Evaluation of a Dual Beam Laser Doppler Displacement Meter Retrofitted to a Coordinate Measuring Machine

Federal Manufacturing & Technologies

S. J. Ramsdale and
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Final Report
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Abstract

A dual beam laser Doppler displacement measuring system was mounted to a fixed-table, cantilever-type coordinate measuring machine (CMM) to establish the feasibility of real time angular error correction for each CMM axis. The performance improvement was evaluated relative to the CMM's standard scales. The dual beam system proved to have no advantage over a single beam laser due to an inability to measure the actual angular errors at the probe location, but showed potential for substantial accuracy improvement over the standard CMM scales when geometry errors were software corrected.

Summary

This project was initiated at the request of Optodyne, Inc. through the Department of Energy's National Machine Tool Partnership Program. The primary purpose was to determine the feasibility of real time angular geometry correction in coordinate measurement using a dual beam laser Doppler displacement measuring (LDDM) system. The experiment was performed on a fixed-table, cantilever-type coordinate measuring machine (CMM) which normally uses linear scales as its displacement measuring system.

The experiment was designed to take data from the CMM's scales and the LDDM system at the same time to provide a fair evaluation of their relative performance. The LDDM was temporarily mounted on the CMM in such a way as to ensure the CMM's restoration to normal service at the conclusion of the project. The laser heads of the LDDM system were mounted to measure linear displacement and yaw angle in the X axis, linear displacement and pitch angle in the Y axis, and linear displacement only in the Z axis.

The CMM was controlled and the scale data taken using the normal data collection software running on the system controller. The LDDM system was interfaced to the touch trigger probe via a personal computer, which was performing data collection for the LDDM at the same time as the CMM controller. The evaluation standard used for the project was a three-dimensional coordinate standard (ball plate) certified to an accuracy of ±(30 microinches + 2 ppm).

Data collection was performed with the ball plate placed flat on the machine on the machine table and flat approximately 9.5 inches above the machine table. Using the flat positions maximized the ability of the experiment to evaluate X and Y axis angular corrections and minimized the influence of a large amount of vibration in the Z axis. Three runs were taken at each position.

Analysis of the raw linear data showed that the CMM's scale data had a much lower uncertainty than the LDDM data. After correcting for measured angular error, the LDDM's calculated uncertainty was much lower, but still higher than the scale and higher than expected. Also, the form error of the individual measurements for the LDDM data was higher than that of the scale data.

Further analysis and troubleshooting showed that the angular correction did not perform as hoped because the angular error at the location of the LDDM was different than that at the probe location. However, it was shown that using linear and squareness corrections in the software would provide an accuracy improvement of 25 to 38 percent using the LDDM as compared to the CMM's scales.

Discussion

Scope and Purpose

This project was initiated at the request of Optodyne, Inc. under the Department of Energy's (DOE) National Machine Tool Partnership (NMTP) program. The purpose of the NMTP program is for DOE to partner with industry in order to develop machine tool technology. Specifically, this project was initiated to determine the feasibility of real time angular geometry correction in coordinate measurement using a dual beam laser Doppler displacement measuring (LDDM) system.

The selection of the coordinate measuring machine (CMM) used and the design of the experiment were limited by the temporary nature of the project. The CMM had to be available for several months and had to be restored to its original configuration. Therefore, no modifications were made to the CMM's controller or its physical structure.

Activity

Background

The AlliedSignal Federal Manufacturing & Technology Dimensional Metrology group has extensive experience in the application of laser interferometer systems in all areas of dimensional measurement. Optodyne had previously requested technical assistance on the evaluation of an LDDM on a single-axis measuring machine compared to other displacement measuring systems. Additionally, the Dimensional Metrology group has extensive experience in the calibration and evaluation of CMM uncertainties. Because of these factors, Optodyne initiated this project.

LDDM Theory of Operation[1]

The LDDM is based on the principles of radar, the Doppler effect, and optical heterodyning. Basically, a retroreflector is illuminated by a helium-neon laser beam. The laser beam reflected by the retroreflector is frequency shifted by the motion of the retroreflector, and the phase of the reflected laser beam is proportional to the position of the retroreflector. That is,

$$X = \frac{c}{2f}\left(N + \frac{phi}{2\pi}\right)$$

where X is the position of the retroreflector,
c is the speed of light,
f is the laser frequency,
N is the number of 2π's and
phi is the phase angle.

The dual beam system consists of two exit laser beams from each laser head, two return beams, and two retroreflectors. The separation of the two laser beams and retroreflectors is a known distance. By comparing the difference in retroreflector position between the two laser beams, the angle can be calculated. Like laser interferometer systems, the LDDM must be compensated for the refractive index of air in non-standard conditions. The dual beam LDDM is shown in Figure 1.

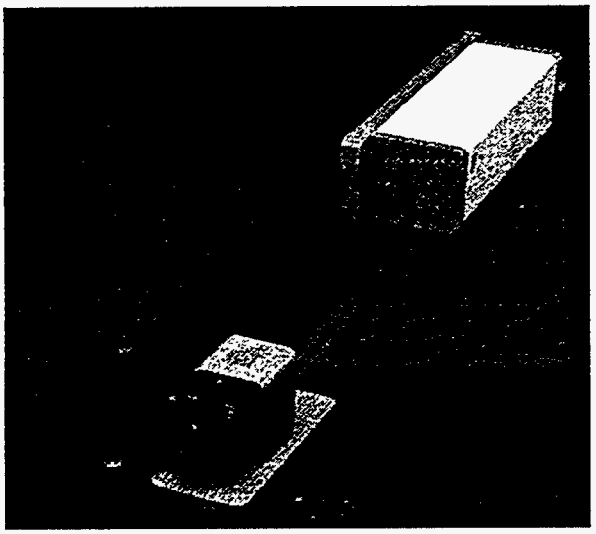

Figure 1. Dual Beam LDDM

Experiment Equipment Setup

CMM Laser Installation

The CMM selected for the experiment was a fixed-table, cantilever-type Cordax 803 direct computer-controlled machine. (See Figure 2.) This CMM was selected due to its availability and its design. This type of CMM seemed to be a logical candidate for real time angular correction because of the large Abbe offset in both the X and Y axes and because its geometry is not as stable as other CMMs, such as a fixed-bridge type. On a CMM with a more stable geometry, mapping out the errors through the operating software, would likely be a better way to improve the accuracy.

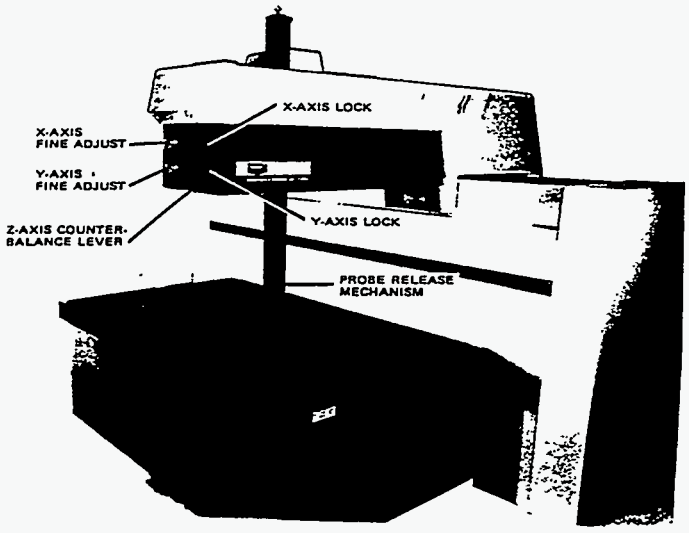

Figure 2. Cordax 803 DCC CMM

Dual beam laser heads and processors were used for the X and Y axes. Because the Z axis had less likelihood of angular errors and a much smaller Abbe offset, a single beam laser was used. The lasers were installed on the CMM as shown in Figures 3 and 4. On the X axis, the laser head was installed oriented to measure yaw. The yaw orientation was selected due to the large Abbe offset and the probability of angular errors in this direction. The Y axis laser head was oriented to measure pitch. The pitch orientation in this axis was selected due to large Abbe offset and a high probability of angular errors.

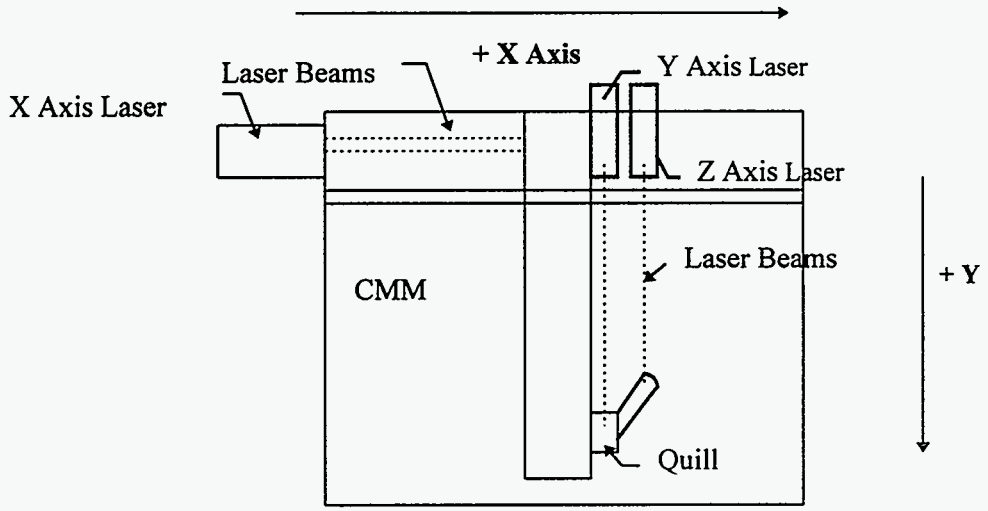

Figure 3. Top View, Laser Installation

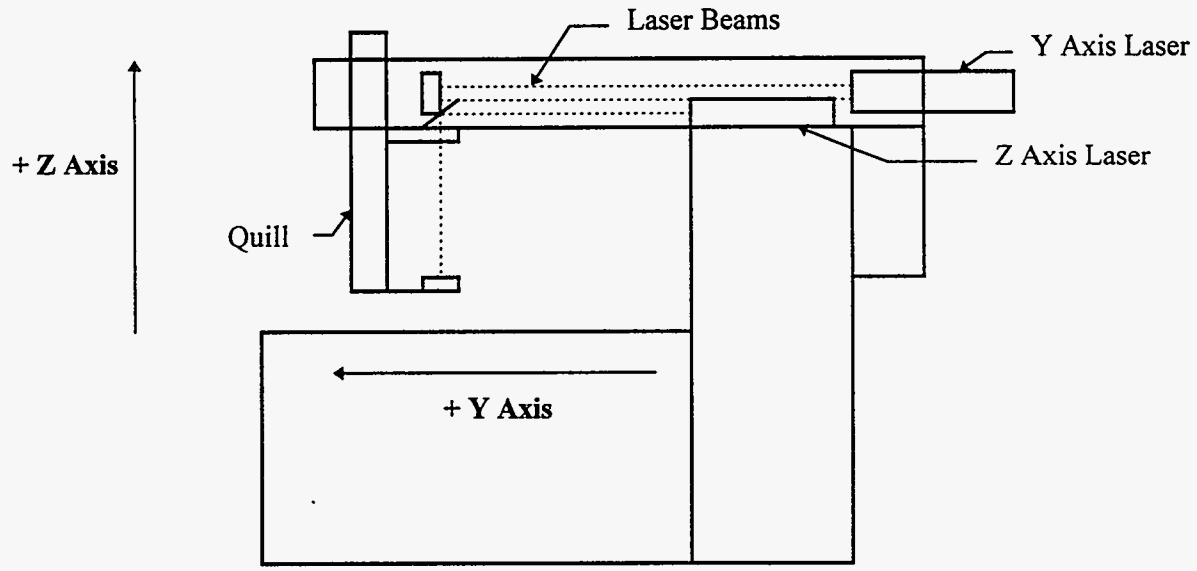

Figure 4. Side View, Laser Installation

CMM Probe and Laser Interface Configuration

The CMM normally takes measurements using a touch-trigger probe. This probe is basically a normally closed switch that opens with physical contact with the part being measured. The probe is wired as part of a latching circuit in the CMM electronics that latches the current displacement readings from each axis of the CMM when the probe triggers. It was decided to control the CMM with its normal controller to facilitate the speed and ease of data collection for this project.

