

Accuracy Assessment
of
Bostomatic 32GS
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 : Bostomatic 32GS

Serial number : 32-366

Calibration type : Positional

Calibrated by : A J Gregory

Date : 18 Mar 2009

Equipment : Agilent 5529 laser interferometer

Calibration ref : C69/09-BOST

Certificate no : 02665

Linear Axis Positional sign convention.

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

$$\text{Error} = \text{Laser Reading (Reference)} - \text{Machine Reading (Command)}$$

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:-

$$\text{Error} = (2000.147\text{mm}) - (2000.000\text{mm}) = +0.147\text{mm Overtravel.}$$

$$\text{Error} = (1999.983\text{mm}) - (2000.000\text{mm}) = -0.017\text{mm Undertravel.}$$

And in a negative moving axis:-

$$\text{Error} = (-2000.147\text{mm}) - (-2000.000\text{mm}) = -0.147\text{mm Overtravel.}$$

$$\text{Error} = (-1999.983\text{mm}) - (-2000.000\text{mm}) = +0.017\text{mm Undertravel.}$$

X axis positional results - As Found

Target Position	Error Averages (µm)			2σ Std Devn (µm)		Dead Zone
	Forward	Reverse	System	Forward	Reverse	
801.000	0.002	0.152	0.077	0.000	0.000	0.150
781.000	-0.779	-0.845	-0.812	0.000	0.000	-0.066
761.000	-1.235	-1.065	-1.150	0.000	0.000	0.170
741.000	-1.061	-1.157	-1.109	0.000	0.000	-0.096
721.000	-0.677	-0.823	-0.750	0.000	0.000	-0.146
701.000	-1.597	-1.663	-1.630	0.000	0.000	-0.066
681.000	-1.433	-1.516	-1.474	0.000	0.000	-0.083
661.000	-1.673	-1.526	-1.600	0.000	0.000	0.147
641.000	-1.681	-1.391	-1.536	0.000	0.000	0.290
621.000	-2.576	-2.470	-2.523	0.000	0.000	0.106
601.000	-2.705	-2.408	-2.557	0.000	0.000	0.297
581.000	-3.135	-2.919	-3.027	0.000	0.000	0.216
561.000	-2.615	-2.469	-2.542	0.000	0.000	0.146
541.000	-2.872	-2.645	-2.758	0.000	0.000	0.227
521.000	-3.104	-2.839	-2.972	0.000	0.000	0.265
501.000	-2.415	-2.362	-2.388	0.000	0.000	0.053
481.000	-2.758	-2.327	-2.543	0.000	0.000	0.431
461.000	-3.052	-2.776	-2.914	0.000	0.000	0.276
441.000	-3.440	-3.065	-3.252	0.000	0.000	0.375
421.000	-2.878	-2.893	-2.885	0.000	0.000	-0.014
401.000	-3.040	-2.898	-2.969	0.000	0.000	0.142
381.000	-3.474	-3.324	-3.399	0.000	0.000	0.150
361.000	-3.594	-3.376	-3.485	0.000	0.000	0.219
341.000	-3.376	-3.037	-3.206	0.000	0.000	0.339
321.000	-3.753	-3.154	-3.454	0.000	0.000	0.599
301.000	-4.161	-3.812	-3.986	0.000	0.000	0.349
281.000	-4.163	-3.868	-4.015	0.000	0.000	0.295
261.000	-3.923	-3.647	-3.785	0.000	0.000	0.275
241.000	-3.255	-2.870	-3.063	0.000	0.000	0.385
221.000	-3.788	-3.532	-3.660	0.000	0.000	0.256
201.000	-3.819	-3.508	-3.664	0.000	0.000	0.311
181.000	-3.787	-3.571	-3.679	0.000	0.000	0.216
161.000	-3.615	-3.457	-3.536	0.000	0.000	0.158
141.000	-4.777	-4.439	-4.608	0.000	0.000	0.339
121.000	-5.096	-4.649	-4.873	0.000	0.000	0.447
101.000	-5.698	-5.300	-5.499	0.000	0.000	0.398
81.000	-5.246	-4.957	-5.101	0.000	0.000	0.290
61.000	-5.926	-5.718	-5.822	0.000	0.000	0.209
41.000	-5.991	-5.817	-5.904	0.000	0.000	0.173
21.000	-6.234	-5.840	-6.037	0.000	0.000	0.394
1.000	-7.282	-6.423	-6.852	0.000	0.000	0.860

Analysis to ISO 230:Part 2:2006 Linear Positioning

Mean reversal value = 0.23 µm
 Mean bidir positional devn = 6.93 µm

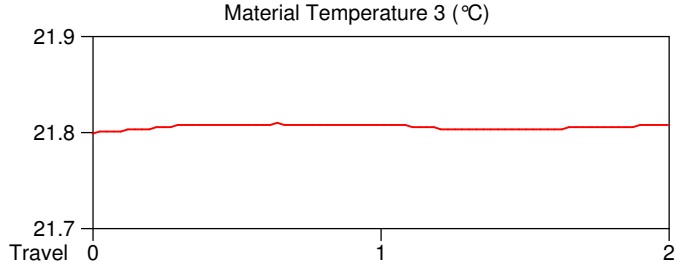
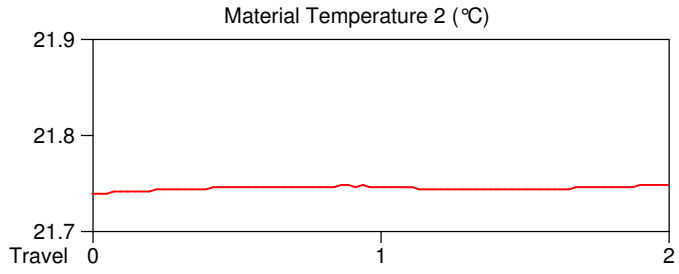
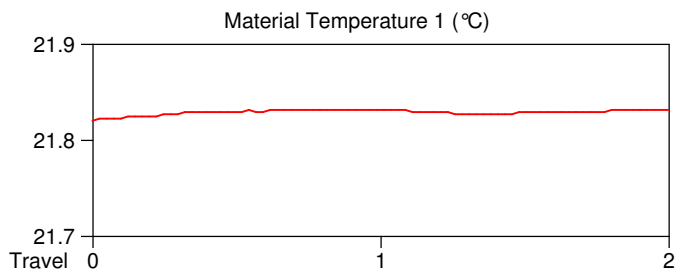
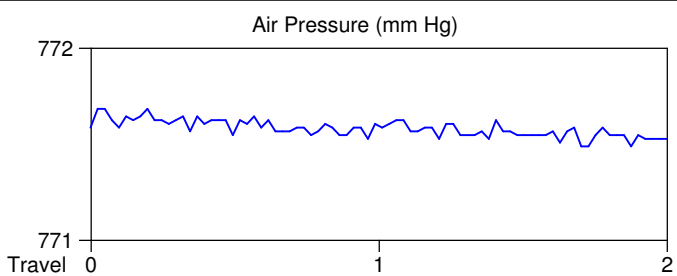
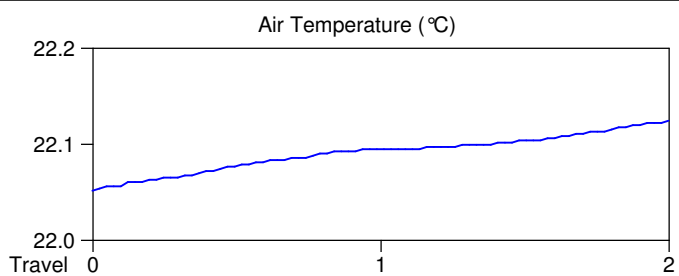
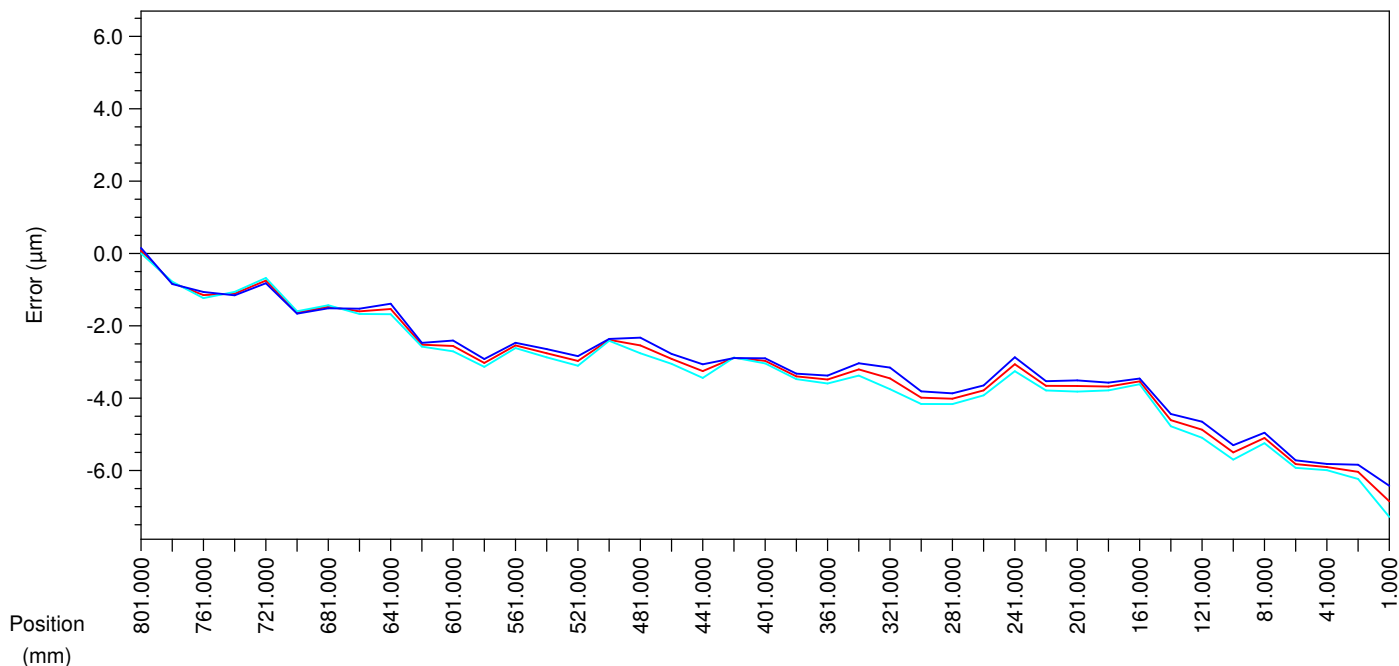
 Air pressure = 771.49/771.68 mm Hg
 Air humidity = 50/50 % rel
 Air temperature = 22.047/22.125 °C
 M/C temperature = 21.786/21.796 °C
 Exp coefficient (Scale) = 8.0 ppm/°C
 Air compensation = 726.47/726.61 ppm
 Total compensation = 705.60/712.25 ppm
 Traceability reference = NPL LL0101/0709

X AXIS POSITIONAL ERROR (ISO 230)

Machine : Bostomatic 32GS
 Serial No : 32-366
 Date : 18 Mar 2009 at 13:47
 Inspector : A J Gregory
 Customer : Thomas Keating Ltd

Mean bidir positional devn = 6.93 μm
 Mean Reversal Value = 0.23 μm
 As Found

— Sys Avg — For Avg — Rev Avg



Test Details

Forward travels : 1
 Reverse travels : 1
 Targets : 41
 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



