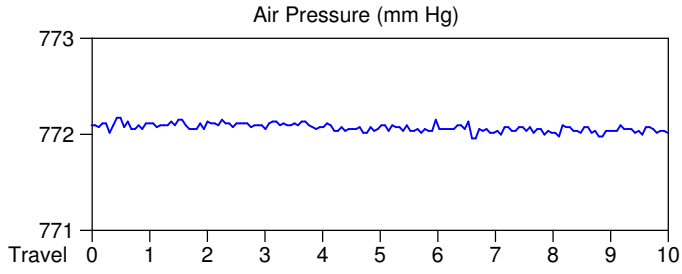
Air pressure	= 771.96/772.17 mm Hg
Air humidity	= 50/50 % rel
Air temperature	= 21.532/21.685 ℃
M/C temperature	= 19.581/19.602 ℃
Exp coefficient (Scale)	= 8.0 ppm/℃
Air compensation	= 725.84/726.00 ppm
Total compensation	= 729.03/730.86 ppm
Traceability reference	= NPL LL0101/0709

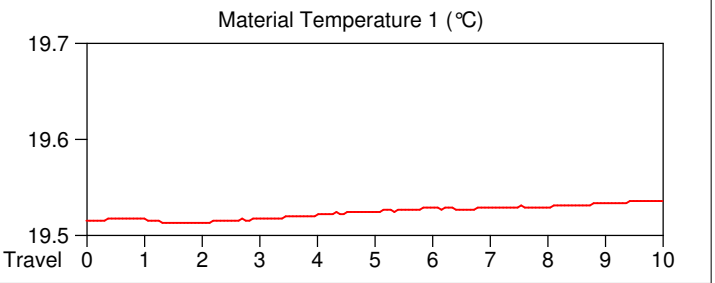
Z AXIS POSITIONAL ERROR (ISO 230)

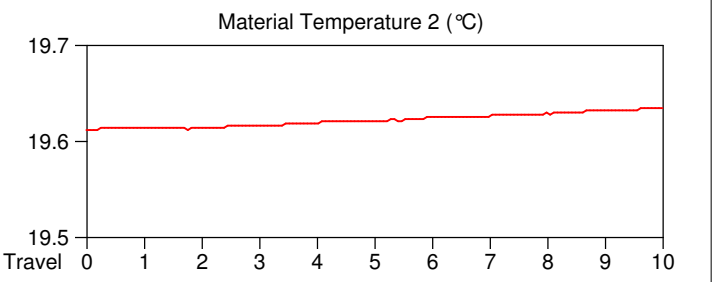
Machine	: DMG DMC50V	Accuracy	= 26.38 µm
Serial No	: 2880-0338	Uni-Direction Repeat	= 1.48 µm
Date	: 20 Mar 2009 at 15:27	Bi-Direction Repeat	= 1.49 µm
Inspector	: A J Gregory	Mean Reversal Value	= 0.27 µm
Customer	: Thomas Keating Ltd	No Compensation	

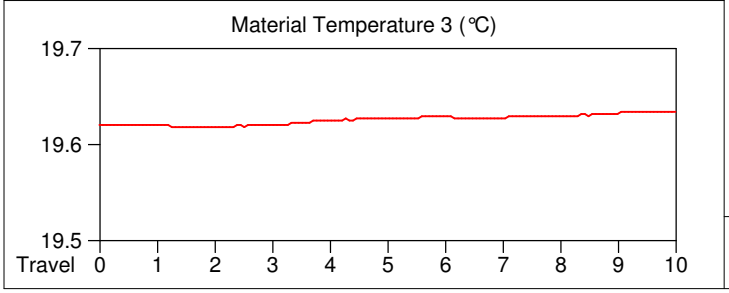












Test Details

Forward travels	: 5
Reverse travels	: 5
Targets	: 16
Target window	: 0.5000 mm
Samples	: 120
Bandwidth	: 0.0010 mm
Steptype	: Linear
Pitch	: 0.0000 mm
Instrument	: Agilent 5529 Laser
Radius/Dia	: Radial
Control	: Open loop (NC)
Static/Fly	: Static
Sample delay	: 0.00 seconds