The LDDM was configured to have an individual PC interface card for each axis of measurement, that is, one interface card for each linear displacement axis and one for each angular measurement axis, for a total of five cards. Each interface card has a counter and an A-to-D converter. The counter keeps track of the total number of full wavelengths and the A-to-D converter, when initiated, converts the analog phase signal to additional displacement. All five interface cards were wired together to the latching circuit. Therefore, when the touch probe triggered, it latched the displacement readings from the CMM scales and the LDDM system simultaneously.

Evaluation Standard

The standard used to evaluate the performance of the CMM was a three-dimensional coordinate standard (i.e., ball plate). The ball plate is basically an array of tooling spheres arranged in a grid pattern affixed to a steel fixture. The spheres are located nominally in a plane to allow very accurate certification of their relative locations. The sphere-to-sphere distances are certified to an uncertainty of ± (30 microinches + 2 ppm). By measuring the ball plate in various orientations, the entire volume of a CMM can be evaluated. The ball plate used for this test had 25 spheres whose locations are depicted in Figure 5. The area used for this evaluation covered approximately 18 by 22 inches and did not use the last row of balls due to limitations of the software written to operate the LDDM.

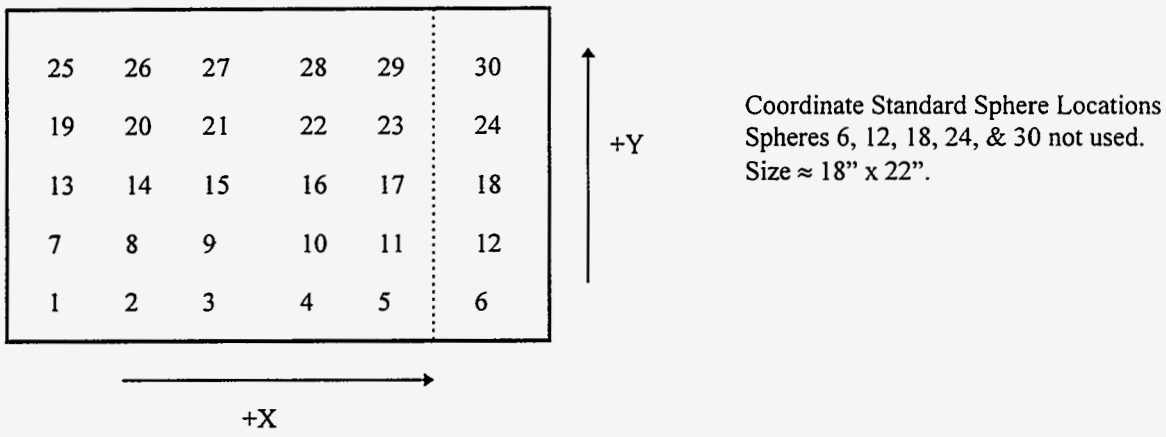

Figure 5. Coordinate Standard Sphere Locations

Data Collection

The data collection scheme was modeled after the method normally used to calibrate and certify the CMM with a couple of modifications. Normally the ball plate is measured in four tilted positions which allow a complete volumetric evaluation of the CMM. Because of the restrictions in modifying the CMM, the Z-axis reflector was mounted in a position that was very prone to vibration. In order to minimize the effect of the Z readings on the evaluation and to maximize the usefulness of the X- and Y-axis angular readings, the ball plate positioned flat in the X-Y plane on the machine table. The ball plate was also measured in a second position flat in the X-Y plane at 9.5 inches above the machine table.

The CMM's data collection software for the CMM's scale evaluation was a slightly modified version of the software used for normal calibration data collection. The ball plate's position is manually located by probing two spheres. The software then takes control of the CMM and probes each of the spheres in succession. Nine probings are taken on each sphere and the location of the center of the sphere is calculated, along with the form error of the sphere fit. The calculated sphere center location is then written to a data file. Simultaneously, the nine probings triggered the LDDM interfaces. The values from each of the five axes (three linear and two angular) were written to a data file for later analysis. Three runs were taken at each of the two positions.

Data Analysis Technique

The data analysis software used was the software normally used for calibration of the CMM. This software uses the data generated during the data collection process and calculates an uncertainty for the CMM. The uncertainty is calculated for axial, planar, and spatial data using the appropriate pairs of spheres for each uncertainty calculation. The software also calculates point-to-point errors in each axis and squareness for each plane. A more detailed explanation of

the data analysis software output is provided in Appendix A. The Cordax data file was in the correct format to be analyzed directly.

In order to analyze the LDDM data, it first had to be converted from raw axis positions to calculated sphere locations. For the initial analysis, only the linear X, Y, and Z data was used. Each group of nine data points for a given sphere probing was run through a least squares sphere fitting routine, which calculated the location of the sphere's center and the form error of the sphere fit. The data was then analyzed using the data analysis software.

To assess the accuracy of the angular correction of LDDM data, the X-axis and Y-axis linear readings for each probing were first run through the least squares fitting routine. The calculated locations of the sphere centers were then corrected for the angular error readings at that position. The linear correction was calculated by applying the measured angle (at the centerline of the two laser beams) over the distance from the centerline of the laser beams to the sphere location. The corrected sphere locations were then analyzed with the data analysis software.

The data analysis software used has the capability to apply linear corrections to each axis of measurement as well as squareness corrections to each plane of measurement. This option allows determination of the uncertainty of the CMM when it is optimized through either hardware or software.

All of the data sets were re-analyzed using this option and the linear and squareness errors from both positions calculated in the analysis of the raw data to determine their potential 'optimum' performance. For the LDDM, this was done with both the linear data and the angular corrected data.

Results

The complete analysis for each data set is contained in Appendix B. The data shown here highlights the findings of the analysis.

Table 1 shows the maximum calculated uncertainty for the Cordax scale data at each analysis position. The slightly higher uncertainty level with the ball plate positioned on the machine table probably indicates that there was some uncorrected pitch error present in the Y axis.

Table 1. Maximum Uncertainty of Cordax System (Uncertainty is in microinches.)

Measurement Type	Ball Plate on the Machine Table	Ball Plate 9.5 Inches Above the Machine Table	Both Positions
Axial	309	296	300
Planar	413	351	382
Spatial	444	366	404

Table 2 shows the maximum uncertainty for the *linear* LDDM data at both positions. This analysis used the linear readings for the X and Y axes of the LDDM data without correcting for the angular readings (errors). The much higher uncertainty indicates that large angular errors exist between the centerline of the laser beams and the probe position. The Cordax scale data has already been compensated for these errors so did not show the large uncertainty.

Table 2. Maximum Uncertainty of LDDM System Without Angular Error Correction
(Uncertainty is in microinches.)

Measurement Type	Ball Plate on the Machine Table	Ball Plate 9.5 Inches Above the Machine Table	Both Positions
Axial	1144	1177	1157
Planar	1115	1137	1125
Spatial	1240	1270	1253

Table 3 shows the maximum uncertainties of the LDDM readings after the linear readings had been corrected for the measured angular errors. The uncertainties improved over the uncorrected data, but were still not as good as had been expected. The calculated point-to-point errors shown in Table 4 provided a clue as to what was happening. Using the Y-axis data as an example shows a point-to-point error of -51.8 ppm in the non-corrected data on the machine table. This would equate to a pitch error in Y of approximately 10 arcseconds. After angular correction, the Y-axis point-to-point error is +24.5 ppm, which would equate to a pitch error of approximately -5 arcseconds. The total spread of measured pitch error was ≈ 15 arcseconds. The angular error correction over-corrected Y-axis pitch, which implies that the pitch error at the quill is different than that at the laser beams.

Table 3. Maximum Uncertainty of LDDM System With Angular Error Correction
(Uncertainty is in microinches.)

Measurement Type	Ball Plate on the Machine Table	Ball Plate 9.5 Inches Above the Machine Table	Both Positions
Axial	854	379	683
Planar	679	460	621
Spatial	775	553	663

Table 4. Point-to-Point Errors (Parts per million)

System	Axis	Ball Plate on Machine Table	Ball Plate 9.5 Inches Above Machine Table	Both Positions
Cordax	X	-5.0	-4.3	-4.6
	Y	-4.5	-6.9	-5.7
LDDM without Angular Correction	X	-7.6	-7.5	-7.5
	Y	-51.8	-53.6	-52.7
LDDM with Angular Correction	X	-11.6	-11.8	-11.7
	Y	24.5	-6.0	9.2

Figures 6 and 7 show what happens on the Y axis as the quill moves from zero to full travel. In Figure 6, the quill is at zero and, for reference purposes, Y-pitch error is zero. The Y beam shows a gradual curve upwards. In Figure 7, with the quill at full travel in Y, the weight of the quill and saddle have bent the Y beam down and also rolled the whole machine slightly in the X axis. The net effect is that at the quill, Y-pitch error remains about at zero over the full travel; but at the location of the Y-axis laser relative to the saddle, the pitch error is about 12 arcseconds. This was indicated by the Y-axis angular laser readings and verified by using an autocollimator at the location of the Y-axis laser and at the machine table.