X axis positional results - No Compensation

Target Position	Error Averages (μm)		System	2 σ Std Devn (μm)		Dead Zone
	Forward	Reverse		Forward	Reverse	
801.000	-0.389	-0.313	-0.351	0.647	0.610	0.076
781.000	-1.655	-1.447	-1.551	0.259	0.456	0.208
761.000	-2.027	-1.901	-1.964	0.825	0.679	0.126
741.000	-1.660	-1.443	-1.552	0.463	0.399	0.217
721.000	-1.159	-1.118	-1.139	0.640	0.667	0.041
701.000	-2.967	-2.888	-2.927	0.417	0.536	0.080
681.000	-3.442	-3.351	-3.396	0.459	0.497	0.091
661.000	-2.888	-2.834	-2.861	0.428	0.538	0.055
641.000	-2.534	-2.537	-2.535	0.390	0.623	-0.003
621.000	-3.617	-3.545	-3.581	0.329	0.595	0.072
601.000	-4.150	-3.944	-4.047	0.418	0.397	0.206
581.000	-2.923	-2.812	-2.867	0.474	0.676	0.111
561.000	-2.679	-2.355	-2.517	0.361	0.469	0.324
541.000	-3.270	-3.047	-3.159	0.403	0.621	0.223
521.000	-3.545	-3.257	-3.401	0.295	0.543	0.288
501.000	-2.589	-2.387	-2.488	0.758	0.718	0.201
481.000	-2.374	-2.068	-2.221	0.409	0.515	0.307
461.000	-2.722	-2.385	-2.553	0.544	0.699	0.337
441.000	-3.111	-2.803	-2.957	0.459	0.347	0.308
421.000	-2.173	-1.911	-2.042	0.544	0.637	0.262
401.000	-2.367	-2.005	-2.186	0.353	0.510	0.362
381.000	-3.289	-2.901	-3.095	0.326	0.525	0.388
361.000	-3.836	-3.568	-3.702	0.387	0.498	0.269
341.000	-3.136	-2.792	-2.964	0.356	0.480	0.344
321.000	-2.755	-2.253	-2.504	0.774	0.448	0.503
301.000	-3.375	-2.944	-3.159	0.470	0.571	0.431
281.000	-2.960	-2.564	-2.762	0.492	0.527	0.396
261.000	-1.725	-1.320	-1.522	0.216	0.514	0.405
241.000	-0.954	-0.504	-0.729	0.381	0.604	0.450
221.000	-1.781	-1.315	-1.548	0.366	0.457	0.466
201.000	-1.786	-1.390	-1.588	0.646	0.720	0.396
181.000	-1.250	-0.879	-1.064	0.400	0.422	0.370
161.000	-1.092	-0.629	-0.860	0.747	0.849	0.462
141.000	-2.796	-2.128	-2.462	0.525	0.588	0.668
121.000	-3.411	-2.874	-3.142	0.534	0.613	0.537
101.000	-3.612	-2.966	-3.289	0.719	0.416	0.647
81.000	-3.743	-3.106	-3.425	0.691	0.540	0.637
61.000	-4.750	-4.239	-4.494	0.388	0.527	0.510
41.000	-5.494	-4.940	-5.217	0.569	0.678	0.554
21.000	-5.320	-4.884	-5.102	0.517	0.576	0.436
1.000	-5.506	-5.136	-5.321	0.473	0.450	0.370

Analysis to ISO 230:Part 2:2006 Linear Positioning

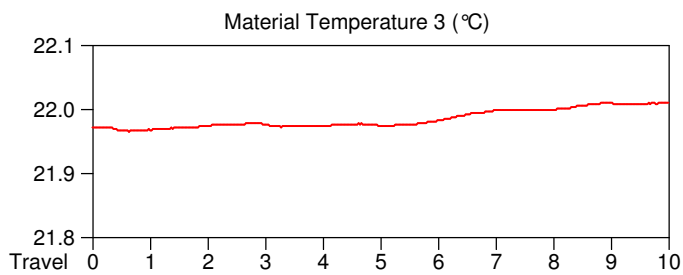
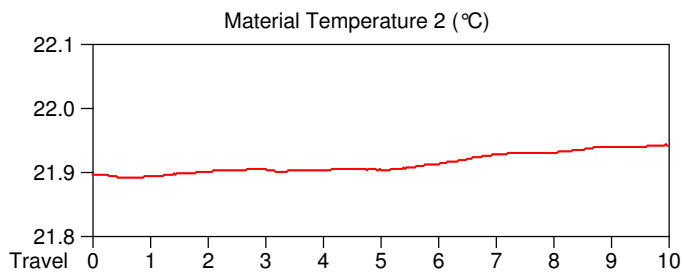
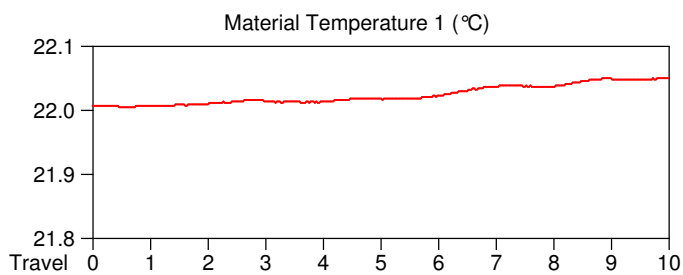
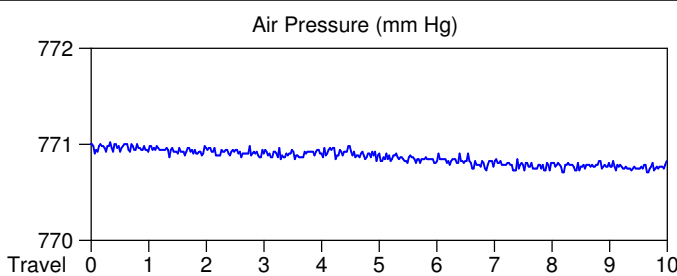
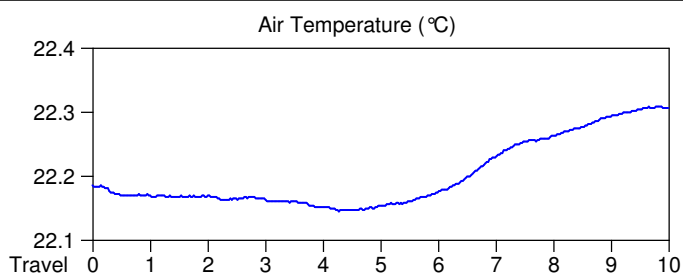
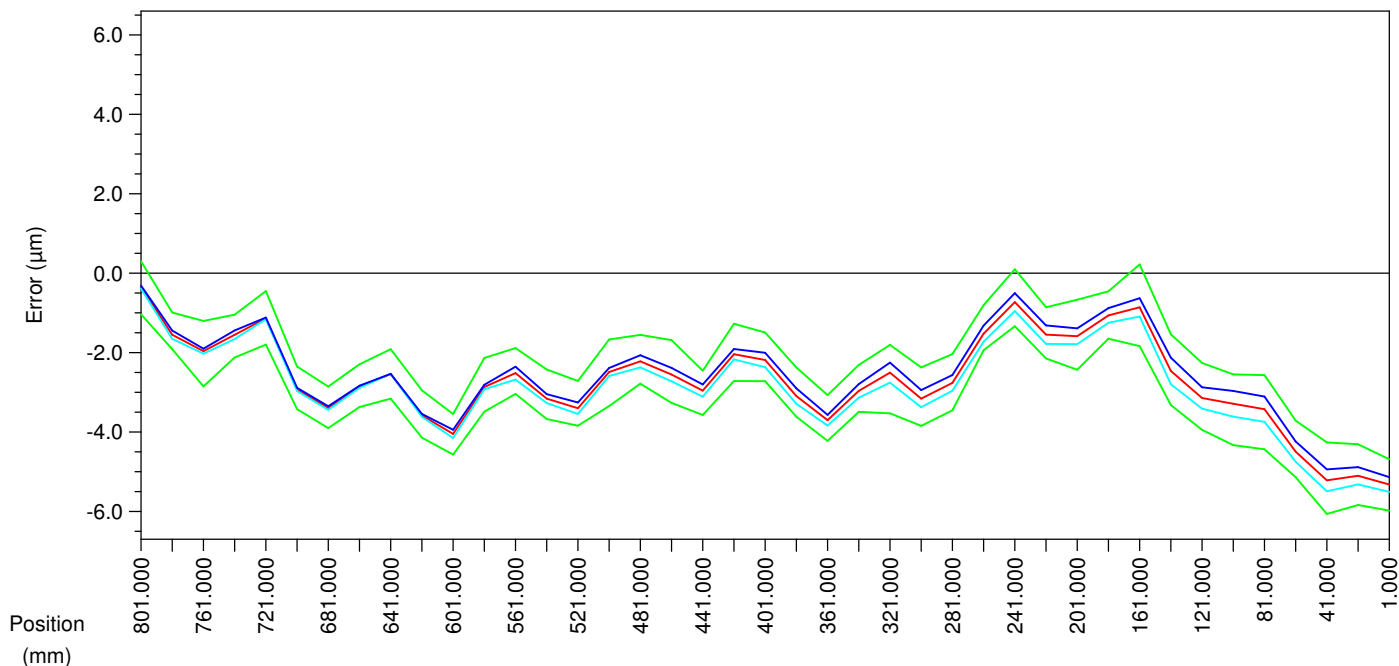
Accuracy	= 6.36 μm
Unidirectional repeatability	= 1.70 μm at 161.000 mm, reverse direction
Bidirectional Repeatability	= 2.06 μm at 161.000 mm
Mean reversal value	= 0.32 μm
Mean bidir positional devn	= 4.97 μm
Air pressure	= 770.71/771.02 mm Hg
Air humidity	= 50/50 % rel
Air temperature	= 22.145/22.309 $^{\circ}\text{C}$
M/C temperature	= 21.954/22.002 $^{\circ}\text{C}$
Exp coefficient (Scale)	= 8.0 ppm/ $^{\circ}\text{C}$
Air compensation	= 726.81/727.06 ppm
Total compensation	= 703.93/711.22 ppm
Traceability reference	= NPL LL0101/0709

X AXIS POSITIONAL ERROR (ISO 230)

Machine : Bostomatic 32GS
 Serial No : 32-366
 Date : 18 Mar 2009 at 15:04
 Inspector : A J Gregory
 Customer : Thomas Keating Ltd

Accuracy = 6.36 μm
 Uni-Direction Repeat = 1.70 μm
 Bi-Direction Repeat = 2.06 μm
 Mean Reversal Value = 0.32 μm
 No Compensation

— Sys Avg — For Avg — Rev Avg — +2 Sigma — -2 Sigma



Test Details

Forward travels : 5
 Reverse travels : 5
 Targets : 41
 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