C. D. Measurements Ltd

Z axis positional results - With Compensation

Target Position	Error Averages (µm) Forward	Reverse	System	2σ Std Devn (µm) Forward	Reverse	Dead Zone
-486.000	-0.274	-0.301	-0.287	0.348	0.157	0.027
-453.000	-0.253	-0.365	-0.309	0.349	0.163	0.112
-420.000	-0.325	-0.549	-0.437	0.317	0.157	0.223
-387.000	-0.264	-0.560	-0.412	0.270	0.241	0.296
-354.000	-0.316	-0.651	-0.483	0.379	0.324	0.335
-321.000	-0.018	-0.403	-0.210	0.337	0.379	0.385
-288.000	-0.045	-0.444	-0.245	0.382	0.319	0.399
-255.000	-0.124	-0.525	-0.324	0.419	0.357	0.401
-222.000	-0.258	-0.647	-0.453	0.283	0.275	0.389
-189.000	-0.188	-0.642	-0.415	0.260	0.274	0.453
-156.000	-0.234	-0.836	-0.535	0.526	0.433	0.603
-123.000	-0.179	-0.767	-0.473	0.558	0.407	0.588
-90.000	-0.277	-0.737	-0.507	0.566	0.401	0.460
-57.000	-0.329	-0.645	-0.487	0.460	0.366	0.315
-24.000	-0.320	-0.587	-0.454	0.589	0.275	0.267
9.000	-0.549	-0.665	-0.607	0.522	0.453	0.116

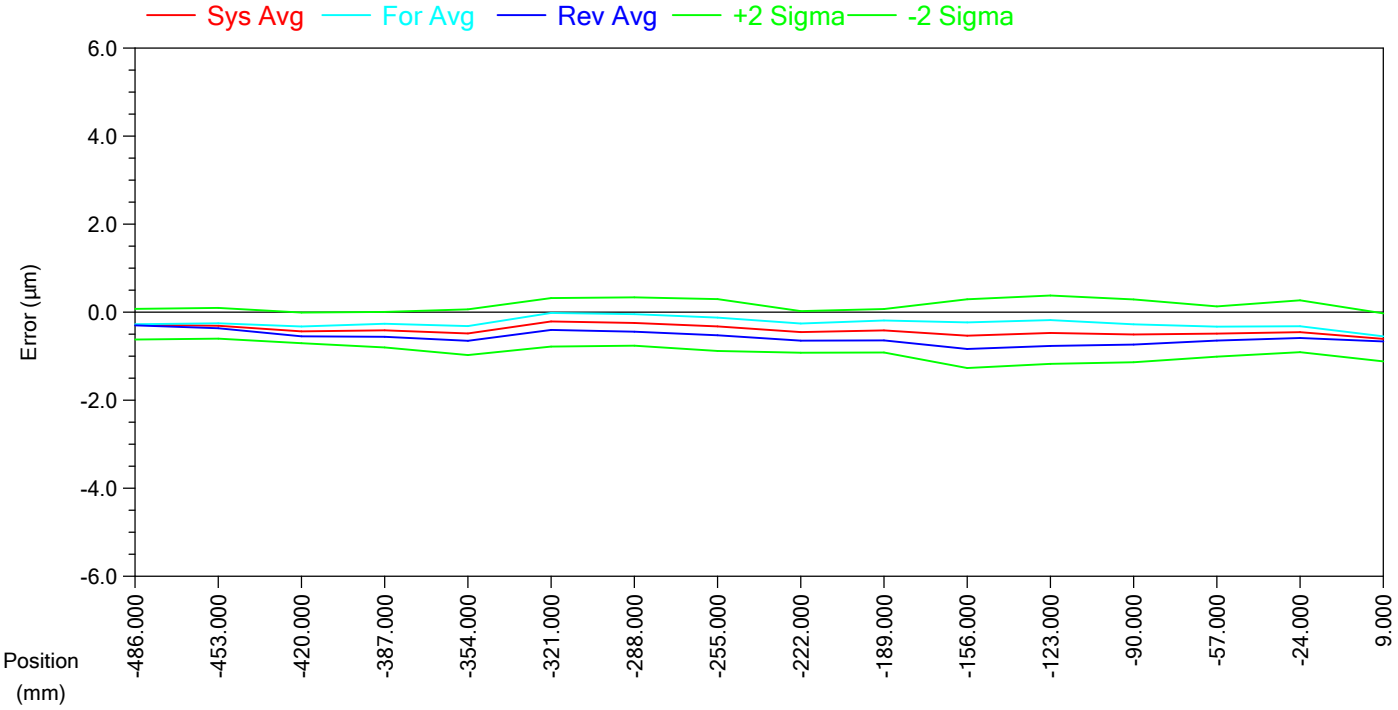
Analysis to ISO 230:Part 2:2006 Linear Positioning