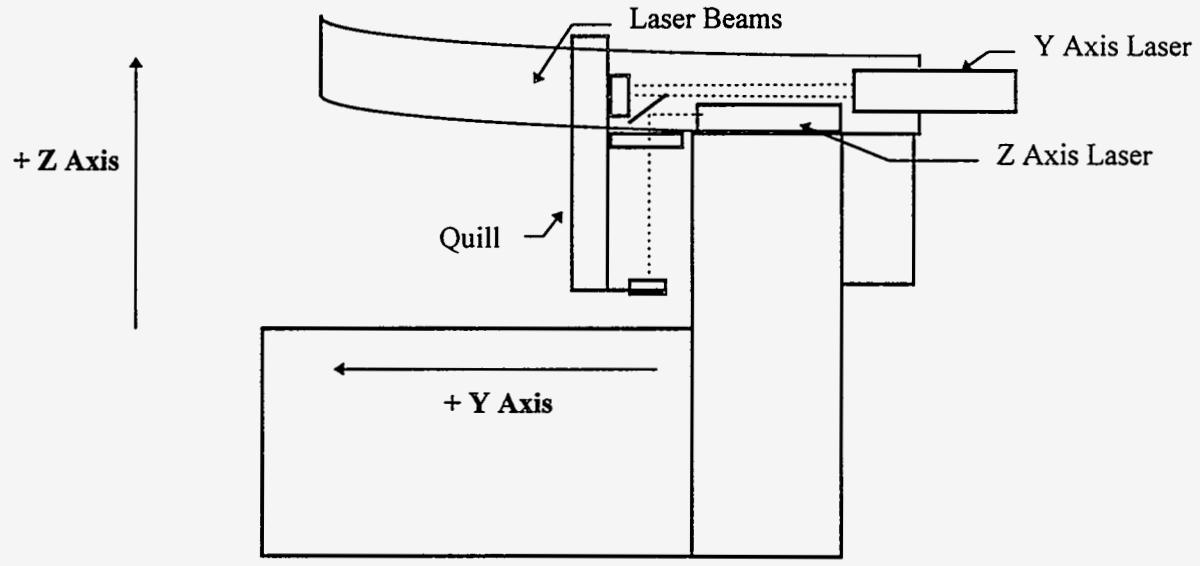

Figure 6. X Axis Roll, Quill at Y Equals Zero

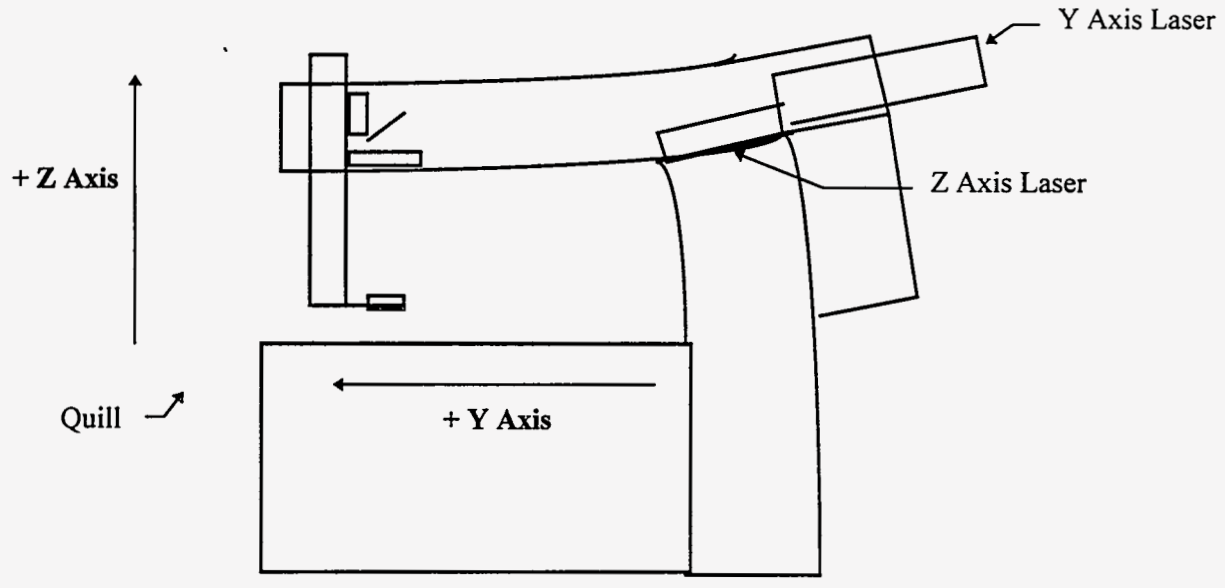

Figure 7. X Axis Roll, Quill at Y Equals Full Travel

In the final part of the data analysis, point-to-point errors and X-Y squareness errors calculated in the analysis of both positions were corrected in the analysis software to evaluate the potential optimum performance of both the Cordax scales and of the LDDM system. Table 5 shows that the corrected LDDM data shows an uncertainty improvement of 25 to 38 percent over the Cordax scales.

Table 5. Maximum Uncertainty With Point-to-Point and Squareness Corrections
(Two positions of data)

System	Axial Uncertainty (Microinches)	Planar Uncertainty (Microinches)	Spatial Uncertainty (Microinches)
Cordax	303	370	370
LDDM without Angular Correction	190	277	282

As a further indication of the CMM's performance, the form error of the sphere fits was evaluated. The touch trigger probe usually contributes the largest portion of this form error. In this test, the difference between the form errors of the Cordax system and the LDDM system also provides an indication of the amount of noise, vibration, and localized scale errors in each system. Table 6 shows the calculated average form error from each system, based on a sample of the sphere fits for each. The form error from the LDDM is significantly higher. This is probably caused by the previously noted vibration and noise in the system. Due to the large number of points taken to fit each sphere, this did not significantly affect the calculated center location.

Table 6. Average Form Error of Sphere Fits

System	Form Error (Microinches)
Cordax	187
LDDM	309

Additional Tests

After the conclusion of the CMM evaluation, two additional tests were run using the LDDM. For both tests, the LDDM readings were taken from the measurement processor and display instead of the PC interface cards. Compensation for the laser wavelength was not performed during measurement, but corrections were applied in the data analysis.

Fixed Bridge CMM Test

The first test was an attempt to perform angular error correction on a fixed-bridge CMM, where it was known the geometry was stable enough to eliminate the problems such as that caused by X-axis roll in the previous CMM evaluation. The CMM used was a granite, air bearing-based machine with a laser interferometer system to measure displacement. The CMM's Y-axis laser interferometer is mounted on the Y-axis carriage approximately 26 inches above the probe location, but in line with the quill. The LDDM laser was placed on the Y-axis carriage,

approximately 33 inches above the CMM probe location. The LDDM had an offset from the quill of about 3 to 4 inches. The LDDM was set up to measure pitch in the Y axis. A single-axis laser interferometer system was set up in the Y axis aligned at the probe location, which eliminated any angular errors for its readings.

A single run of data was taken in 2-inch increments over the 36 inches of travel of the CMM's Y axis. The data from the single-axis laser was taken to be the 'true' value since its measurements were not affected by machine geometry. The readings taken from the CMM laser system and the LDDM were compared to the single-axis readings to determine their accuracy. Both sets of readings were proportionally corrected for zero drift during the run. The zero corrected data was then linearly corrected for point-to-point error. The LDDM data was then also corrected for angular error readings. Table 7 shows a summary of the corrected data.

Table 7. Fixed Bridge CMM Linear Comparison Data

Nominal Length (Inch)	CMM Laser Deviations (Microinch)	LDDM Deviations (Microinch)	CMM Laser Deviations Corrected 0.17 ppm (Microinch)	LDDM Deviations Corrected 7.54 ppm (Microinch)	LDDM Deviations Corrected 7.54 ppm & Angle (Microinch)
0	0	0	0	0	0
2	-12	-18	-12	-3	-63
4	10	-12	9	18	-72
6	12	-17	11	29	29
8	-7	-53	-8	7	-53
10	-16	-98	-18	-23	-53
12	-15	-125	-17	-35	-35
14	1	-135	-2	-30	-60
16	2	-151	-1	-30	0
18	-6	-162	-9	-26	-26
20	-3	-176	-7	-25	5
22	1	-175	-3	-9	51
24	13	-182	9	-1	89
26	13	-172	8	24	144
28	0	-200	-5	11	71
30	-1	-219	-7	7	127
32	9	-231	3	10	70
34	11	-260	5	-3	27
36	17	-242	10	30	120
0	0	0	0	0	-30

During the test, vibration or noise in the LDDM system made it difficult to take the individual readings. The readings would vary by about plus or minus 5 microinches. The apparent median reading was the reading recorded. While that noise did not substantially affect the linear data, it may be the cause for bad angular corrections. As the data shows, angular error correction made the LDDM data much worse than the non-corrected data. A contributing factor to this is that the angular errors in this CMM are probably smaller than the noise in the LDDM.

LDDM Angle Accuracy Verification Test

The second test was simply a verification of the dual beam LDDM's ability to accurately measure angles. This test was performed using a small angle generator which produces angles accurate to one-tenth arcsecond. The results shown in Table 8 indicate that on average the LDDM has reasonably good accuracy in the measurement of angles. However, while taking data, the apparent noise in the system was over an arcsecond and the range of readings over three runs also approached an arcsecond.

Table 8. LDDM Angle Verification Data

Nominal Angle (Arcseconds)	Calculated Angle (Arcseconds)			Average (Arcseconds)	Range (Arcseconds)	Average Deviation (Arcseconds)
	Run 1	Run 2	Run 3			
0	0.00	0.00	0.00	0.00	0.00	0.00
5	5.06	4.88	4.69	4.88	0.38	-0.12
10	9.56	10.13	9.94	9.88	0.56	-0.12
20	19.69	20.44	20.25	20.13	0.75	0.13
30	30.00	30.19	30.00	30.06	0.19	0.06
60	59.63	60.00	60.00	59.75	0.38	-0.25
120	119.45	119.82	119.63	119.63	0.38	-0.37
300	299.27	299.27	299.08	299.21	0.19	-0.79
600	599.29	598.54	598.73	598.85	0.75	-1.15
0	-0.19	0.19	-0.19	-0.06	0.38	-0.06

Accomplishments

The performance of a coordinate measuring machine (CMM) retrofitted with a dual beam laser Doppler displacement measuring (LDDM) system has been investigated as well as the performance characteristics of the LDDM system.

It has been determined that certain types of CMM architecture are not suited for the application of the LDDM dual beam system. The ability to place the LDDM system in a location which will not undergo angular displacement is critical to the application of real time geometry correction. For this reason the Cordax 803 was found to be unsuitable for the application of a dual beam system.

Other factors such as vibration, the amount of geometry error present in the CMM, and the accuracy of the CMM will determine the suitability of incorporation of the LDDM system dual beam system. When tested on a CMM with very little angular error, the system showed a loss in performance. The angle accuracy testing did confirm that the LDDM system has the ability to sense angular errors and therefore could be useful on CMMs with angular errors greater than two arcseconds. This is provided the system can be placed in a location on the CMM that is not susceptible to angular displacement. With a reduction in noise, the system could probably be applied on CMMs with much smaller angular errors.

A significant improvement was shown in the performance of the CMM when the LDDM system was used as a displacement measuring system. Using the data from a single beam of the LDDM system showed a potential of 25 to 38 percent improvement over the measurements from the Cordax 803 system.

Reference

[1]C. P. Wang, "Using the Laser Doppler Displacement Meter For Precision Positioning and Motion Control," *Motion Control*, June 1991.

Appendix A

Data Analysis Software Description

Data Analysis Software Description

The data analysis of the measurements is divided into three categories: Axial, Planar, and Spatial measurements. The calibration worksheets list each measurement category on separate pages with the data or measurement type indicated near the top of each page.

Each of the measurement types is further broken down into smaller categories which are common to each. These categories are performance specification, number of measured distances, average absolute deviation, average deviation, standard deviation over the work zone, standard deviation of multiple runs, radial bias of standard, standard deviation of the standard, uncertainty of a single run, uncertainty of three runs, and allowable deviation. The fifteen largest positive and negative deviations are also listed for each measurement type. These smaller categories are further broken down into size groupings which are labeled inch groups.

The two categories listed as performance specifications and allowable deviation are different methods of saying the same thing. Allowable deviation lists the maximum allowable deviation, according to the performance specification, for each size grouping.

The number of measured distances is the total number of average lengths for each size group listed without regard to the number of runs.

The average absolute deviation and the average deviation are self explanatory.

The standard deviation over the work zone is the sample standard deviation of the deviations from nominal of the average lengths. The standard deviation of multiple runs is actually the square root of the average variance within multiple runs.

The radial bias and standard deviation of the standard are the type A and type B standard uncertainties of the ball plate for each size grouping.

The category titled uncertainty of a single run is the uncertainty of a single measurement for the differing size groupings. This is calculated through a root-sum-square (RSS) combination of the average absolute deviation, the standard deviation over the work zone, the standard deviation of multiple runs, the radial bias of the standard, and the standard deviation of the standard. Only two-thirds of the standard deviation of multiple runs is RSSed due to a covariance which exists between the standard deviation over the work zone and the standard deviation of multiple runs. The RSS calculation is multiplied by two for an approximate ninety-five percent confidence interval.