X axis positional results - With Compensation

Target Position	Error Averages (μm)		System	2 σ Std Devn (μm)		Dead Zone
	Forward	Reverse		Forward	Reverse	
801.000	0.296	0.444	0.370	0.647	0.666	0.148
781.000	0.055	0.288	0.172	0.487	0.339	0.233
761.000	-0.544	-0.301	-0.422	0.560	0.420	0.242
741.000	-0.305	-0.109	-0.207	0.430	0.398	0.196
721.000	0.755	0.949	0.852	0.369	0.465	0.194
701.000	-0.223	0.013	-0.105	0.500	0.592	0.236
681.000	-0.944	-0.758	-0.851	0.175	0.237	0.186
661.000	-0.117	-0.001	-0.059	0.378	0.545	0.116
641.000	-0.171	0.040	-0.065	0.172	0.158	0.211
621.000	-0.028	0.129	0.051	0.580	0.524	0.157
601.000	-1.000	-0.737	-0.869	0.265	0.218	0.263
581.000	-0.348	0.011	-0.169	0.574	0.435	0.359
561.000	-0.006	0.279	0.136	0.312	0.069	0.285
541.000	-0.273	0.043	-0.115	0.533	0.603	0.316
521.000	-0.910	-0.516	-0.713	0.215	0.104	0.394
501.000	-0.553	-0.225	-0.389	0.613	0.438	0.328
481.000	0.046	0.382	0.214	0.392	0.362	0.337
461.000	-0.728	-0.360	-0.544	0.577	0.527	0.368
441.000	-0.916	-0.464	-0.690	0.279	0.343	0.452
421.000	-0.894	-0.448	-0.671	0.529	0.520	0.446
401.000	-0.123	0.312	0.094	0.400	0.388	0.435
381.000	-0.321	0.134	-0.093	0.250	0.206	0.455
361.000	-0.692	-0.210	-0.451	0.487	0.422	0.482
341.000	-0.709	-0.195	-0.452	0.423	0.357	0.514
321.000	-0.068	0.396	0.164	0.537	0.273	0.464
301.000	-0.743	-0.238	-0.490	0.374	0.184	0.505
281.000	-1.276	-0.883	-1.079	0.513	0.390	0.392
261.000	-1.143	-0.698	-0.921	0.274	0.083	0.445
241.000	-0.486	-0.090	-0.288	0.525	0.384	0.397
221.000	-0.548	-0.136	-0.342	0.292	0.178	0.411
201.000	-0.779	-0.320	-0.550	0.352	0.383	0.459
181.000	-0.572	-0.063	-0.318	0.310	0.288	0.509
161.000	-0.094	0.400	0.153	0.401	0.406	0.494
141.000	-0.364	0.092	-0.136	0.263	0.354	0.456
121.000	-0.904	-0.476	-0.690	0.406	0.387	0.428
101.000	-0.772	-0.308	-0.540	0.302	0.195	0.464
81.000	0.032	0.491	0.262	0.324	0.275	0.458
61.000	-0.503	-0.038	-0.270	0.364	0.355	0.465
41.000	-0.760	-0.348	-0.554	0.268	0.204	0.412
21.000	-1.187	-0.784	-0.985	0.398	0.311	0.403
1.000	-0.999	-0.595	-0.797	0.338	0.385	0.404

Analysis to ISO 230:Part 2:2006 Linear Positioning

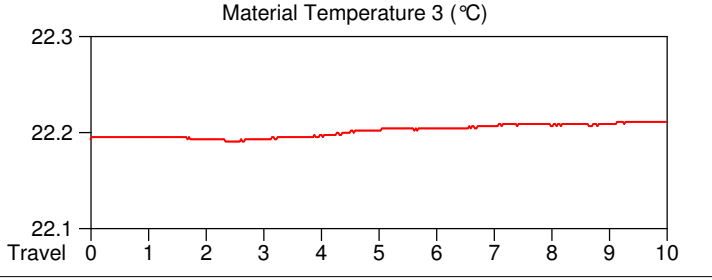
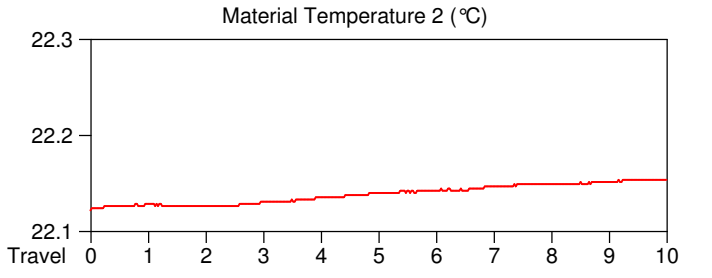
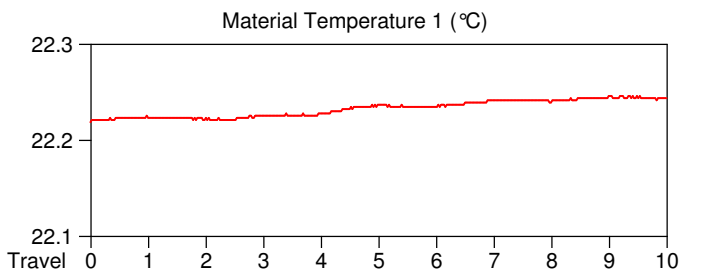
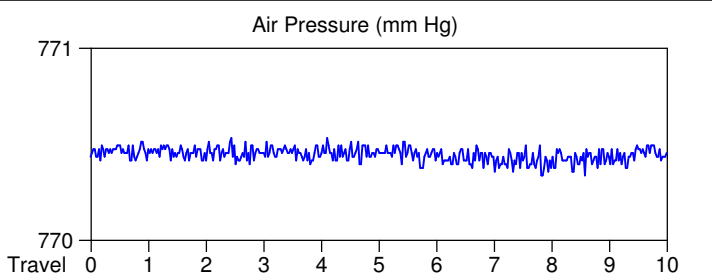
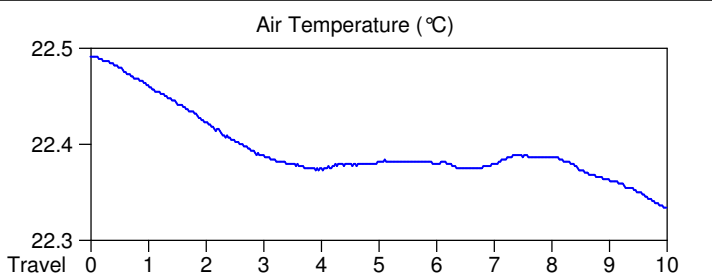
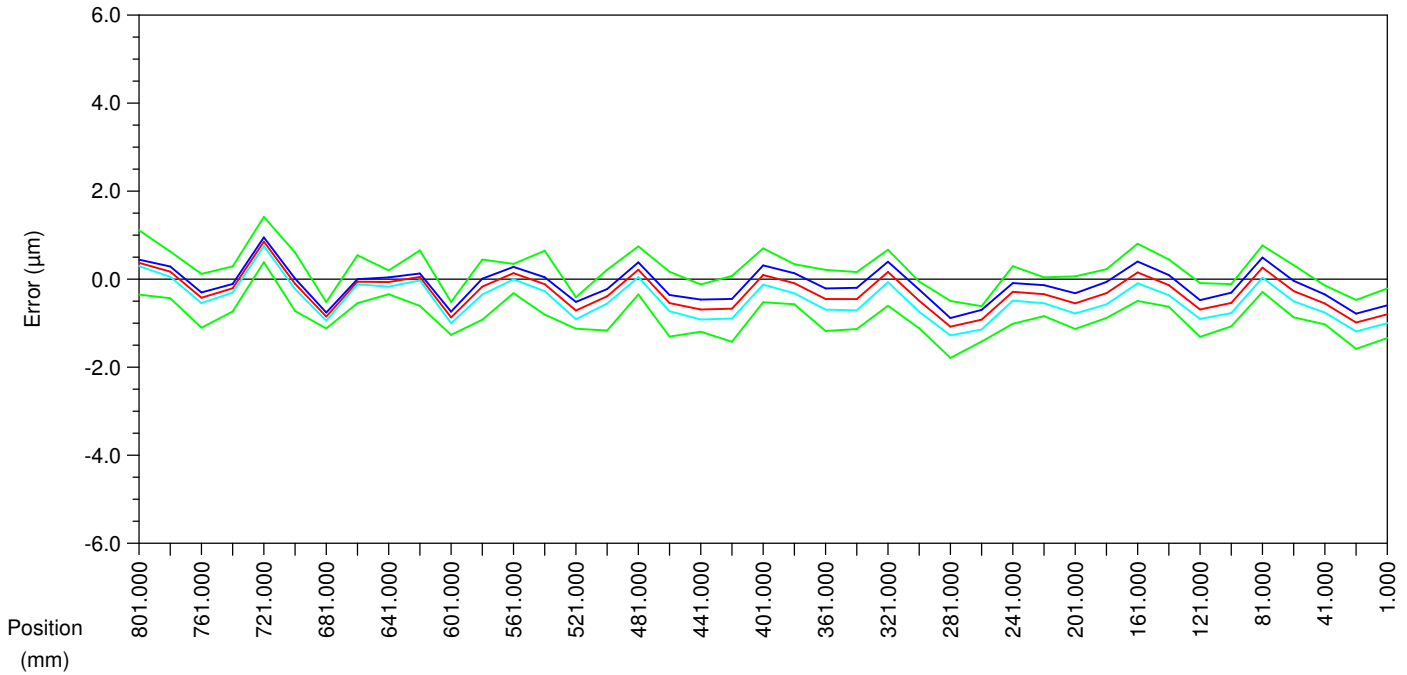
Accuracy	= 3.20 μm
Unidirectional repeatability	= 1.33 μm at 801.000 mm, reverse direction
Bidirectional Repeatability	= 1.49 μm at 421.000 mm
Mean reversal value	= 0.36 μm
Mean bidir positional devn	= 1.93 μm
Air pressure	= 770.34/770.53 mm Hg
Air humidity	= 50/50 % rel
Air temperature	= 22.334/22.491 $^{\circ}\text{C}$
M/C temperature	= 22.178/22.204 $^{\circ}\text{C}$
Exp coefficient (Scale)	= 8.0 ppm/ $^{\circ}\text{C}$
Air compensation	= 727.17/727.34 ppm
Total compensation	= 701.85/709.91 ppm
Traceability reference	= NPL LL0101/0709

X AXIS POSITIONAL ERROR (ISO 230)

Machine : Bostomatic 32GS
 Serial No : 32-366
 Date : 18 Mar 2009 at 17:07
 Inspector : A J Gregory
 Customer : Thomas Keating Ltd

Accuracy = 3.20 μm
 Uni-Direction Repeat = 1.33 μm
 Bi-Direction Repeat = 1.49 μm
 Mean Reversal Value = 0.36 μm
 With Compensation

— Sys Avg — For Avg — Rev Avg — +2 Sigma — -2 Sigma



Test Details

Forward travels : 5
 Reverse travels : 5
 Targets : 41
 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



Y axis positional results - As Found

Target Position	Error Averages (μm)		System	2σ Std Devn (μm)		Dead Zone
	Forward	Reverse		Forward	Reverse	
1.000	1.340	1.388	1.364	0.000	0.000	-0.048
21.000	0.831	0.970	0.900	0.000	0.000	-0.139
41.000	1.168	1.154	1.161	0.000	0.000	0.014
61.000	0.989	0.748	0.868	0.000	0.000	0.241
81.000	0.765	0.697	0.731	0.000	0.000	0.067
101.000	0.927	0.529	0.728	0.000	0.000	0.397
121.000	0.619	0.250	0.435	0.000	0.000	0.369
141.000	1.488	1.114	1.301	0.000	0.000	0.374
161.000	1.555	1.093	1.324	0.000	0.000	0.461
181.000	2.165	1.897	2.031	0.000	0.000	0.267
201.000	2.728	2.540	2.634	0.000	0.000	0.188
221.000	2.700	2.562	2.631	0.000	0.000	0.138
241.000	2.582	2.418	2.500	0.000	0.000	0.164
261.000	2.982	2.645	2.814	0.000	0.000	0.337
281.000	3.083	2.693	2.888	0.000	0.000	0.391
301.000	2.541	2.135	2.338	0.000	0.000	0.406
321.000	2.772	2.307	2.540	0.000	0.000	0.464
341.000	3.145	2.724	2.934	0.000	0.000	0.421
361.000	3.391	3.022	3.206	0.000	0.000	0.368
381.000	4.076	3.728	3.902	0.000	0.000	0.348
401.000	4.300	4.164	4.232	0.000	0.000	0.135