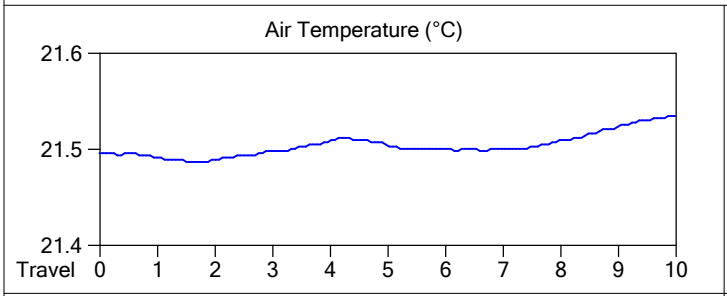
Accuracy	= 1.65 µm
Unidirectional repeatability	= 1.18 µm at -24.000 mm, forward direction
Bidirectional Repeatability	= 1.56 µm at -156.000 mm
Mean reversal value	= 0.34 µm
Mean bidir positional devn	= 0.40 µm

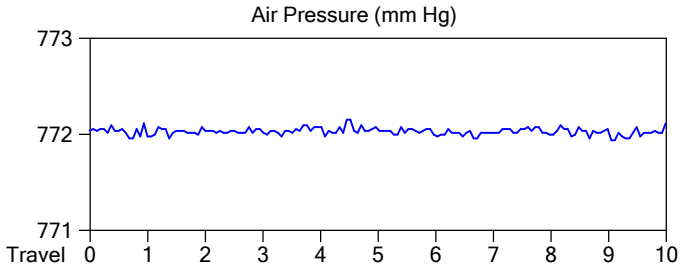
Air pressure	= 771.94/772.15 mm Hg
Air humidity	= 50/50 % rel
Air temperature	= 21.487/21.535 °C
M/C temperature	= 19.610/19.637 °C
Exp coefficient (Scale)	= 8.0 ppm/°C
Air compensation	= 725.79/725.88 ppm
Total compensation	= 728.74/730.38 ppm
Traceability reference	= NPL LL0101/0709

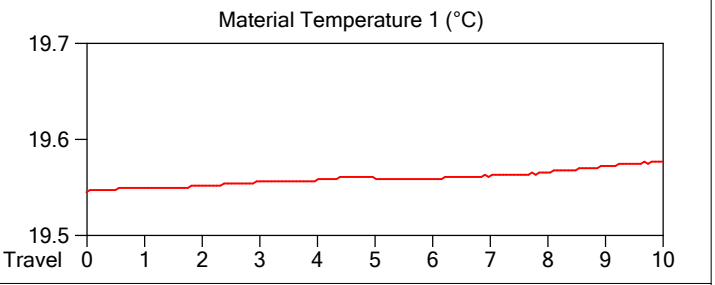
Z AXIS POSITIONAL ERROR (ISO 230)

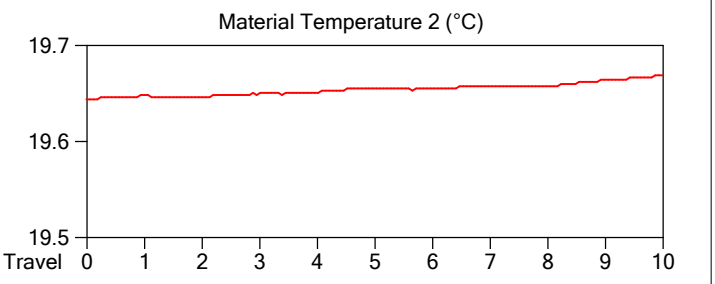
Machine	: DMG DMC50V	Accuracy	= 1.65 µm
Serial No	: 2880-0338	Uni-Direction Repeat	= 1.18 µm
Date	: 20 Mar 2009 at 15:43	Bi-Direction Repeat	= 1.56 µm
Inspector	: A J Gregory	Mean Reversal Value	= 0.34 µm
Customer	: Thomas Keating Ltd	With Compensation	