The uncertainty of three runs is the same as the one run uncertainty except that the standard deviation of multiple runs is not RSSed.

The analysis also lists the fifteen largest positive deviations and the fifteen largest negative deviations. For more than one position of data, the largest deviations will be from all positions.

The analysis will also note any deviations beyond the tolerance of the performance specification.

In addition to the common features, each measurement type includes analysis specific to its type.

The Axial data analysis page will display the average X and Y axis point-to-point errors. The analysis program calculates the point-to-point error by first establishing the data type: axial, planar, or spatial. If the data is from an axial measurement, the measurement axis is determined. For each axis, the deviation from nominal for the axial measurements is averaged. The data is collected from a ball plate which is placed approximately parallel to the XY plane in two positions. The first resting at the table surface and the second raised 9.5 inches above the table surface. The point-to-point errors from both positions were used when corrections were applied to the data.

The Planar data analysis page will show the calculated XY squareness in parts per million and in arcseconds. The squareness was calculated by analyzing the distance between six sphere pairs. A line between each sphere pair forms a diagonal in the XY plane. Half of the sphere pairs form a line at approximately 45 degrees to the positive X axis while the other half form a line at approximately 135 degrees from the positive X axis. The squareness error from both positions was used when corrections were applied to the data.

The Spatial data analysis page divides the data into additional groups of nominal lengths compared to the Planar analysis page. Because only flat positions were tested in this project, there is not a significant difference between the Planar and Spatial analysis pages.

Appendix B

Analysis Data

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* CORDAX CALIBRATION WORKSHEET *

****

Cordax data taken with ball plate on machine table. No corrections applied.

16000 Ball plate Exp. date: 08-25-96

Software: Name PC1808, ID# CS-09P-144, Issue A, Revision 06/02/95

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.

Axial Data Performance Specification = +/-(0.00035 inch + 17 ppm)

Inch Groups	≤5	5-12	≥12
Number measured distances	20	50	30
Average absolute deviation	97	99	85
Average deviation	-11	-44	-81
Std dev over work zone	117	111	64
Std dev of multiple runs	28	26	39
Radial bias of standard	6	7	8
Std dev of the standard	17	21	25
Uncertainty of single run	309	304	228
Uncertainty of three runs	306	301	219
Allowable deviation	427	503	580

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Axial allowable deviation.

Position	Spheres		Distance	Deviation	Position	Spheres		Distance	Deviation
1	4	16	9.000	202	1	13	19	4.500	-218
1	5	17	9.000	194	1	13	25	9.000	-241
1	4	10	4.500	144	1	16	28	9.000	-231
1	3	9	4.500	140	1	17	29	9.000	-230
1	1	13	9.000	165	1	15	27	9.000	-204
1	5	11	4.500	138	1	16	22	4.500	-169
1	3	15	9.000	161	1	15	21	4.500	-167
1	2	8	4.500	130	1	17	23	4.500	-166
1	2	14	9.000	141	1	14	26	9.000	-177
1	1	7	4.501	110	1	14	20	4.500	-145
1	9	10	5.601	90	1	7	19	9.000	-163
1	21	22	5.600	83	1	7	25	13.500	-187
1	27	28	5.600	80	1	25	27	11.200	-173
1	3	4	5.600	69	1	9	27	13.500	-183
1	15	16	5.600	62	1	11	29	13.500	-174

0 of 100 Single-axis measurements exceed the Axial Allowable Deviation.

The following data are an estimate of the CMM axial point-to-point errors:

X axis: average point-to-point error is -5.0 ppm.

Y axis: average point-to-point error is -4.5 ppm.

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* CORDAX CALIBRATION WORKSHEET *

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Cordax data taken with ball plate on machine table. No corrections applied.

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.

Planar Data Performance Specification = +/-(0.00035 inch + 25 ppm)

Inch Groups	≤5	5-6	6-10	10-12	12-17	≥17
Number measured distances	20	20	47	39	78	96
Average absolute deviation	97	73	129	124	119	123
Average deviation	-11	-35	-42	-58	-68	-92
Std dev over work zone	117	68	154	161	140	130
Std dev of multiple runs	28	18	31	31	39	43
Radial bias of standard	6	6	7	7	8	9
Std dev of the standard	17	18	21	23	25	29
Uncertainty of single run	309	206	408	413	376	369
Uncertainty of three runs	306	204	405	410	371	362
Allowable deviation	463	490	575	630	688	800

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Planar allowable deviation.

Position	Spheres		Distance	Deviation	Position	Spheres		Distance	Deviation
1	3	10	7.184	273	1	13	20	7.184	-434
1	3	16	10.600	296	1	7	20	10.600	-416
1	4	16	9.000	202	1	13	21	12.070	-439
1	21	28	7.184	186	1	7	21	14.368	-476
1	2	13	10.600	211	1	13	26	10.600	-406
1	5	17	9.000	194	1	16	23	7.184	-346
1	2	16	14.368	222	1	13	27	14.368	-408
1	4	10	4.500	144	1	16	29	10.600	-347
1	5	16	10.600	190	1	14	21	7.184	-294
1	3	9	4.500	140	1	10	23	10.599	-330
1	5	11	4.500	138	1	7	27	17.541	-418
1	2	10	12.071	193	1	7	26	14.615	-376
1	1	13	9.000	165	1	13	19	4.500	-218
1	2	8	4.500	130	1	7	23	24.140	-432
1	3	15	9.000	161	1	10	29	14.615	-323

0 of 300 1 and 2 Axis Measurements exceed the Planar Allowable Deviation.
The following data are an estimate of the CMM planar squareness errors:
The indicated XY plane squareness is 8.7 (1.80 arcseconds).
* May be affected by yaw, pitch, roll, and straightness of the included axes.

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* CORDAX CALIBRATION WORKSHEET *

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Cordax data taken with ball plate on machine table. No corrections applied.

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.

Spatial Data Performance Specification = +/-(0.00035 inch + 30 ppm)

Inch Groups	≤6	6-10	10-12	12 14	14-17	17 19	19 24	>24
Number measured distances	40	47	39	34	44	41	39	16
Average absolute deviation	85	129	124	110	125	105	130	152
Average deviation	23	-42	-58	-56	-77	-67	-102	-135
Std dev over work zone	95	154	161	133	146	120	127	153
Std dev of multiple runs	23	31	31	36	41	42	43	49
Radial bias of standard	6	6	7	7	8	8	9	10
Std dev of the standard	17	19	22	23	25	28	30	34
Uncertainty of single run	261	408	413	354	394	331	375	444
Uncertainty of three runs	258	405	410	349	388	324	368	437
Allowable deviation	485	566	668	712	782	872	922	1074

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Spatial allowable deviation.

Position	Spheres		Distance	Deviation
1	3	10	7.184	273
1	3	16	10.600	296
1	21	28	7.184	186
1	4	16	9.000	202
1	2	13	10.600	211
1	5	17	9.000	194
1	4	10	4.500	144
1	3	9	4.500	140
1	5	11	4.500	138
1	5	16	10.600	190
1	2	16	14.368	222
1	2	10	12.071	193
1	2	8	4.500	130
1	1	13	9.000	165
1	3	15	9.000	161

Position	Spheres		Distance	Deviation
1	13	20	7.184	-434
1	7	20	10.600	-416
1	13	21	12.070	-439
1	16	23	7.184	-346
1	7	21	14.368	-476
1	13	26	10.600	-406
1	13	27	14.368	-408
1	16	29	10.600	-347
1	14	21	7.184	-294
1	10	23	10.599	-330
1	7	26	14.615	-376
1	7	27	17.541	-418
1	13	19	4.500	-218
1	10	29	14.615	-323
1	7	23	24.140	-432

0 of 300 Total Radial Measurements exceed the Spatial Allowable Deviation.

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* CORDAX CALIBRATION WORKSHEET *

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Cordax data taken with ball plate raised 9.5 inches above machine table. No corrections applied.

16000 Ball plate Exp. date: 08-25-96

Software: Name PC1808, ID# CS-09P-144, Issue A, Revision 06/02/95

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.

Axial Data Performance Specification = +/-(0.00035 inch + 17 ppm)

Inch Groups	<5	5-12	>12
Number measured distances	20	50	30
Average absolute deviation	87	95	94
Average deviation	-17	-50	-94
Std dev over work zone	117	102	53
Std dev of multiple runs	17	18	23
Radial bias of standard	6	7	8
Std dev of the standard	17	21	25
Uncertainty of single run	296	283	225
Uncertainty of three runs	295	282	222
Allowable deviation	427	503	580

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Axial allowable deviation.

Position	Spheres		Distance	Deviation	Position	Spheres		Distance	Deviation
1	3	9	4.500	129	1	13	19	4.500	-217
1	5	11	4.500	124	1	15	21	4.500	-206
1	4	10	4.500	116	1	14	20	4.500	-206
1	2	8	4.500	107	1	9	21	9.000	-223
1	1	7	4.501	100	1	8	20	9.000	-214
1	1	13	9.000	115	1	16	22	4.500	-180
1	5	17	9.000	114	1	17	23	4.500	-179
1	3	15	9.000	113	1	7	19	9.000	-202
1	4	16	9.000	105	1	10	22	9.000	-191
1	21	22	5.600	89	1	16	28	9.000	-188
1	2	14	9.000	99	1	11	23	9.000	-188
1	9	10	5.601	86	1	14	26	9.000	-188
1	15	16	5.600	81	1	13	25	9.000	-176
1	27	28	5.600	70	1	10	28	13.500	-199
1	3	4	5.600	55	1	8	26	13.500	-196

0 of 100 Single-axis measurements exceed the Axial Allowable Deviation.

The following data are an estimate of the CMM axial point-to-point errors:

X axis: average point-to-point error is -4.3 ppm.

Y axis: average point-to-point error is -6.9 ppm.

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* CORDAX CALIBRATION WORKSHEET *

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Cordax data taken with ball plate raised 9.5 inches above machine table. No corrections applied.

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.

Planar Data Performance Specification = +/-(0.00035 inch + 25 ppm)

Inch Groups	≤5	5-6	6-10	10-12	12-17	≥17
Number measured distances	20	20	47	39	78	96
Average absolute deviation	87	70	113	112	111	111
Average deviation	-17	-32	-53	-71	-82	-100
Std dev over work zone	117	68	132	132	116	97
Std dev of multiple runs	17	17	19	20	22	22
Radial bias of standard	6	6	7	7	8	9
Std dev of the standard	17	18	21	23	25	29
Uncertainty of single run	296	201	351	351	327	304
Uncertainty of three runs	295	199	350	349	325	301
Allowable deviation	463	490	575	630	688	800

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Planar allowable deviation.

Position	Spheres		Distance	Deviation	Position	Spheres		Distance	Deviation
1	3	10	7.184	260	1	13	20	7.184	-357
1	2	10	12.071	210	1	7	20	10.600	-382
1	3	16	10.600	198	1	7	21	14.368	-415
1	3	9	4.500	129	1	10	23	10.599	-339
1	21	28	7.184	145	1	16	23	7.184	-288
1	5	11	4.500	124	1	13	21	12.070	-353
1	2	9	7.184	136	1	14	21	7.184	-278
1	4	10	4.500	116	1	13	26	10.600	-318
1	2	8	4.500	107	1	8	21	10.600	-292
1	3	11	12.070	148	1	13	19	4.500	-217
1	2	16	14.368	160	1	7	26	14.615	-322
1	1	7	4.501	100	1	15	21	4.500	-206
1	1	13	9.000	115	1	14	20	4.500	-206
1	5	17	9.000	114	1	13	27	14.368	-315
1	3	15	9.000	113	1	7	27	17.541	-341

0 of 300 1 and 2 Axis Measurements exceed the Planar Allowable Deviation.
The following data are an estimate of the CMM planar squareness errors:
The indicated XY plane squareness is 5.4 (1.11 arcseconds).
* May be affected by yaw, pitch, roll, and straightness of the included axes.