Analysis to ISO 230:Part 2:2006 Linear Positioning

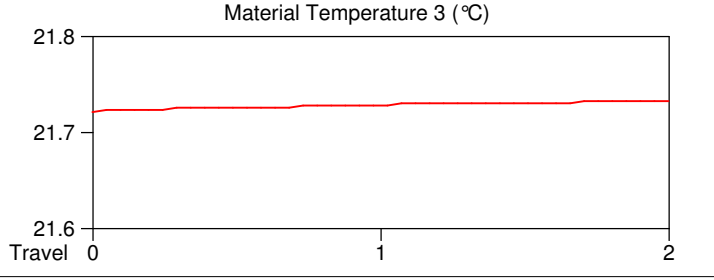
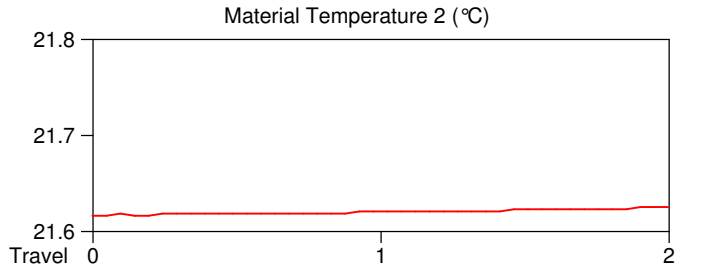
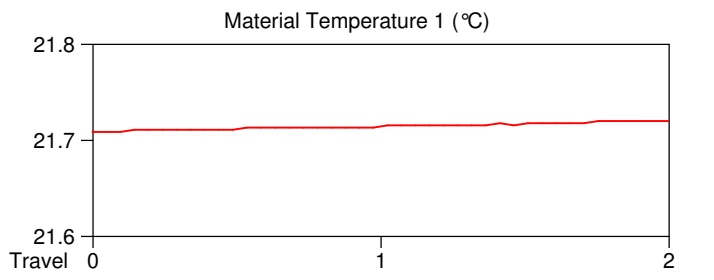
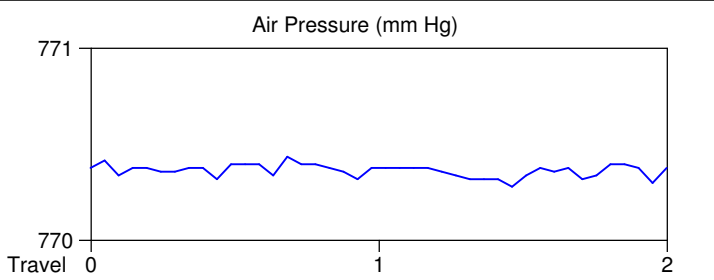
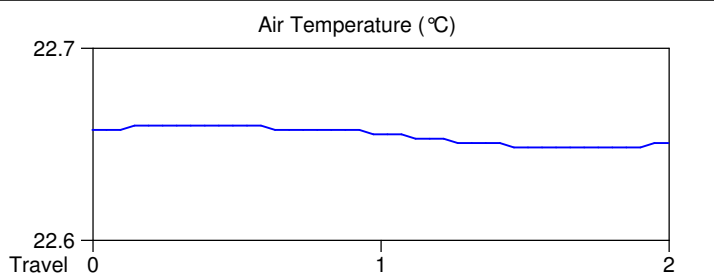
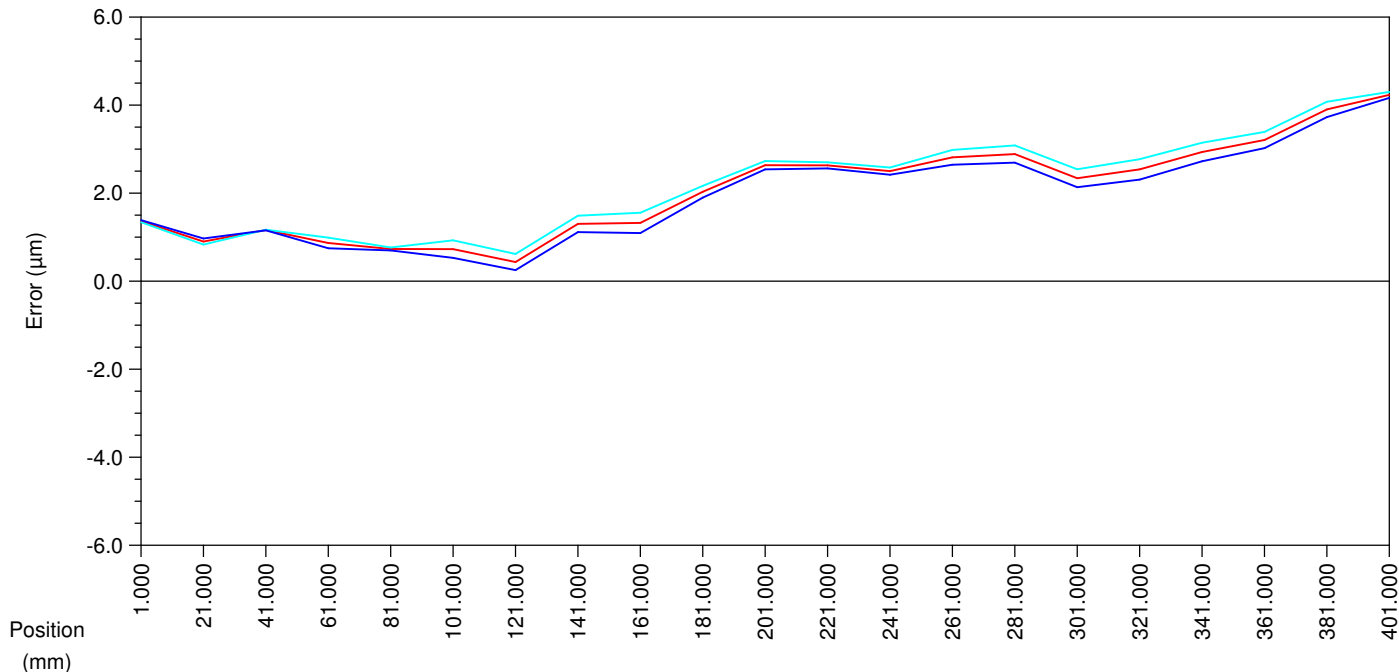
Mean reversal value	= 0.26 μm
Mean bidir positional devn	= 3.80 μm
Air pressure	= 770.28/770.44 mm Hg
Air humidity	= 50/50 % rel
Air temperature	= 22.648/22.660 $^{\circ}\text{C}$
M/C temperature	= 21.682/21.693 $^{\circ}\text{C}$
Exp coefficient (Scale)	= 8.0 ppm/ $^{\circ}\text{C}$
Air compensation	= 727.49/727.54 ppm
Total compensation	= 707.83/714.06 ppm
Traceability reference	= NPL LL0101/0709

Y AXIS POSITIONAL ERROR (ISO 230)

Machine : Bostomatic 32GS
 Serial No : 32-366
 Date : 19 Mar 2009 at 11:15
 Inspector : A J Gregory
 Customer : Thomas Keating Ltd

Mean bidir positional devn = 3.80 μm
 Mean Reversal Value = 0.26 μm
 As Found

— Sys Avg — For Avg — Rev Avg



Test Details

Forward travels : 1
 Reverse travels : 1
 Targets : 21
 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



Y axis positional results - No Compensation

Target Position	Error Averages (μm)		System	2 σ Std Devn (μm)		Dead Zone
	Forward	Reverse		Forward	Reverse	
1.000	-0.050	0.068	0.009	0.271	0.225	-0.118
21.000	-0.282	-0.304	-0.293	0.174	0.117	0.022
41.000	0.452	0.443	0.447	0.260	0.185	0.008
61.000	1.601	1.492	1.546	0.080	0.040	0.109
81.000	3.171	3.051	3.111	0.288	0.196	0.119
101.000	4.827	4.643	4.735	0.087	0.085	0.184
121.000	6.505	6.287	6.396	0.244	0.176	0.218
141.000	7.040	6.792	6.916	0.186	0.155	0.248
161.000	6.759	6.490	6.624	0.222	0.185	0.269
181.000	5.885	5.619	5.752	0.198	0.124	0.265
201.000	5.150	4.893	5.021	0.284	0.163	0.257
221.000	3.622	3.397	3.509	0.308	0.212	0.225
241.000	2.454	2.177	2.315	0.124	0.129	0.277
261.000	1.840	1.539	1.689	0.432	0.341	0.301
281.000	1.618	1.309	1.463	0.221	0.172	0.309
301.000	1.961	1.640	1.800	0.415	0.204	0.321
321.000	2.587	2.179	2.383	0.138	0.116	0.409
341.000	3.754	3.344	3.549	0.319	0.248	0.410
361.000	4.698	4.362	4.530	0.128	0.114	0.336
381.000	5.560	5.249	5.405	0.203	0.240	0.312
401.000	5.527	5.464	5.495	0.205	0.190	0.063