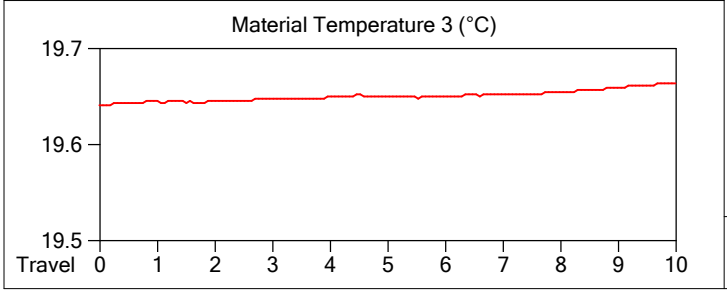












Test Details

Forward travels	: 5
Reverse travels	: 5
Targets	: 16
Target window	: 0.5000 mm
Samples	: 120
Bandwidth	: 0.0010 mm
Steptype	: Linear
Pitch	: 0.0000 mm
Instrument	: Agilent 5529 Laser
Radius/Dia	: Radial
Control	: Open loop (NC)
Static/Fly	: Static
Sample delay	: 0.00 seconds

C. D. Measurements Ltd

CERTIFICATE OF CALIBRATION

Issued by CD Measurements Ltd. UKAS Laboratory No 0334

This laboratory is accredited in accordance with the recognised International Standard ISO/IEC 17025:2005. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system.

The joint ISO-ILAC-IAF communiqué can be found at www.cdmeasurements.com/downloads.htm which clarifies the relationship between ISO9001:2000 and ISO17025:2005.

CERTIFICATE OF CALIBRATION

Issued by : **CD MEASUREMENTS LIMITED**
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UKAS CALIBRATION
0334

Certificate Number : 02667

Date of Issue : 27 Mar 2009

Approved Signatory

Basis of Test : ISO 230:Part 2:2006 Linear Positioning

A. Butterworth

Customer & Site location : Thomas Keating Ltd
Station Mills
Billingshurst
West Sussex
RH14 9SH

Machine : DMG DMC50V

Serial No : 2880-0338

Method : This machine was calibrated on 20 Mar 2009 at the above site location as follows:-
Agilent 5529 laser interferometer and the above specification.
The results corrected to 20℃ are shown on the following sheet.

Uncertainty : ± (0.15 µm + 0.93 µm/metre)

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor k=2, providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

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UKAS ACCREDITED CALIBRATION LABORATORY No. 0334

Date of Issue
27 Mar 2009

Certificate Number
02667

X axis positional results : Tested from -9.0mm to 486.0mm @ Y182.0 Z-447.0
: With Compensation

Accuracy	= 1.46 µm
Unidirectional repeatability	= 0.65 µm at 189.000 mm, reverse direction
Bidirectional Repeatability	= 1.04 µm at 123.000 mm
Mean reversal value	= 0.37 µm
Mean bidir positional devn	= 0.52 µm
Air pressure	= 772.39/772.62 mm Hg
Air humidity	= 50/50 % rel
Air temperature	= 21.753/21.794 ℃
M/C temperature	= 19.177/19.221 ℃
Exp coefficient (Scale)	= 8.0 ppm/℃
Air compensation	= 725.86/725.98 ppm
Total compensation	= 732.17/735.51 ppm

Y axis positional results : Tested from -12.0mm to 406.0mm @ X216.3 Z-428.7
: With Compensation

Accuracy	= 1.37 µm
Unidirectional repeatability	= 1.05 µm at 406.000 mm, forward direction
Bidirectional Repeatability	= 1.06 µm at 340.000 mm
Mean reversal value	= 0.21 µm
Mean bidir positional devn	= 0.52 µm
Air pressure	= 772.09/772.29 mm Hg
Air humidity	= 50/50 % rel
Air temperature	= 21.854/21.988 ℃
M/C temperature	= 19.459/19.509 ℃
Exp coefficient (Scale)	= 8.0 ppm/℃
Air compensation	= 726.10/726.25 ppm
Total compensation	= 730.03/732.53 ppm

Z axis positional results : Tested from -486.0mm to 9.0mm @ X247.2 Y161.7
: With Compensation

Accuracy	= 1.65 µm
Unidirectional repeatability	= 1.18 µm at -24.000 mm, forward direction
Bidirectional Repeatability	= 1.56 µm at -156.000 mm
Mean reversal value	= 0.34 µm
Mean bidir positional devn	= 0.40 µm
Air pressure	= 771.94/772.15 mm Hg
Air humidity	= 50/50 % rel
Air temperature	= 21.487/21.535 ℃
M/C temperature	= 19.610/19.637 ℃
Exp coefficient (Scale)	= 8.0 ppm/℃
Air compensation	= 725.79/725.88 ppm
Total compensation	= 728.74/730.38 ppm