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* CORDAX CALIBRATION WORKSHEET *

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Cordax data taken with ball plate 9.5 inches above machine table. No corrections applied.

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.

Spatial Data Performance Specification = +/-(0.00035 inch + 30 ppm)

Inch Groups	≤6	6-10	10-12	12 14	14-17	17 19	19 24	>24
Number measured distances	40	47	39	34	44	41	39	16
Average absolute deviation	79	113	112	110	111	95	115	144
Average deviation	-24	-53	-71	-63	-96	-79	-105	-143
Std dev over work zone	95	132	132	118	114	92	95	105
Std dev of multiple runs	17	19	20	23	21	21	22	25
Radial bias of standard	6	6	7	7	8	8	9	10
Std dev of the standard	17	19	22	23	25	28	30	34
Uncertainty of single run	251	351	351	328	325	273	306	366
Uncertainty of three runs	249	349	349	326	323	271	304	364
Allowable deviation	485	566	668	712	782	872	922	1074

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Spatial allowable deviation.

Position	Spheres		Distance	Deviation	Position	Spheres		Distance	Deviation
1	3	10	7.184	260	1	13	20	7.184	-357
1	3	16	10.600	198	1	7	20	10.600	-382
1	2	10	12.071	210	1	7	21	14.368	-415
1	3	9	4.500	129	1	16	23	7.184	-288
1	21	28	7.184	145	1	10	23	10.599	-339
1	5	11	4.500	124	1	13	21	12.070	-353
1	2	9	7.184	136	1	14	21	7.184	-278
1	4	10	4.500	116	1	13	26	10.600	-318
1	2	8	4.500	107	1	13	19	4.500	-217
1	3	11	12.070	148	1	8	21	10.600	-292
1	1	7	4.501	100	1	15	21	4.500	-206
1	2	16	14.368	160	1	14	20	4.500	-206
1	1	13	9.000	115	1	7	26	14.615	-322
1	5	17	9.000	114	1	13	27	14.368	-315
1	3	15	9.000	113	1	7	27	17.541	-341

0 of 300 Total Radial Measurements exceed the Spatial Allowable Deviation.

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* CORDAX CALIBRATION WORKSHEET *

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Cordax data taken with both positions analyzed. No corrections applied.

16000 Ball plate Exp. date: 08-25-96

Software: Name PC1808, ID# CS-09P-144, Issue A, Revision 06/02/95

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.

Axial Data Performance Specification = +/-(0.00035 inch + 17 ppm)

Inch Groups	≤5	5-12	≥12
Number measured distances	40	100	60
Average absolute deviation	92	97	89
Average deviation	-14	-47	-87
Std dev over work zone	116	106	59
Std dev of multiple runs	23	23	32
Radial bias of standard	6	7	8
Std dev of the standard	17	21	25
Uncertainty of single run	300	293	226
Uncertainty of three runs	298	291	220
Allowable deviation	427	503	580

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Axial allowable deviation.

Position	Spheres		Distance	Deviation	Position	Spheres		Distance	Deviation
2	4	16	9.000	202	2	13	19	4.500	-218
2	5	17	9.000	194	1	13	19	4.500	-217
2	4	10	4.500	144	1	15	21	4.500	-206
2	3	9	4.500	140	1	14	20	4.500	-206
2	1	13	9.000	165	2	13	25	9.000	-241
2	5	11	4.500	138	2	16	28	9.000	-231
2	3	15	9.000	161	2	17	29	9.000	-230
2	2	8	4.500	130	1	9	21	9.000	-223
1	3	9	4.500	129	1	8	20	9.000	-214
1	5	11	4.500	124	1	16	22	4.500	-180
2	2	14	9.000	141	1	17	23	4.500	-179
1	4	10	4.500	116	2	15	27	9.000	-204
2	1	7	4.501	110	1	7	19	9.000	-202
1	2	8	4.500	107	2	16	22	4.500	-169
1	1	7	4.501	100	2	15	21	4.500	-167

0 of 200 Single-axis measurements exceed the Axial Allowable Deviation.

The following data are an estimate of the CMM axial point-to-point errors:

X axis: average point-to-point error is -4.6 ppm.

Y axis: average point-to-point error is -5.7 ppm.

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* CORDAX CALIBRATION WORKSHEET *

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Cordax data taken with both positions analyzed. No corrections applied.

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.

Planar Data Performance Specification = +/-(0.00035 inch + 25 ppm)

Inch Groups	≤5	5-6	6-10	10-12	12-17	≥17
Number measured distances	40	40	94	78	156	192
Average absolute deviation	92	72	121	118	115	117
Average deviation	-14	-34	-47	-64	-75	-96
Std dev over work zone	116	67	143	146	128	115
Std dev of multiple runs	23	18	26	26	32	35
Radial bias of standard	6	6	7	7	8	9
Std dev of the standard	17	18	21	23	25	29
Uncertainty of single run	300	202	379	382	352	337
Uncertainty of three runs	298	200	377	379	348	333
Allowable deviation	463	490	575	630	688	800

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Planar allowable deviation.

Position	Spheres		Distance	Deviation	Position	Spheres		Distance	Deviation
2	3	10	7.184	273	2	13	20	7.184	-434
1	3	10	7.184	260	2	7	20	10.600	-416
2	3	16	10.600	296	1	13	20	7.184	-357
2	4	16	9.000	202	2	13	21	12.070	-439
2	21	28	7.184	186	2	7	21	14.368	-476
2	2	13	10.600	211	2	13	26	10.600	-406
2	5	17	9.000	194	2	16	23	7.184	-346
1	2	10	12.071	210	1	7	20	10.600	-382
1	3	16	10.600	198	1	7	21	14.368	-415
2	2	16	14.368	222	2	13	27	14.368	-408
2	4	10	4.500	144	2	16	29	10.600	-347
2	5	16	10.600	190	2	14	21	7.184	-294
2	3	9	4.500	140	1	10	23	10.599	-339
2	5	11	4.500	138	1	16	23	7.184	-288
2	2	10	12.071	193	1	13	21	12.070	-353

0 of 600 1 and 2 Axis Measurements exceed the Planar Allowable Deviation.

The following data are an estimate of the CMM planar squareness errors:

The indicated XY plane squareness is 7.0 (1.45 arcseconds).

* May be affected by yaw, pitch, roll, and straightness of the included axes.

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* CORDAX CALIBRATION WORKSHEET *

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Cordax data taken with both positions analyzed. No corrections applied.

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.

Spatial Data Performance Specification = +/-(0.00035 inch + 30 ppm)

Inch Groups	<6	6-10	10-12	12 14	14-17	17 19	19 24	>24
Number measured distances	80	94	78	68	88	82	78	32
Average absolute deviation	82	121	118	110	118	100	122	148
Average deviation	-24	-47	-64	-60	-86	-73	-104	-139
Std dev over work zone	95	143	146	125	130	107	112	129
Std dev of multiple runs	21	26	26	30	33	33	34	39
Radial bias of standard	6	6	7	7	8	8	9	10
Std dev of the standard	17	19	22	23	25	28	30	34
Uncertainty of single run	255	379	382	340	360	303	341	404
Uncertainty of three runs	253	377	379	337	356	298	336	399
Allowable deviation	485	566	668	712	782	872	922	1074

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Spatial allowable deviation.

Position	Spheres		Distance	Deviation	Position	Spheres		Distance	Deviation
2	3	10	7.184	273	2	13	20	7.184	-434
1	3	10	7.184	260	1	13	20	7.184	-357
2	3	16	10.600	296	2	7	20	10.600	-416
2	21	28	7.184	186	2	13	21	12.070	-439
2	4	16	9.000	202	2	16	23	7.184	-346
2	2	13	10.600	211	2	7	21	14.368	-476
2	5	17	9.000	194	2	13	26	10.600	-406
2	4	10	4.500	144	1	7	20	10.600	-382
1	3	16	10.600	198	1	7	21	14.368	-415
1	2	10	12.071	210	2	13	27	14.368	-408
2	3	9	4.500	140	2	16	29	10.600	-347
2	5	11	4.500	138	2	14	21	7.184	-294
2	5	16	10.600	190	1	16	23	7.184	-288
2	2	16	14.368	222	1	10	23	10.599	-339
2	2	10	12.071	193	1	13	21	12.070	-353

0 of 600 Total Radial Measurements exceed the Spatial Allowable Deviation.

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* LDDM CALIBRATION WORKSHEET *

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LDDM data taken with ball plate on machine table. No corrections applied.

16000 Ball plate Exp. date: 08-25-96

Software: Name PC1808, ID# CS-09P-144, Issue A, Revision 06/02/95

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.

Axial Data Performance Specification = +/-(0.00035 inch + 17 ppm)

Inch Groups	≤5	5-12	≥12
Number measured distances	20	50	30
Average absolute deviation	224	191	463
Average deviation	-224	-188	-463
Std dev over work zone	79	206	333
Std dev of multiple runs	50	38	48
Radial bias of standard	6	7	8
Std dev of the standard	17	21	25
Uncertainty of single run	484	566	1144
Uncertainty of three runs	477	562	1141
Allowable deviation	427	503	580

>>>>>***** CMM Uncertainty Exceeds the Axial Allowable Deviation *****<<<<<

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Axial allowable deviation.

Position	Spheres		Distance	Deviation	Position	Spheres		Distance	Deviation
1	1	2	5.601	57	1	1	25	18.000	-939
1	7	8	5.600	6	1	2	26	18.000	-924
1	13	14	5.600	3	1	10	28	13.500	-806
1	19	20	5.600	-9	1	3	27	18.000	-897
1	1	3	11.201	-11	1	11	29	13.500	-772
1	7	9	11.200	-28	1	7	25	13.500	-767
1	13	15	11.200	-29	1	1	19	13.500	-765
1	14	15	5.599	-32	1	4	28	18.000	-863
1	8	9	5.600	-34	1	5	29	18.000	-862
1	28	29	5.600	-36	1	8	26	13.500	-758
1	10	11	5.599	-40	1	9	27	13.500	-710
1	1	4	16.800	-59	1	3	21	13.500	-708
1	25	26	5.600	-44	1	2	20	13.500	-697
1	19	21	11.200	-56	1	7	19	9.000	-593
1	21	22	5.600	-47	1	16	28	9.000	-592

24 of 100 Single-axis measurements exceed the Axial Allowable Deviation.

The following data are an estimate of the CMM axial point-to-point errors:

X axis: average point-to-point error is -7.6 ppm.

Y axis: average point-to-point error is -51.8 ppm.

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* LDDM CALIBRATION WORKSHEET *

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LDDM data taken with ball plate on machine table. No corrections applied.

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.