Analysis to ISO 230:Part 2:2006 Linear Positioning

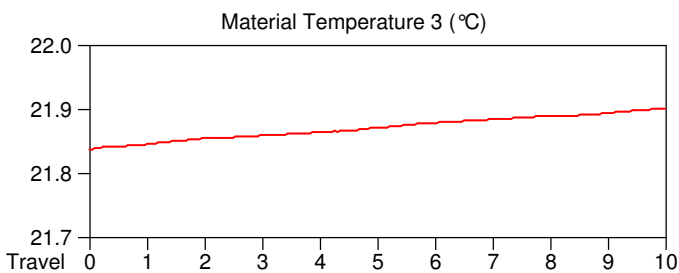
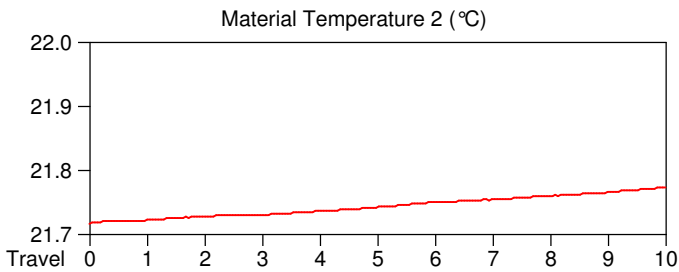
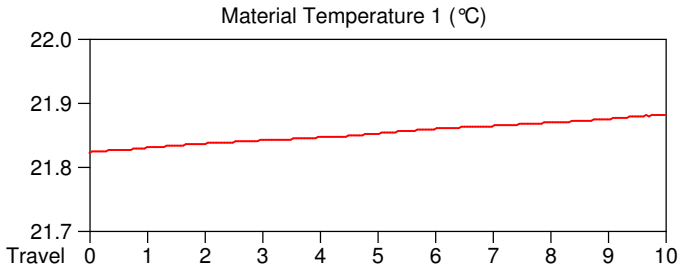
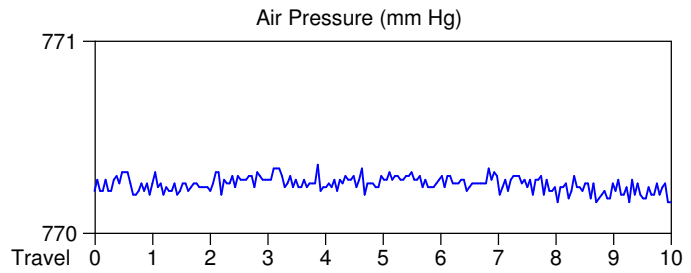
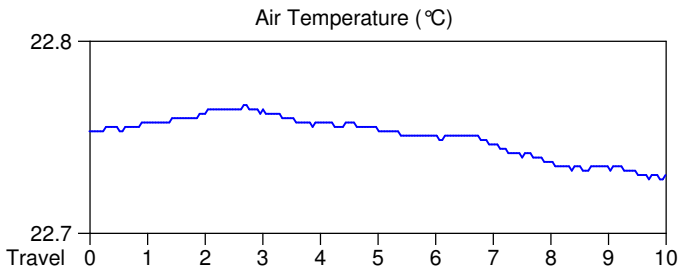
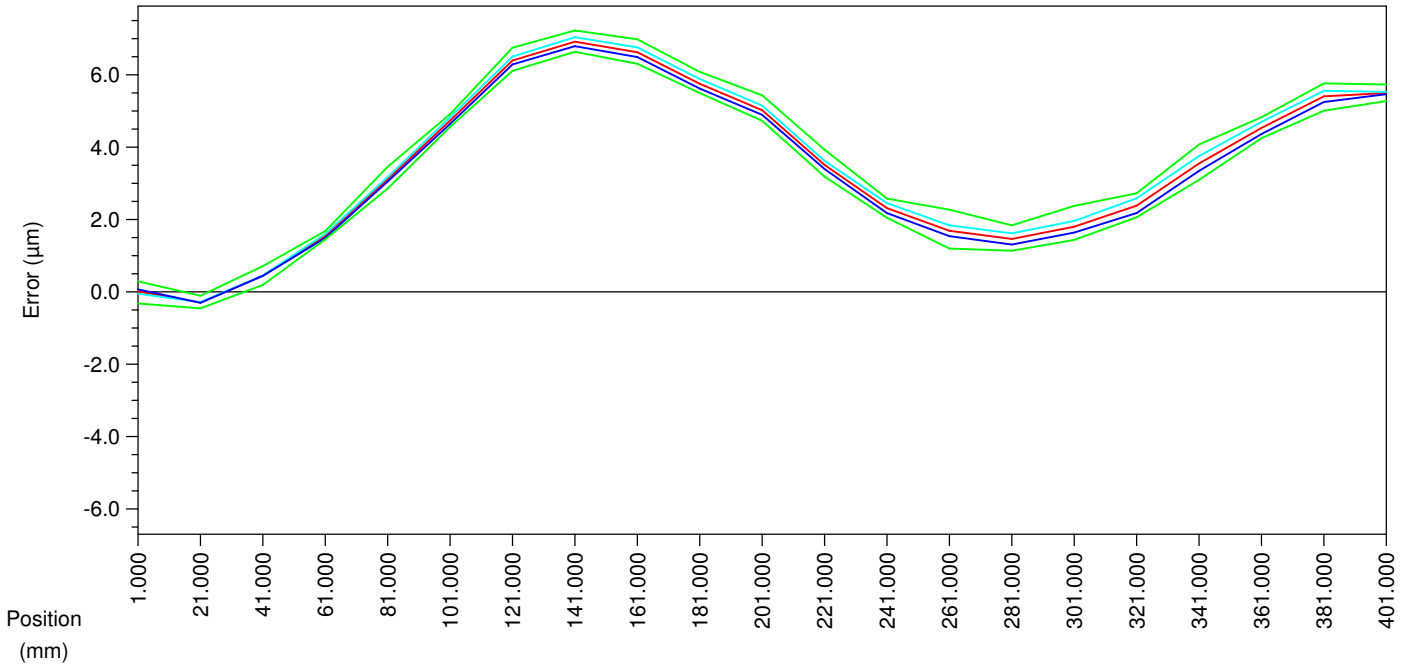
Accuracy	= 7.68 μm
Unidirectional repeatability	= 0.86 μm at 261.000 mm, forward direction
Bidirectional Repeatability	= 1.07 μm at 261.000 mm
Mean reversal value	= 0.22 μm
Mean bidir positional devn	= 7.21 μm
Air pressure	= 770.16/770.36 mm Hg
Air humidity	= 50/50 % rel
Air temperature	= 22.728/22.767 $^{\circ}\text{C}$
M/C temperature	= 21.792/21.852 $^{\circ}\text{C}$
Exp coefficient (Scale)	= 8.0 ppm/ $^{\circ}\text{C}$
Air compensation	= 727.61/727.67 ppm
Total compensation	= 706.68/713.32 ppm
Traceability reference	= NPL LL0101/0709

Y AXIS POSITIONAL ERROR (ISO 230)

Machine : Bostomatic 32GS
 Serial No : 32-366
 Date : 19 Mar 2009 at 11:47
 Inspector : A J Gregory
 Customer : Thomas Keating Ltd

Accuracy = 7.68 μm
 Uni-Direction Repeat = 0.86 μm
 Bi-Direction Repeat = 1.07 μm
 Mean Reversal Value = 0.22 μm
 No Compensation

— Sys Avg — For Avg — Rev Avg — +2 Sigma — -2 Sigma



Test Details

Forward travels : 5
 Reverse travels : 5
 Targets : 21
 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



Y axis positional results - With Compensation

Target Position	Error Averages (μm)			2σ Std Devn (μm)			Dead Zone
	Forward	Reverse	System	Forward	Reverse		
1.000	-0.191	-0.212	-0.202	0.126	0.226		0.021
21.000	-0.579	-0.703	-0.641	0.212	0.230		0.124
41.000	-0.446	-0.559	-0.503	0.117	0.015		0.113
61.000	-0.376	-0.574	-0.475	0.159	0.088		0.198
81.000	-0.058	-0.246	-0.152	0.110	0.088		0.188
101.000	0.109	-0.188	-0.040	0.350	0.226		0.298
121.000	0.256	-0.030	0.113	0.072	0.069		0.286
141.000	0.049	-0.254	-0.102	0.231	0.152		0.303
161.000	-0.117	-0.408	-0.263	0.108	0.180		0.291
181.000	0.052	-0.339	-0.144	0.351	0.331		0.391
201.000	-0.285	-0.582	-0.434	0.138	0.143		0.297
221.000	-0.174	-0.489	-0.331	0.237	0.280		0.315
241.000	-0.386	-0.673	-0.530	0.113	0.169		0.287
261.000	-0.428	-0.759	-0.593	0.070	0.113		0.331
281.000	-0.574	-0.911	-0.743	0.228	0.203		0.337
301.000	-0.402	-0.704	-0.553	0.142	0.161		0.303
321.000	-0.301	-0.721	-0.511	0.260	0.257		0.420
341.000	-0.277	-0.676	-0.477	0.236	0.222		0.399
361.000	-0.377	-0.786	-0.581	0.169	0.138		0.408
381.000	-0.117	-0.462	-0.289	0.135	0.102		0.345
401.000	-0.120	-0.276	-0.198	0.151	0.132		0.156

Analysis to ISO 230:Part 2:2006 Linear Positioning

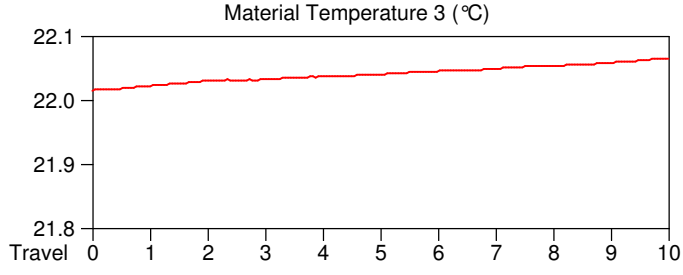
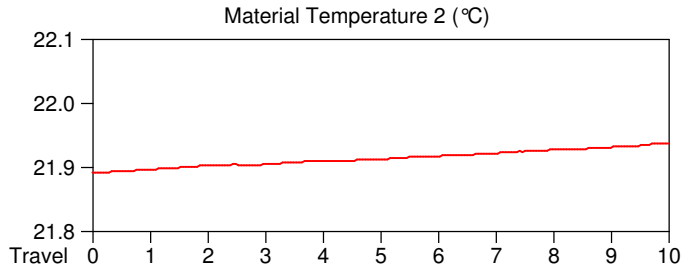
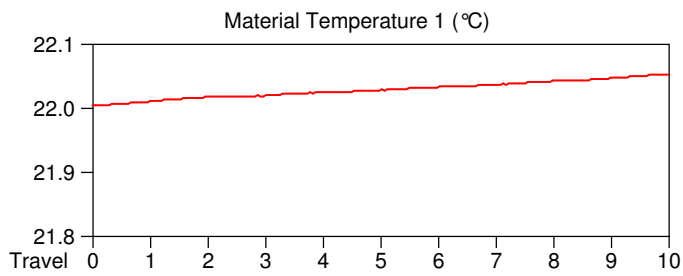
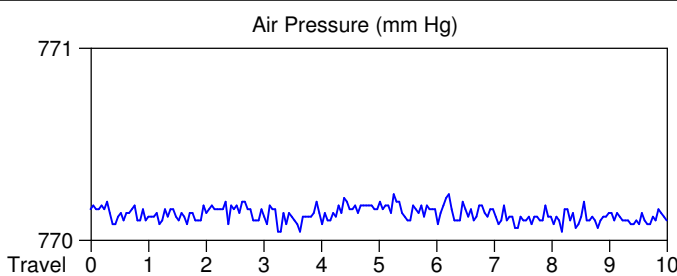
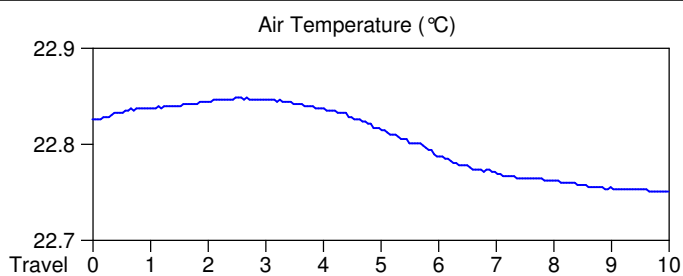
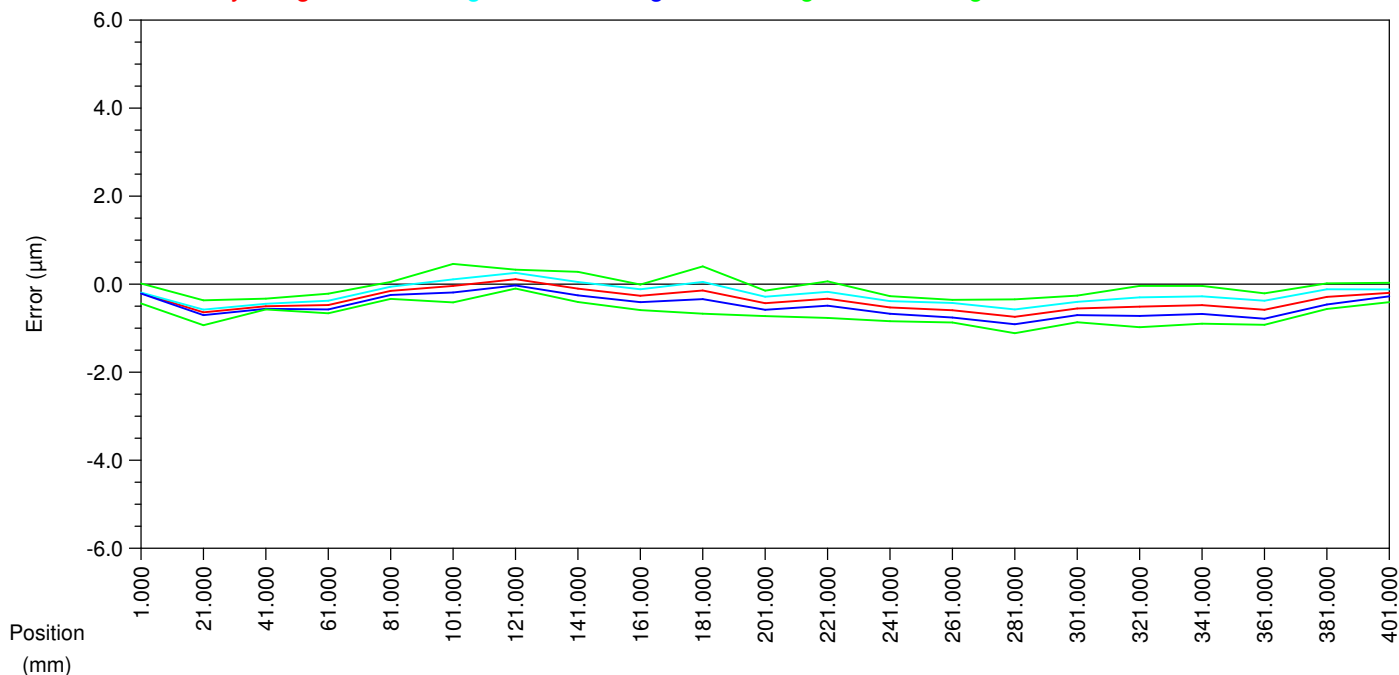
Accuracy	= 1.57 μm
Unidirectional repeatability	= 0.70 μm at 181.000 mm, forward direction
Bidirectional Repeatability	= 1.07 μm at 181.000 mm
Mean reversal value	= 0.28 μm
Mean bidir positional devn	= 0.86 μm
Air pressure	= 770.05/770.24 mm Hg
Air humidity	= 50/50 % rel
Air temperature	= 22.751/22.849 $^{\circ}\text{C}$
M/C temperature	= 21.971/22.019 $^{\circ}\text{C}$
Exp coefficient (Scale)	= 8.0 ppm/ $^{\circ}\text{C}$
Air compensation	= 727.66/727.81 ppm
Total compensation	= 704.68/712.00 ppm
Traceability reference	= NPL LL0101/0709