Planar Data Performance Specification = +/-(0.00035 inch + 25 ppm)

Inch Groups	≤5	5-6	6-10	10-12	12-17	≥17
Number measured distances	20	20	47	39	78	96
Average absolute deviation	224	46	271	299	389	481
Average deviation	-224	-40	-271	-299	-387	-481
Std dev over work zone	79	34	188	205	262	277
Std dev of multiple runs	50	27	46	44	47	50
Radial bias of standard	6	6	7	7	8	9
Std dev of the standard	17	18	21	23	25	29
Uncertainty of single run	484	128	666	730	942	1115
Uncertainty of three runs	477	121	662	726	939	1112
Allowable deviation	463	490	575	630	688	800

>>>>>***** CMM Uncertainty Exceeds the Planar Allowable Deviation *****<<<<<

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Planar allowable deviation.

Position	Spheres		Distance	Deviation	Position	Spheres		Distance	Deviation
1	1	2	5.601	57	1	1	26	18.852	-1043
1	15	19	12.070	56	1	7	26	14.615	-896
1	8	13	7.184	9	1	10	29	14.615	-874
1	7	8	5.600	6	1	1	20	14.616	-841
1	13	14	5.600	3	1	1	25	18.000	-939
1	3	10	7.184	0	1	10	28	13.500	-806
1	9	13	12.070	-6	1	10	23	10.599	-715
1	19	20	5.600	-9	1	7	20	10.600	-711
1	1	3	11.201	-11	1	2	26	18.000	-924
1	14	19	7.184	-12	1	3	26	18.851	-925
1	1	10	17.393	-31	1	4	29	18.851	-923
1	17	19	22.847	-37	1	11	29	13.500	-772
1	17	22	7.184	-23	1	3	27	18.000	-897
1	7	9	11.200	-28	1	7	25	13.500	-767
1	1	9	12.071	-30	1	1	19	13.500	-765

31 of 300 1 and 2 Axis Measurements exceed the Planar Allowable Deviation.

The following data are an estimate of the CMM planar squareness errors:

The indicated XY plane squareness is 7.7 (1.58 arcseconds).

* May be affected by yaw, pitch, roll, and straightness of the included axes.

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* LDDM CALIBRATION WORKSHEET *

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LDDM data taken with ball plate on machine table. No corrections applied.

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.

Spatial Data Performance Specification = +/-(0.00035 inch + 30 ppm)

Inch Groups	≤6	6-10	10-12	12 14	14-17	17 19	19 24	≥24
Number measured distances	40	47	39	34	44	41	39	16
Average absolute deviation	135	271	299	334	431	531	409	529
Average deviation	-132	-271	-299	-331	-431	-531	-409	-529
Std dev over work zone	111	188	205	280	242	316	244	218
Std dev of multiple runs	40	46	44	47	48	51	48	52
Radial bias of standard	6	6	7	7	8	8	9	10
Std dev of the standard	17	19	22	23	25	28	30	34
Uncertainty of single run	358	666	730	877	992	1240	957	1149
Uncertainty of three runs	352	661	726	873	989	1237	954	1146
Allowable deviation	485	566	668	712	782	872	922	1074

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Spatial allowable deviation.

Position	Spheres		Distance	Deviation	Position	Spheres		Distance	Deviation
1	1	2	5.601	57	1	1	26	18.852	-1043
1	15	19	12.070	56	1	7	26	14.615	-896
1	8	13	7.184	9	1	10	29	14.615	-874
1	7	8	5.600	6	1	10	23	10.599	-715
1	13	14	5.600	3	1	1	20	14.616	-841
1	3	10	7.184	0	1	10	28	13.500	-806
1	9	13	12.070	-6	1	7	20	10.600	-711
1	1	3	11.201	-11	1	1	25	18.000	-939
1	19	20	5.600	-9	1	2	26	18.000	-924
1	14	19	7.184	-12	1	11	29	13.500	-772
1	17	19	22.847	-37	1	7	25	13.500	-767
1	1	10	17.393	-31	1	1	19	13.500	-765
1	17	22	7.184	-23	1	3	26	18.851	-925
1	7	9	11.200	-28	1	4	29	18.851	-923
1	1	9	12.071	-30	1	3	27	18.000	-897

16 of 300 Total Radial Measurements exceed the Spatial Allowable Deviation.

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* LDDM CALIBRATION WORKSHEET *

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LDDM data taken with ball plate raised 9.5 inches above machine table. No corrections applied.

16000 Ball plate Exp. date: 08-25-96

Software: Name PC1808, ID# CS-09P-144, Issue A, Revision 06/02/95

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.

Axial Data Performance Specification = +/-(0.00035 inch + 17 ppm)

Inch Groups	≤5	5-12	≥12
Number measured distances	20	50	30
Average absolute deviation	234	192	474
Average deviation	-234	-191	-474
Std dev over work zone	58	208	347
Std dev of multiple runs	29	27	25
Radial bias of standard	6	7	8
Std dev of the standard	17	21	25
Uncertainty of single run	485	570	1177
Uncertainty of three runs	482	568	1176
Allowable deviation	427	503	580

>>>>>***** CMM Uncertainty Exceeds the Axial Allowable Deviation *****<<<<<

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Axial allowable deviation.

Position	Spheres		Distance	Deviation	Position	Spheres		Distance	Deviation
1	13	14	5.600	16	1	2	26	18.000	-961
1	8	9	5.600	10	1	1	25	18.000	-940
1	13	15	11.200	-2	1	5	29	18.000	-935
1	19	20	5.600	-10	1	4	28	18.000	-933
1	2	3	5.600	-12	1	3	27	18.000	-904
1	7	9	11.200	-18	1	8	26	13.500	-775
1	1	2	5.601	-18	1	2	20	13.500	-773
1	14	15	5.599	-19	1	1	19	13.500	-765
1	26	27	5.600	-19	1	10	28	13.500	-750
1	20	21	5.600	-22	1	9	27	13.500	-741
1	1	3	11.201	-30	1	7	25	13.500	-739
1	19	21	11.200	-32	1	3	21	13.500	-733
1	7	8	5.600	-28	1	11	29	13.500	-730
1	28	29	5.600	-41	1	5	23	13.500	-728
1	8	10	11.200	-55	1	4	22	13.500	-718

23 of 100 Single-axis measurements exceed the Axial Allowable Deviation.

The following data are an estimate of the CMM axial point-to-point errors:

X axis: average point-to-point error is -7.5 ppm.

Y axis: average point-to-point error is -53.6 ppm.

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* LDDM CALIBRATION WORKSHEET *

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LDDM data taken with ball plate raised 9.5 inches above machine table. No corrections applied.

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.

Planar Data Performance Specification = +/-(0.00035 inch + 25 ppm)

Inch Groups	≤5	5-6	6-10	10-12	12-17	>17
Number measured distances	20	20	47	39	78	96
Average absolute deviation	234	44	279	306	393	492
Average deviation	-234	-42	-279	-306	-393	-492
Std dev over work zone	58	31	172	196	264	282
Std dev of multiple runs	29	24	28	31	26	24
Radial bias of standard	6	6	7	7	8	9
Std dev of the standard	17	18	21	23	25	29
Uncertainty of single run	485	121	659	729	950	1137
Uncertainty of three runs	482	115	658	727	949	1136
Allowable deviation	463	490	575	630	688	800

>>>>>***** CMM Uncertainty Exceeds the Planar Allowable Deviation *****<<<<<

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Planar allowable deviation.

Position	Spheres		Distance	Deviation	Position	Spheres		Distance	Deviation
1	13	14	5.600	16	1	1	26	18.852	-1004
1	8	9	5.600	10	1	2	26	18.000	-961
1	15	19	12.070	12	1	1	25	18.000	-940
1	13	15	11.200	-2	1	5	29	18.000	-935
1	19	20	5.600	-10	1	4	28	18.000	-933
1	2	3	5.600	-12	1	7	26	14.615	-827
1	7	9	11.200	-18	1	1	20	14.616	-824
1	1	9	12.071	-20	1	4	29	18.851	-933
1	2	10	12.071	-20	1	4	27	18.851	-931
1	1	2	5.601	-18	1	3	27	18.000	-904
1	14	15	5.599	-19	1	8	26	13.500	-775
1	26	27	5.600	-19	1	2	20	13.500	-773
1	20	21	5.600	-22	1	1	19	13.500	-765
1	14	19	7.184	-25	1	10	29	14.615	-789
1	1	3	11.201	-30	1	3	26	18.851	-902

34 of 300 1 and 2 Axis Measurements exceed the Planar Allowable Deviation.

The following data are an estimate of the CMM planar squareness errors:

The indicated XY plane squareness is 4.9 (1.01 arcseconds).

* May be affected by yaw, pitch, roll, and straightness of the included axes.

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* LDDM CALIBRATION WORKSHEET *

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LDDM data taken with ball plate raised 9.5 inches above machine table. No corrections applied.

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.

Spatial Data Performance Specification = +/-(0.00035 inch + 30 ppm)

Inch Groups	<6	6-10	10-12	12 14	14-17	17 19	19 24	>24
Number measured distances	40	47	39	34	44	41	39	16
Average absolute deviation	139	279	306	334	439	544	415	547
Average deviation	-138	-279	-306	-333	-439	-544	-415	-547
Std dev over work zone	107	172	196	284	240	326	243	213
Std dev of multiple runs	26	28	31	27	26	22	24	28
Radial bias of standard	6	6	7	7	8	8	9	10
Std dev of the standard	17	19	22	23	25	28	30	34
Uncertainty of single run	356	659	729	879	1004	1270	965	1177
Uncertainty of three runs	353	658	727	878	1003	1269	964	1176
Allowable deviation	485	566	668	712	782	872	922	1074

>>>>>***** CMM Uncertainty Exceeds the Spatial Allowable Deviation *****<<<<<

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Spatial allowable deviation.

Position	Spheres		Distance	Deviation
1	13	14	5.600	16
1	8	9	5.600	10
1	15	19	12.070	12
1	13	15	11.200	-2
1	19	20	5.600	-10
1	2	3	5.600	-12
1	7	9	11.200	-18
1	1	9	12.071	-20
1	2	10	12.071	-20
1	1	2	5.601	-18
1	14	15	5.599	-19
1	26	27	5.600	-19
1	20	21	5.600	-22
1	1	3	11.201	-30
1	14	19	7.184	-25

Position	Spheres		Distance	Deviation
1	1	26	18.852	-1004
1	2	26	18.000	-961
1	1	25	18.000	-940
1	5	29	18.000	-935
1	7	26	14.615	-827
1	4	28	18.000	-933
1	1	20	14.616	-824
1	8	26	13.500	-775
1	2	20	13.500	-773
1	4	29	18.851	-933
1	4	27	18.851	-931
1	3	27	18.000	-904
1	1	19	13.500	-765
1	10	29	14.615	-789
1	10	28	13.500	-750

14 of 300 Total Radial Measurements exceed the Spatial Allowable Deviation.

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* LDDM CALIBRATION WORKSHEET *

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LDDM data taken with both positions analyzed. No corrections applied.

16000 Ball plate Exp. date: 08-25-96

Software: Name PC1808, ID# CS-09P-144, Issue A, Revision 06/02/95

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.

Axial Data Performance Specification = +/-(0.00035 inch + 17 ppm)

Inch Groups	≤5	5-12	≥12
Number measured distances	40	100	60
Average absolute deviation	229	191	468
Average deviation	-229	-189	-468
Std dev over work zone	68	206	337
Std dev of multiple runs	41	33	38
Radial bias of standard	6	7	8
Std dev of the standard	17	21	25
Uncertainty of single run	484	566	1157
Uncertainty of three runs	479	564	1156
Allowable deviation	427	503	580

>>>>>***** CMM Uncertainty Exceeds the Axial Allowable Deviation *****<<<<<

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Axial allowable deviation.

Position	Spheres		Distance	Deviation	Position	Spheres		Distance	Deviation
1	1	2	5.601	57	2	2	26	18.000	-961
2	13	14	5.600	16	2	1	25	18.000	-940
2	8	9	5.600	10	1	1	25	18.000	-939
1	7	8	5.600	6	2	5	29	18.000	-935
1	13	14	5.600	3	2	4	28	18.000	-933
2	13	15	11.200	-2	1	2	26	18.000	-924
1	19	20	5.600	-9	1	10	28	13.500	-806
1	1	3	11.201	-11	2	3	27	18.000	-904
2	19	20	5.600	-10	1	3	27	18.000	-897
2	2	3	5.600	-12	2	8	26	13.500	-775
2	7	9	11.200	-18	2	2	20	13.500	-773
2	1	2	5.601	-18	1	11	29	13.500	-772
2	14	15	5.599	-19	1	7	25	13.500	-767
2	26	27	5.600	-19	1	1	19	13.500	-765
2	20	21	5.600	-22	2	1	19	13.500	-765

47 of 200 Single-axis measurements exceed the Axial Allowable Deviation.

The following data are an estimate of the CMM axial point-to-point errors:

X axis: average point-to-point error is -7.5 ppm.

Y axis: average point-to-point error is -52.7 ppm.

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* LDDM CALIBRATION WORKSHEET *

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LDDM data taken with both positions analyzed. No corrections applied.

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.

Planar Data Performance Specification = +/-(0.00035 inch + 25 ppm)

Inch Groups	≤5	5-6	6-10	10-12	12-17	>17
Number measured distances	40	40	94	78	156	192
Average absolute deviation	229	45	275	302	391	487
Average deviation	-229	-41	-275	-302	-390	-487
Std dev over work zone	68	32	179	199	262	279
Std dev of multiple runs	41	25	38	38	38	39
Radial bias of standard	6	6	7	7	8	9
Std dev of the standard	17	18	21	23	25	29
Uncertainty of single run	484	125	662	728	945	1125
Uncertainty of three runs	479	118	659	725	943	1123
Allowable deviation	463	490	575	630	688	800

>>>>>***** CMM Uncertainty Exceeds the Planar Allowable Deviation *****<<<<<

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Planar allowable deviation.

Position	Spheres		Distance	Deviation	Position	Spheres		Distance	Deviation
1	1	2	5.601	57	1	1	26	18.852	-1043
1	15	19	12.070	56	1	7	26	14.615	-896
2	13	14	5.600	16	1	10	29	14.615	-874
2	8	9	5.600	10	2	1	26	18.852	-1004
2	15	19	12.070	12	2	2	26	18.000	-961
1	8	13	7.184	9	1	1	20	14.616	-841
1	7	8	5.600	6	2	1	25	18.000	-940
1	13	14	5.600	3	1	1	25	18.000	-939
1	3	10	7.184	-0	1	10	28	13.500	-806
2	13	15	11.200	-2	2	5	29	18.000	-935
1	9	13	12.070	-6	2	4	28	18.000	-933
1	19	20	5.600	-9	1	10	23	10.599	-715
1	1	3	11.201	-11	1	7	20	10.600	-711
2	19	20	5.600	-10	2	7	26	14.615	-827
1	14	19	7.184	-12	1	2	26	18.000	-924

65 of 600 1 and 2 Axis Measurements exceed the Planar Allowable Deviation.

The following data are an estimate of the CMM planar squareness errors:

The indicated XY plane squareness is 6.3 (1.29 arcseconds).

* May be affected by yaw, pitch, roll, and straightness of the included axes.

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* LDDM CALIBRATION WORKSHEET *

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LDDM data taken with both positions analyzed. No corrections applied.

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.

Spatial Data Performance Specification = +/-(0.00035 inch + 30 ppm)

Inch Groups	≤6	6-10	10-12	12 14	14-17	17 19	19 24	≥24
Number measured distances	80	94	78	68	88	82	78	32
Average absolute deviation	137	275	302	334	435	537	412	538
Average deviation	-135	-275	-302	-332	-435	-537	-412	-538
Std dev over work zone	108	179	199	280	240	319	242	213
Std dev of multiple runs	34	38	38	38	38	39	38	42
Radial bias of standard	6	6	7	7	8	8	9	10
Std dev of the standard	17	19	22	23	25	28	30	34
Uncertainty of single run	356	661	728	875	997	1253	959	1161
Uncertainty of three runs	352	658	725	873	995	1251	957	1159
Allowable deviation	485	566	668	712	782	872	922	1074

>>>>>***** CMM Uncertainty Exceeds the Spatial Allowable Deviation *****<<<<<

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Spatial allowable deviation.

Position	Spheres		Distance	Deviation
1	1	2	5.601	57
1	15	19	12.070	56
2	13	14	5.600	16
2	8	9	5.600	10
2	15	19	12.070	12
1	8	13	7.184	9
1	7	8	5.600	6
1	13	14	5.600	3
1	3	10	7.184	-0
2	13	15	11.200	-2
1	9	13	12.070	-6
1	1	3	11.201	-11
1	19	20	5.600	-9
2	19	20	5.600	-10
1	14	19	7.184	-12

Position	Spheres		Distance	Deviation
1	1	26	18.852	-1043
1	7	26	14.615	-896
1	10	29	14.615	-874
2	1	26	18.852	-1004
2	2	26	18.000	-961
1	10	23	10.599	-715
1	1	20	14.616	-841
1	10	28	13.500	-806
1	7	20	10.600	-711
2	1	25	18.000	-940
1	1	25	18.000	-939
2	5	29	18.000	-935
2	7	26	14.615	-827
2	4	28	18.000	-933
2	1	20	14.616	-824

30 of 600 Total Radial Measurements exceed the Spatial Allowable Deviation.

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* LDDM CALIBRATION WORKSHEET *

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LDDM data taken with ball plate on machine table. Corrected for Angular Errors Only.

16000 Ball plate Exp. date: 08-25-96

Software: Name PC1808, ID# CS-09P-144, Issue A, Revision 06/02/95

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.

Axial Data Performance Specification = +/-(0.00035 inch + 17 ppm)

Inch Groups	≤5	5-12	≥12
Number measured distances	20	50	30
Average absolute deviation	122	139	292
Average deviation	113	-2	73
Std dev over work zone	76	161	306
Std dev of multiple runs	86	72	66
Radial bias of standard	6	7	8
Std dev of the standard	17	21	25
Uncertainty of single run	323	443	854
Uncertainty of three runs	291	427	847
Allowable deviation	427	503	580

>>>>>***** CMM Uncertainty Exceeds the Axial Allowable Deviation *****<<<<<

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Axial allowable deviation.

Position	Spheres		Distance	Deviation	Position	Spheres		Distance	Deviation
1	4	16	9.000	392	1	2	5	16.800	-362
1	4	28	18.000	501	1	2	4	11.200	-236
1	3	27	18.000	489	1	14	17	16.800	-277
1	9	27	13.500	425	1	8	11	16.800	-272
1	2	26	18.000	448	1	3	5	11.200	-208
1	5	29	18.000	448	1	8	10	11.200	-200
1	8	26	13.500	378	1	20	23	16.800	-233
1	2	14	9.000	297	1	15	17	11.200	-195
1	1	25	18.000	380	1	1	5	22.401	-259
1	3	21	13.500	330	1	25	29	22.400	-255
1	1	19	13.500	322	1	2	3	5.600	-154
1	10	28	13.500	318	1	26	29	16.800	-215
1	15	27	9.000	267	1	14	16	11.199	-174
1	8	14	4.500	226	1	13	17	22.400	-234
1	9	21	9.000	265	1	25	28	16.800	-199

0 of 100 Single-axis measurements exceed the Axial Allowable Deviation.

The following data are an estimate of the CMM axial point-to-point errors:

X axis: average point-to-point error is -11.6 ppm.

Y axis: average point-to-point error is 24.5 ppm.

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* LDDM CALIBRATION WORKSHEET *

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LDDM data taken with ball plate on machine table. Corrected for Angular Errors Only.

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.

Planar Data Performance Specification = +/-(0.00035 inch + 25 ppm)

Inch Groups	≤5	5-6	6-10	10-12	12-17	≥17
Number measured distances	20	20	47	39	78	96
Average absolute deviation	122	81	149	167	190	212
Average deviation	113	-59	87	41	52	28
Std dev over work zone	76	65	152	195	222	254
Std dev of multiple runs	86	55	77	74	80	86
Radial bias of standard	6	6	7	7	8	9
Std dev of the standard	17	18	21	23	25	29
Uncertainty of single run	323	229	446	530	601	679
Uncertainty of three runs	291	211	428	516	587	664
Allowable deviation	463	490	575	630	688	800

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Planar allowable deviation.

Position	Spheres		Distance	Deviation	Position	Spheres		Distance	Deviation
1	8	19	10.600	462	1	16	23	7.184	-343
1	2	19	14.615	503	1	14	23	17.392	-439
1	4	16	9.000	392	1	15	23	12.070	-321
1	5	28	18.851	551	1	14	22	12.070	-319
1	4	28	18.000	501	1	2	5	16.800	-362
1	3	28	18.851	513	1	5	8	17.392	-354
1	8	25	14.615	444	1	13	23	22.847	-407
1	9	27	13.500	425	1	7	23	24.140	-407
1	3	16	10.600	379	1	8	23	19.059	-351
1	2	25	18.851	505	1	13	22	17.392	-309
1	3	27	18.000	489	1	4	8	12.070	-248
1	11	28	14.615	435	1	14	21	7.184	-200
1	17	28	10.600	347	1	8	17	17.392	-294
1	2	26	18.000	448	1	2	4	11.200	-236
1	5	29	18.000	448	1	14	17	16.800	-277

0 of 300 1 and 2 Axis Measurements exceed the Planar Allowable Deviation.
The following data are an estimate of the CMM planar squareness errors:
The indicated XY plane squareness is 10.0 (2.06 arcseconds).
* May be affected by yaw, pitch, roll, and straightness of the included axes.

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* LDDM CALIBRATION WORKSHEET *

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LDDM data taken with ball plate on machine table. Corrected for Angular Errors Only.

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.

Spatial Data Performance Specification = +/-(0.00035 inch + 30 ppm)

Inch Groups	≤6	6-10	10-12	12 14	14-17	17 19	19 24	≥24
Number measured distances	40	47	39	34	44	41	39	16
Average absolute deviation	102	149	167	182	196	255	188	162
Average deviation	27	87	41	34	66	119	-47	-19
Std dev over work zone	112	152	195	220	226	283	215	191
Std dev of multiple runs	72	77	74	72	86	79	89	99
Radial bias of standard	6	6	7	7	8	8	9	10
Std dev of the standard	17	19	22	23	25	28	30	34
Uncertainty of single run	326	446	530	584	617	775	592	531
Uncertainty of three runs	304	428	516	572	600	765	574	505
Allowable deviation	485	566	668	712	782	872	922	1074

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Spatial allowable deviation.

Position	Spheres		Distance	Deviation
1	8	19	10.600	462
1	2	19	14.615	503
1	4	16	9.000	392
1	5	28	18.851	551
1	3	16	10.600	379
1	8	25	14.615	444
1	9	27	13.500	425
1	4	28	18.000	501
1	3	28	18.851	513
1	2	25	18.851	505
1	11	28	14.615	435
1	3	27	18.000	489
1	17	28	10.600	347
1	2	26	18.000	448
1	5	29	18.000	448

Position	Spheres		Distance	Deviation
1	16	23	7.184	-343
1	14	23	17.392	-439
1	15	23	12.070	-321
1	14	22	12.070	-319
1	2	5	16.800	-362
1	5	8	17.392	-354
1	13	23	22.847	-407
1	8	23	19.059	-351
1	7	23	24.140	-407
1	13	22	17.392	-309
1	14	21	7.184	-200
1	4	8	12.070	-248
1	2	4	11.200	-236
1	8	17	17.392	-294
1	14	17	16.800	-277

0 of 300 Total Radial Measurements exceed the Spatial Allowable Deviation.