Y AXIS POSITIONAL ERROR (ISO 230)

Machine : Bostomatic 32GS
 Serial No : 32-366
 Date : 19 Mar 2009 at 12:44
 Inspector : A J Gregory
 Customer : Thomas Keating Ltd

Accuracy = 1.57 μm
 Uni-Direction Repeat = 0.70 μm
 Bi-Direction Repeat = 1.07 μm
 Mean Reversal Value = 0.28 μm
 With Compensation

— Sys Avg — For Avg — Rev Avg — +2 Sigma — -2 Sigma



Test Details

Forward travels : 5
 Reverse travels : 5
 Targets : 21
 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



Z axis positional results - As Found

Target Position	Error Averages (μm)			2 σ Std Devn (μm)		Dead Zone
	Forward	Reverse	System	Forward	Reverse	
29.000	-0.064	-1.187	-0.625	0.000	0.000	1.123
53.000	-0.231	-1.449	-0.840	0.000	0.000	1.218
77.000	-0.052	-1.152	-0.602	0.000	0.000	1.100
101.000	-0.266	-1.201	-0.734	0.000	0.000	0.935
125.000	-0.002	-0.952	-0.477	0.000	0.000	0.950
149.000	-0.226	-1.011	-0.618	0.000	0.000	0.786
173.000	0.653	-0.495	0.079	0.000	0.000	1.148
197.000	1.006	-0.166	0.420	0.000	0.000	1.171
221.000	0.751	-0.575	0.088	0.000	0.000	1.326
245.000	1.113	-0.356	0.379	0.000	0.000	1.469
269.000	1.825	0.317	1.071	0.000	0.000	1.507
293.000	1.794	0.250	1.022	0.000	0.000	1.544
317.000	1.276	-0.436	0.420	0.000	0.000	1.712
341.000	0.841	-0.696	0.073	0.000	0.000	1.537
365.000	1.275	-0.157	0.559	0.000	0.000	1.432
389.000	1.495	0.177	0.836	0.000	0.000	1.318
413.000	1.507	0.106	0.806	0.000	0.000	1.401
437.000	2.006	0.306	1.156	0.000	0.000	1.700
461.000	1.857	0.025	0.941	0.000	0.000	1.831
485.000	2.443	0.427	1.435	0.000	0.000	2.015
509.000	1.608	0.169	0.889	0.000	0.000	1.439

Analysis to ISO 230:Part 2:2006 Linear Positioning

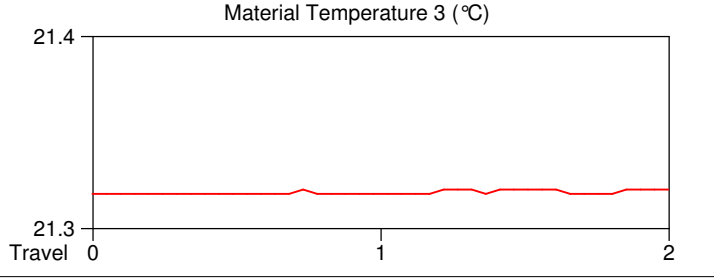
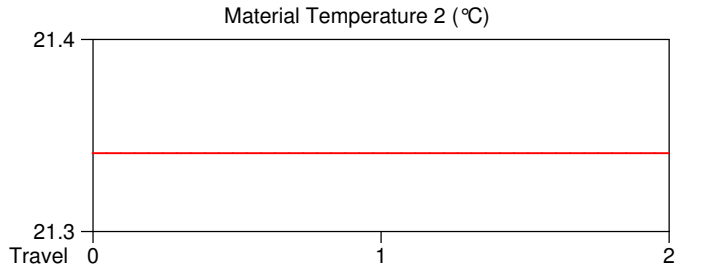
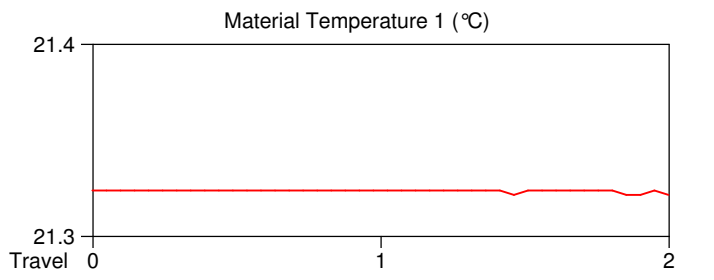
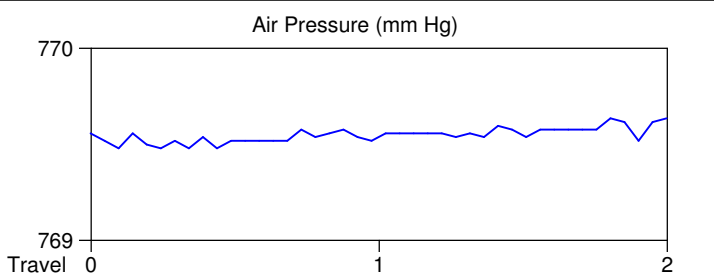
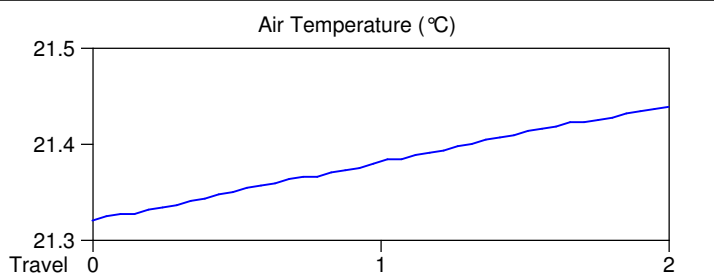
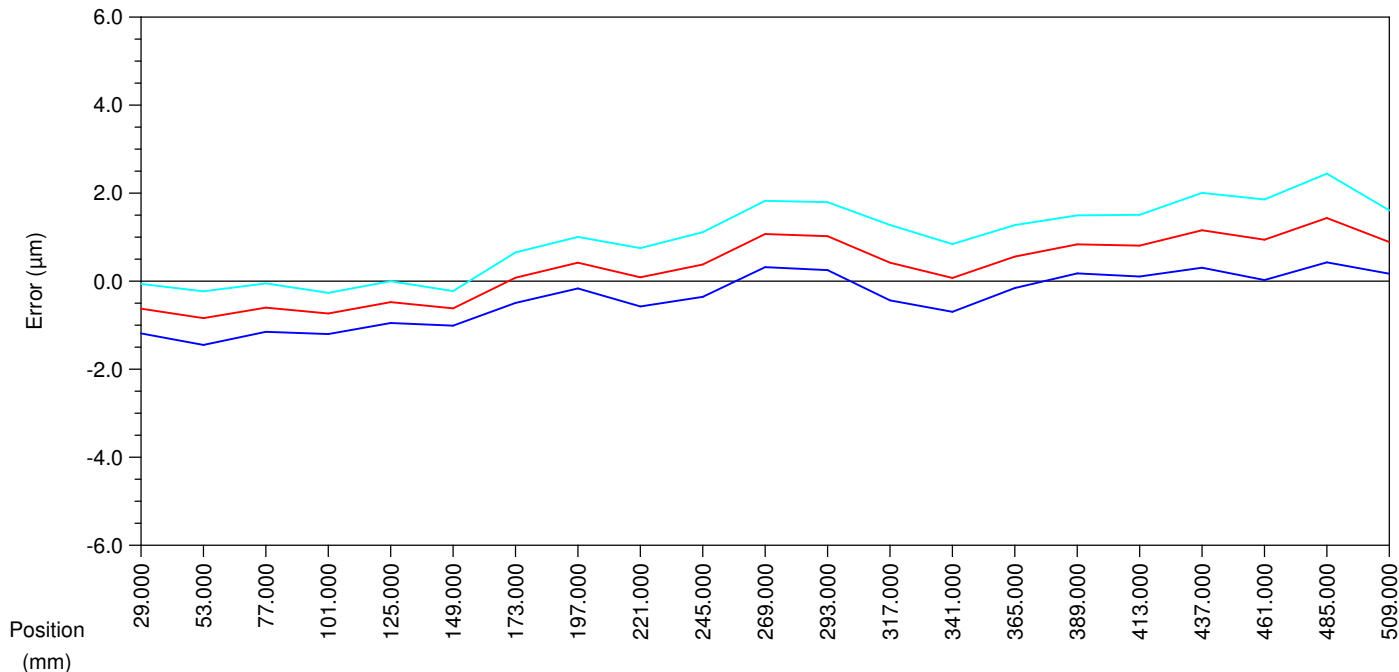
Mean reversal value	= 1.36 μm
Mean bidir positional devn	= 2.27 μm
Air pressure	= 769.48/769.64 mm Hg
Air humidity	= 50/50 % rel
Air temperature	= 21.314/21.439 $^{\circ}\text{C}$
M/C temperature	= 21.328/21.328 $^{\circ}\text{C}$
Exp coefficient (Scale)	= 8.0 ppm/ $^{\circ}\text{C}$
Air compensation	= 726.53/726.66 ppm
Total compensation	= 710.99/716.04 ppm
Traceability reference	= NPL LL0101/0709

Z AXIS POSITIONAL ERROR (ISO 230)

Machine : Bostomatic 32GS
 Serial No : 32-366
 Date : 19 Mar 2009 at 8:23
 Inspector : A J Gregory
 Customer : Thomas Keating Ltd

Mean bidir positional devn = 2.27 μm
 Mean Reversal Value = 1.36 μm
 As Found

— Sys Avg — For Avg — Rev Avg



Test Details

Forward travels : 1
 Reverse travels : 1
 Targets : 21
 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 - No Compensation

Target Position	Error Averages (μm)			2σ Std Devn (μm)			Dead Zone
	Forward	Reverse	System	Forward	Reverse		
29.000	1.360	0.389	0.875	1.109	0.666	0.971	
53.000	-1.014	-1.757	-1.386	0.592	0.600	0.743	
77.000	-2.319	-3.128	-2.723	0.459	0.548	0.809	
101.000	-2.982	-3.525	-3.254	0.723	0.446	0.543	
125.000	-4.112	-4.779	-4.445	0.726	0.523	0.667	
149.000	-5.141	-5.855	-5.498	0.536	0.383	0.714	
173.000	-5.270	-6.130	-5.700	0.448	0.425	0.860	
197.000	-6.626	-7.626	-7.126	0.532	0.477	1.000	
221.000	-8.324	-9.452	-8.888	0.467	0.407	1.128	
245.000	-9.067	-10.472	-9.770	0.483	0.407	1.405	
269.000	-9.458	-10.940	-10.199	0.416	0.501	1.482	
293.000	-10.102	-11.520	-10.811	0.483	0.482	1.418	
317.000	-9.904	-11.473	-10.689	0.423	0.373	1.570	
341.000	-9.734	-11.263	-10.498	0.352	0.380	1.529	
365.000	-10.775	-12.222	-11.499	0.427	0.535	1.447	
389.000	-11.674	-12.934	-12.304	0.604	0.611	1.260	
413.000	-11.935	-13.265	-12.600	0.380	0.483	1.329	
437.000	-13.195	-14.809	-14.002	0.334	0.357	1.614	
461.000	-14.533	-16.262	-15.397	0.350	0.350	1.729	
485.000	-14.536	-16.337	-15.437	0.917	0.852	1.801	
509.000	-14.932	-16.288	-15.610	1.061	1.040	1.356	

Analysis to ISO 230:Part 2:2006 Linear Positioning

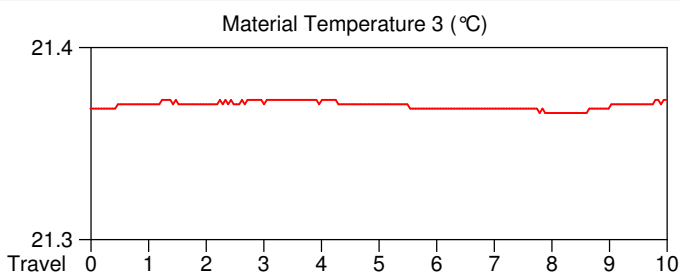
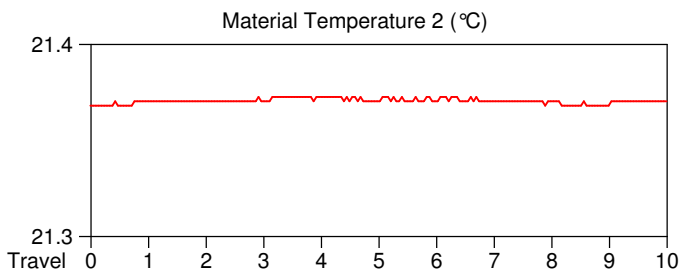
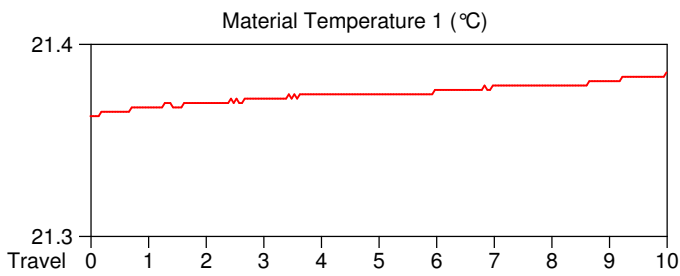
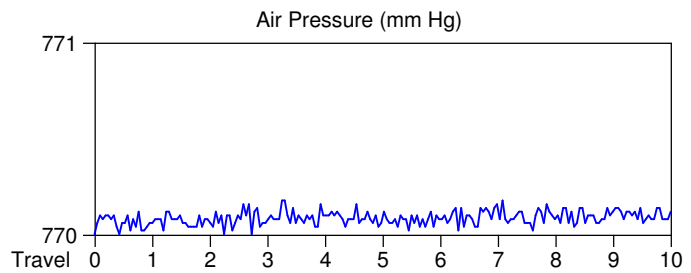
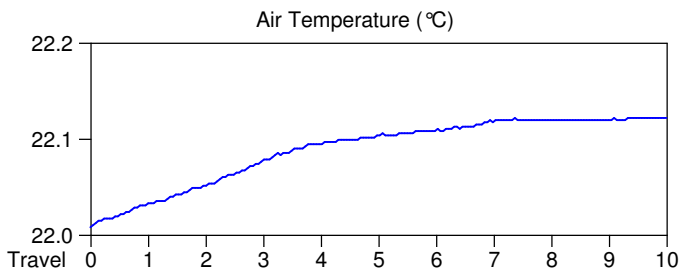
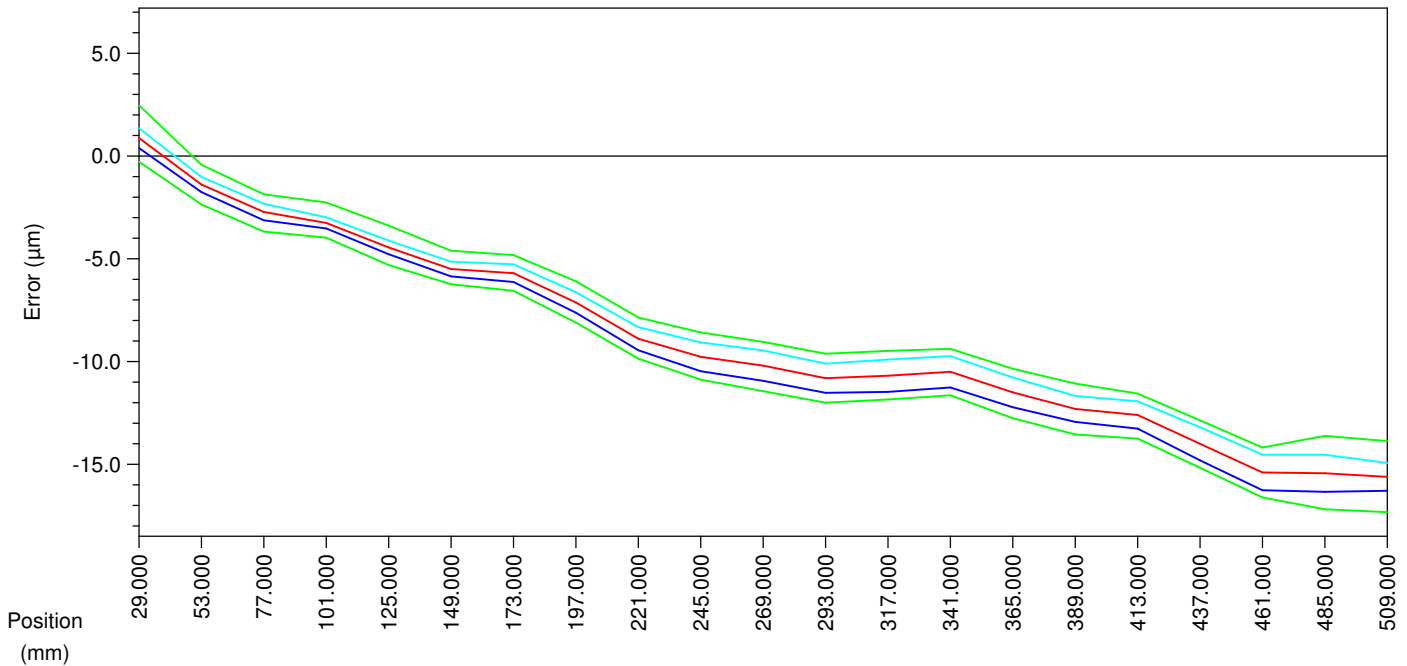
Accuracy	= 19.80 μm
Unidirectional repeatability	= 2.22 μm at 29.000 mm, forward direction
Bidirectional Repeatability	= 3.57 μm at 485.000 mm
Mean reversal value	= 1.21 μm
Mean bidir positional devn	= 16.48 μm
Air pressure	= 770.01/770.18 mm Hg
Air humidity	= 50/50 % rel
Air temperature	= 22.004/22.122 $^{\circ}\text{C}$
M/C temperature	= 21.366/21.376 $^{\circ}\text{C}$
Exp coefficient (Scale)	= 8.0 ppm/ $^{\circ}\text{C}$
Air compensation	= 727.00/727.13 ppm
Total compensation	= 711.04/716.15 ppm
Traceability reference	= NPL LL0101/0709

Z AXIS POSITIONAL ERROR (ISO 230)

Machine : Bostomatic 32GS
 Serial No : 32-366
 Date : 19 Mar 2009 at 8:52
 Inspector : A J Gregory
 Customer : Thomas Keating Ltd

Accuracy = 19.80 μm
 Uni-Direction Repeat = 2.22 μm
 Bi-Direction Repeat = 3.57 μm
 Mean Reversal Value = 1.21 μm
 No Compensation

— Sys Avg — For Avg — Rev Avg — +2 Sigma — -2 Sigma



Test Details

Forward travels : 5
 Reverse travels : 5
 Targets : 21
 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)		System	2σ Std Devn (μm)		Dead Zone
	Forward	Reverse		Forward	Reverse	
29.000	-0.333	-1.532	-0.933	0.492	0.631	1.200
53.000	-0.962	-1.640	-1.301	0.440	0.389	0.678
77.000	-0.503	-1.224	-0.863	0.521	0.594	0.720
101.000	-0.981	-1.664	-1.322	0.409	0.524	0.683
125.000	-1.187	-2.003	-1.595	0.954	0.691	0.816
149.000	-0.753	-1.529	-1.141	0.588	0.675	0.776
173.000	-0.480	-1.484	-0.982	0.513	0.633	1.004
197.000	-0.464	-1.513	-0.989	0.613	0.618	1.049
221.000	-0.547	-1.780	-1.163	0.796	0.817	1.233
245.000	-1.019	-2.476	-1.748	0.643	0.713	1.457
269.000	-0.839	-2.434	-1.636	0.483	0.578	1.595
293.000	-0.696	-2.197	-1.446	0.535	0.455	1.502
317.000	-0.624	-2.363	-1.493	0.649	0.696	1.739
341.000	-0.578	-2.195	-1.387	0.601	0.649	1.617
365.000	-0.268	-1.930	-1.099	0.655	0.700	1.662
389.000	-0.773	-2.257	-1.515	0.600	0.629	1.483
413.000	-0.680	-2.287	-1.484	0.806	0.782	1.607
437.000	-0.207	-2.085	-1.146	0.723	0.793	1.878
461.000	-0.425	-2.423	-1.424	0.751	0.755	1.998
485.000	-0.511	-2.559	-1.535	0.580	0.490	2.048
509.000	-0.255	-1.631	-0.943	0.508	0.491	1.376

Analysis to ISO 230:Part 2:2006 Linear Positioning

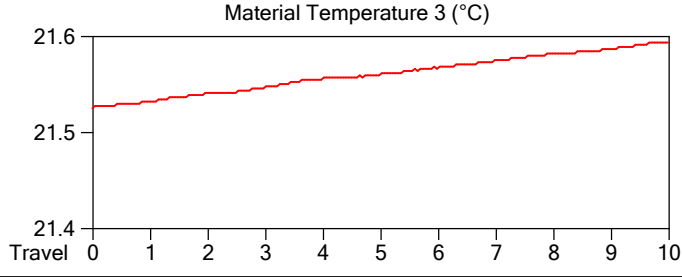
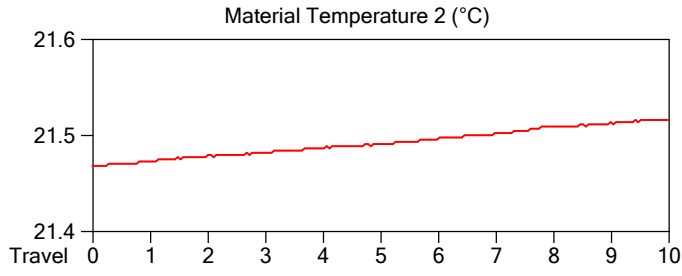
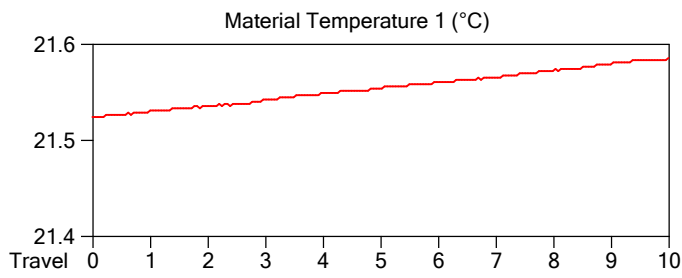
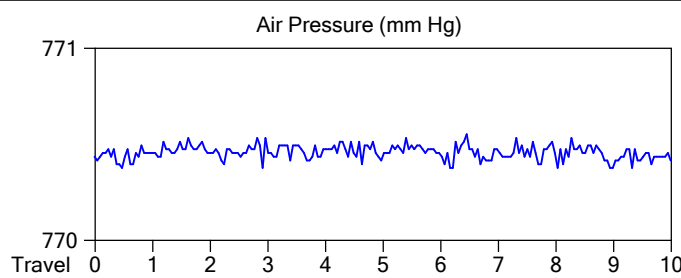
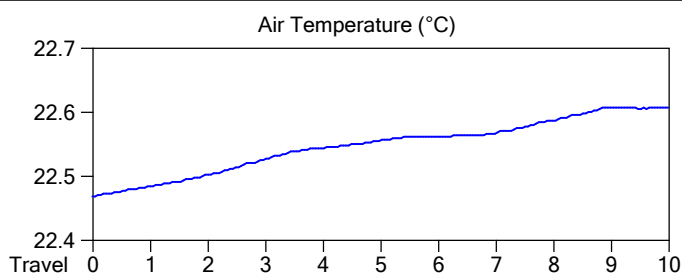
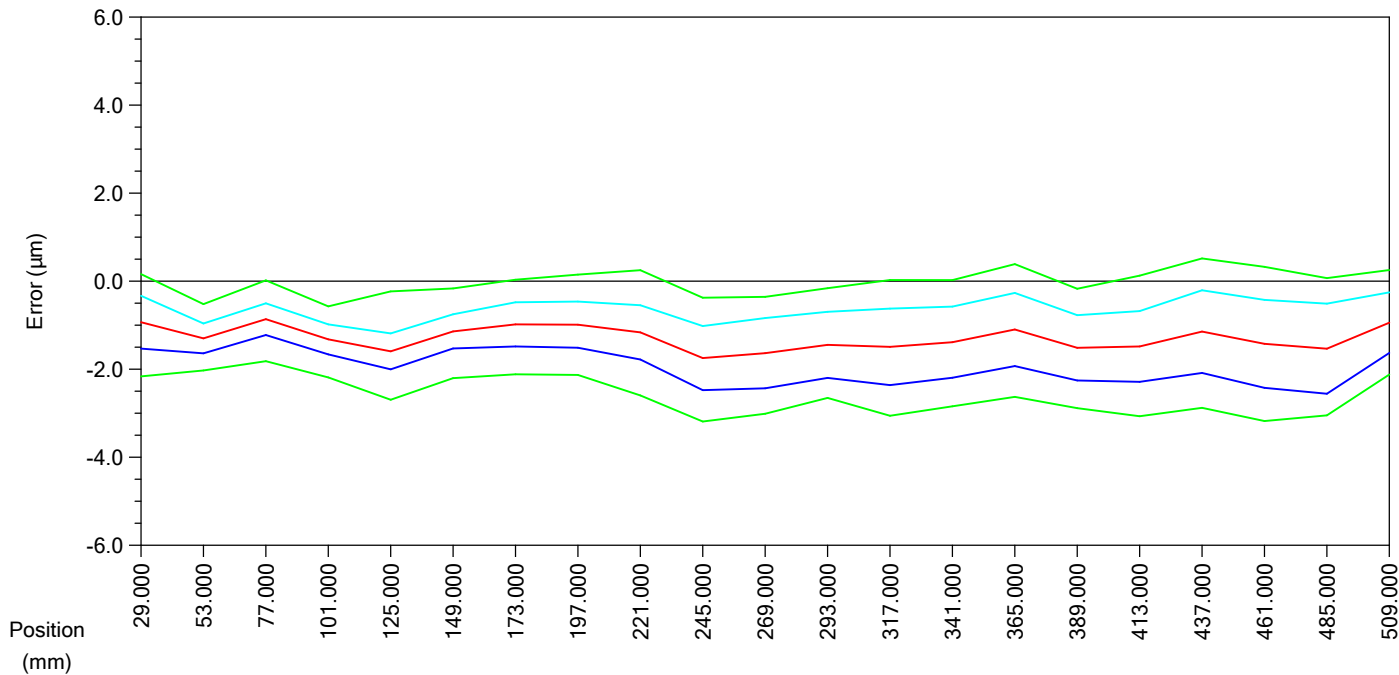
Accuracy	= 3.70 μm
Unidirectional repeatability	= 1.91 μm at 125.000 mm, forward direction
Bidirectional Repeatability	= 3.50 μm at 461.000 mm
Mean reversal value	= 1.34 μm
Mean bidir positional devn	= 0.88 μm
Air pressure	= 770.38/770.55 mm Hg
Air humidity	= 50/50 % rel
Air temperature	= 22.468/22.607 $^{\circ}\text{C}$
M/C temperature	= 21.506/21.565 $^{\circ}\text{C}$
Exp coefficient (Scale)	= 8.0 ppm/ $^{\circ}\text{C}$
Air compensation	= 727.30/727.46 ppm
Total compensation	= 709.69/715.27 ppm
Traceability reference	= NPL LL0101/0709

Z AXIS POSITIONAL ERROR (ISO 230)

Machine : Bostomatic 32GS
 Serial No : 32-366
 Date : 19 Mar 2009 at 10:19
 Inspector : A J Gregory
 Customer : Thomas Keating Ltd

Accuracy = 3.70 μm
 Uni-Direction Repeat = 1.91 μm
 Bi-Direction Repeat = 3.50 μm
 Mean Reversal Value = 1.34 μm
 With Compensation

— Sys Avg — For Avg — Rev Avg — +2 Sigma — -2 Sigma



Test Details

Forward travels : 5
 Reverse travels : 5
 Targets : 21
 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



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**
Chomlea House, Hadfield Road, Hadfield, Glossop, Derbyshire, SK13 2ER.
Telephone : 01457 852929 Facsimile : 01457 860619
Email : calibration@cdmeasurements.com



0334

Certificate Number : 02665
Date of Issue : 27 Mar 2009
Basis of Test : ISO 230:Part 2:2006 Linear Positioning

Page 1 of 2 Pages

Approved Signatory

A. Butterworth

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

Machine : Bostomatic 32GS

Serial No : 32-366

Method : This machine was calibrated on 19 Mar 2009 at the above site location as follows:-
Agilent 5529 laser interferometer and the above specification.
The results corrected to 20 °C are shown on the following sheet.

Uncertainty : $\pm (0.15 \mu\text{m} + 2.17 \mu\text{m}/\text{metre})$

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.

This certificate is issued in accordance with the laboratory accreditation requirements of the United Kingdom Accreditation Service. It provides traceability of measurement to recognised national standards, and to units of measurement realised at the National Physical Laboratory or other recognised national standards laboratories. This certificate may not be reproduced other than in full, except with the prior written approval of the issuing laboratory.

CERTIFICATE OF CALIBRATION

UKAS ACCREDITED CALIBRATION LABORATORY No. 0334

Date of Issue
27 Mar 2009

Certificate Number
02665

Page 2 of 2 Pages

X axis positional results : Tested from 801.0mm to 1.0mm @ Y144.9 Z62.5
: With Compensation

Accuracy	= 3.20 μm
Unidirectional repeatability	= 1.33 μm at 801.000 mm, reverse direction
Bidirectional Repeatability	= 1.49 μm at 421.000 mm
Mean reversal value	= 0.36 μm
Mean bidir positional devn	= 1.93 μm

Air pressure	= 770.34/770.53 mm Hg
Air humidity	= 50/50 % rel
Air temperature	= 22.334/22.491 $^{\circ}\text{C}$
M/C temperature	= 22.178/22.204 $^{\circ}\text{C}$
Exp coefficient (Scale)	= 8.0 ppm/ $^{\circ}\text{C}$
Air compensation	= 727.17/727.34 ppm
Total compensation	= 701.85/709.91 ppm

Y axis positional results : Tested from 1.0mm to 401.0mm @ X421.7 Z65.7
: With Compensation

Accuracy	= 1.57 μm
Unidirectional repeatability	= 0.70 μm at 181.000 mm, forward direction
Bidirectional Repeatability	= 1.07 μm at 181.000 mm
Mean reversal value	= 0.28 μm
Mean bidir positional devn	= 0.86 μm

Air pressure	= 770.05/770.24 mm Hg
Air humidity	= 50/50 % rel
Air temperature	= 22.751/22.849 $^{\circ}\text{C}$
M/C temperature	= 21.971/22.019 $^{\circ}\text{C}$
Exp coefficient (Scale)	= 8.0 ppm/ $^{\circ}\text{C}$
Air compensation	= 727.66/727.81 ppm
Total compensation	= 704.68/712.00 ppm

Z axis positional results : Tested from 29.0mm to 509.0mm @ X428.8 Y185.5
: With Compensation

Accuracy	= 3.70 μm
Unidirectional repeatability	= 1.91 μm at 125.000 mm, forward direction
Bidirectional Repeatability	= 3.50 μm at 461.000 mm
Mean reversal value	= 1.34 μm
Mean bidir positional devn	= 0.88 μm

Air pressure	= 770.38/770.55 mm Hg
Air humidity	= 50/50 % rel
Air temperature	= 22.468/22.607 $^{\circ}\text{C}$
M/C temperature	= 21.506/21.565 $^{\circ}\text{C}$
Exp coefficient (Scale)	= 8.0 ppm/ $^{\circ}\text{C}$
Air compensation	= 727.30/727.46 ppm
Total compensation	= 709.69/715.27 ppm