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* LDDM CALIBRATION WORKSHEET *

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LDDM data taken with ball plate 9.5 inches above machine table. Corrected for Angular Errors Only.

16000 Ball plate Exp. date: 08-25-96

Software: Name PC1808, ID# CS-09P-144, Issue A, Revision 06/02/95

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.

Axial Data Performance Specification = +/-(0.00035 inch + 17 ppm)

Inch Groups	≤5	5-12	≥12
Number measured distances	20	50	30
Average absolute deviation	40	87	156
Average deviation	-25	-83	-155
Std dev over work zone	44	67	88
Std dev of multiple runs	65	60	67
Radial bias of standard	6	7	8
Std dev of the standard	17	21	25
Uncertainty of single run	162	244	379
Uncertainty of three runs	124	224	362
Allowable deviation	427	503	580

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Axial allowable deviation.

Position	Spheres		Distance	Deviation	Position	Spheres		Distance	Deviation
1	17	23	4.500	55	1	9	11	11.200	-273
1	11	23	9.000	41	1	10	11	5.599	-201
1	19	20	5.600	36	1	2	5	16.800	-285
1	3	9	4.500	31	1	8	11	16.800	-282
1	21	27	4.500	30	1	3	5	11.200	-240
1	22	28	4.500	22	1	7	11	22.400	-318
1	13	14	5.600	12	1	1	5	22.401	-316
1	19	25	4.500	9	1	14	17	16.800	-268
1	5	23	13.500	12	1	15	17	11.200	-225
1	13	25	9.000	6	1	25	29	22.400	-275
1	1	7	4.501	1	1	13	17	22.400	-256
1	13	19	4.500	-3	1	20	23	16.800	-206
1	19	21	11.200	-9	1	26	29	16.800	-205
1	8	9	5.600	-9	1	27	29	11.200	-170
1	14	20	4.500	-12	1	9	21	9.000	-158

0 of 100 Single-axis measurements exceed the Axial Allowable Deviation.

The following data are an estimate of the CMM axial point-to-point errors:

X axis: average point-to-point error is -11.8 ppm.

Y axis: average point-to-point error is -6.0 ppm.

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* LDDM CALIBRATION WORKSHEET *

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LDDM data taken with ball plate 9.5 inches above machine table. Corrected for Angular Errors Only.

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.

Planar Data Performance Specification = +/-(0.00035 inch + 25 ppm)

Inch Groups	≤5	5-6	6-10	10-12	12-17	≥17
Number measured distances	20	20	47	39	78	96
Average absolute deviation	40	72	83	117	140	197
Average deviation	-25	-67	-64	-105	-131	-195
Std dev over work zone	44	54	80	88	99	105
Std dev of multiple runs	65	47	64	56	54	58
Radial bias of standard	6	6	7	7	8	9
Std dev of the standard	17	18	21	23	25	29
Uncertainty of single run	162	198	257	311	357	460
Uncertainty of three runs	124	183	234	297	346	451
Allowable deviation	463	490	575	630	688	800

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Planar allowable deviation.

Position	Spheres		Distance	Deviation	Position	Spheres		Distance	Deviation
1	14	19	7.184	173	1	9	23	14.368	-344
1	15	19	12.070	123	1	9	17	12.070	-309
1	8	19	10.600	76	1	15	23	12.070	-303
1	9	19	14.368	85	1	9	29	17.541	-361
1	17	23	4.500	55	1	10	17	7.183	-239
1	14	25	10.600	72	1	5	9	12.070	-285
1	2	9	7.184	53	1	9	11	11.200	-273
1	10	19	19.059	68	1	5	8	17.392	-337
1	17	22	7.184	40	1	14	23	17.392	-335
1	19	20	5.600	36	1	7	23	24.140	-404
1	11	23	9.000	41	1	15	29	14.368	-300
1	3	10	7.184	37	1	8	23	19.059	-342
1	17	28	10.600	43	1	10	11	5.599	-201
1	1	9	12.071	44	1	7	29	26.154	-409
1	3	9	4.500	31	1	5	7	22.848	-373

0 of 300 1 and 2 Axis Measurements exceed the Planar Allowable Deviation.

The following data are an estimate of the CMM planar squareness errors:

The indicated XY plane squareness is 6.1 (1.26 arcseconds).

* May be affected by yaw, pitch, roll, and straightness of the included axes.

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* LDDM CALIBRATION WORKSHEET *

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LDDM data taken with ball plate 9.5 inches above machine table. Corrected for Angular Errors Only.

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.

Spatial Data Performance Specification = +/-(0.00035 inch + 30 ppm)

Inch Groups	≤6	6-10	10-12	12 14	14-17	17 19	19 24	≥24
Number measured distances	40	47	39	34	44	41	39	16
Average absolute deviation	56	83	117	127	150	158	217	250
Average deviation	-46	-64	-105	-115	-144	-156	-213	-250
Std dev over work zone	53	80	88	99	98	97	103	100
Std dev of multiple runs	57	64	56	56	52	58	55	65
Radial bias of standard	6	6	7	7	8	8	9	10
Std dev of the standard	17	19	22	23	25	28	30	34
Uncertainty of single run	182	256	311	338	371	387	492	553
Uncertainty of three runs	157	234	297	325	361	375	483	543
Allowable deviation	485	566	668	712	782	872	922	1074

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Spatial allowable deviation.

Position	Spheres		Distance	Deviation
1	14	19	7.184	173
1	15	19	12.070	123
1	17	23	4.500	55
1	8	19	10.600	76
1	9	19	14.368	85
1	14	25	10.600	72
1	2	9	7.184	53
1	10	19	19.059	68
1	17	22	7.184	40
1	19	20	5.600	36
1	11	23	9.000	41
1	3	10	7.184	37
1	17	28	10.600	43
1	3	9	4.500	31
1	21	27	4.500	30

Position	Spheres		Distance	Deviation
1	9	23	14.368	-344
1	9	17	12.070	-309
1	15	23	12.070	-303
1	10	17	7.183	-239
1	9	29	17.541	-361
1	5	9	12.070	-285
1	9	11	11.200	-273
1	10	11	5.599	-201
1	5	8	17.392	-337
1	14	23	17.392	-335
1	15	29	14.368	-300
1	7	23	24.140	-404
1	8	23	19.059	-342
1	16	23	7.184	-205
1	7	29	26.154	-409

0 of 300 Total Radial Measurements exceed the Spatial Allowable Deviation.

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* LDDM CALIBRATION WORKSHEET *

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LDDM data taken with both positions analyzed. Corrected for Angular Errors Only.

16000 Ball plate Exp. date: 08-25-96

Software: Name PC1808, ID# CS-09P-144, Issue A, Revision 06/02/95

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.

Axial Data Performance Specification = +/-(0.00035 inch + 17 ppm)

Inch Groups	<5	5-12	>12
Number measured distances	40	100	60
Average absolute deviation	81	113	224
Average deviation	44	-42	-41
Std dev over work zone	93	129	251
Std dev of multiple runs	76	66	67
Radial bias of standard	6	7	8
Std dev of the standard	17	21	25
Uncertainty of single run	279	362	683
Uncertainty of three runs	250	346	675
Allowable deviation	427	503	580

>>>>>***** CMM Uncertainty Exceeds the Axial Allowable Deviation *****<<<<<

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Axial allowable deviation.

Position	Spheres		Distance	Deviation	Position	Spheres		Distance	Deviation
1	4	16	9.000	392	1	2	5	16.800	-362
1	4	28	18.000	501	2	9	11	11.200	-273
1	3	27	18.000	489	2	10	11	5.599	-201
1	9	27	13.500	425	2	2	5	16.800	-285
1	2	26	18.000	448	2	8	11	16.800	-282
1	5	29	18.000	448	2	3	5	11.200	-240
1	8	26	13.500	378	1	2	4	11.200	-236
1	2	14	9.000	297	1	14	17	16.800	-277
1	1	25	18.000	380	2	7	11	22.400	-318
1	3	21	13.500	330	2	1	5	22.401	-316
1	1	19	13.500	322	1	8	11	16.800	-272
1	10	28	13.500	318	2	14	17	16.800	-268
1	15	27	9.000	267	2	15	17	11.200	-225
1	8	14	4.500	226	1	3	5	11.200	-208
1	9	21	9.000	265	2	25	29	22.400	-275

0 of 200 Single-axis measurements exceed the Axial Allowable Deviation.

The following data are an estimate of the CMM axial point-to-point errors:

X axis: average point-to-point error is -11.7 ppm.

Y axis: average point-to-point error is 9.2 ppm.

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* LDDM CALIBRATION WORKSHEET *

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LDDM data taken with both position analyzed. Corrected for Angular Errors Only.

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.

Planar Data Performance Specification = +/-(0.00035 inch + 25 ppm)

Inch Groups	≤5	5-6	6-10	10-12	12-17	>17
Number measured distances	40	40	94	78	156	192
Average absolute deviation	81	76	116	142	165	204
Average deviation	44	-63	11	-32	-40	-83
Std dev over work zone	93	59	143	168	195	224
Std dev of multiple runs	76	51	71	66	68	74
Radial bias of standard	6	6	7	7	8	9
Std dev of the standard	17	18	21	23	25	29
Uncertainty of single run	279	213	388	455	524	621
Uncertainty of three runs	250	196	370	442	512	609
Allowable deviation	463	490	575	630	688	800

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Planar allowable deviation.

Position	Spheres		Distance	Deviation	Position	Spheres		Distance	Deviation
1	8	19	10.600	462	1	16	23	7.184	-343
1	2	19	14.615	503	1	14	23	17.392	-439
1	4	16	9.000	392	1	15	23	12.070	-321
1	5	28	18.851	551	1	14	22	12.070	-319
1	4	28	18.000	501	2	9	23	14.368	-344
1	3	28	18.851	513	2	9	17	12.070	-309
1	8	25	14.615	444	1	2	5	16.800	-362
1	9	27	13.500	425	2	15	23	12.070	-303
1	3	16	10.600	379	2	9	29	17.541	-361
1	2	25	18.851	505	2	10	17	7.183	-239
1	3	27	18.000	489	1	5	8	17.392	-354
1	11	28	14.615	435	1	13	23	22.847	-407
1	17	28	10.600	347	2	5	9	12.070	-285
1	2	26	18.000	448	2	9	11	11.200	-273
1	5	29	18.000	448	2	5	8	17.392	-337

0 of 600 1 and 2 Axis Measurements exceed the Planar Allowable Deviation.

The following data are an estimate of the CMM planar squareness errors:

The indicated XY plane squareness is 8.1 (1.66 arcseconds).

* May be affected by yaw, pitch, roll, and straightness of the included axes.

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* LDDM CALIBRATION WORKSHEET *

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LDDM data taken with both positions analyzed. Corrected for Angular Errors Only.

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.

Spatial Data Performance Specification = +/-(0.00035 inch + 30 ppm)

Inch Groups	≤6	6-10	10-12	12 14	14-17	17 19	19 24	≥24
Number measured distances	80	94	78	68	88	82	78	32
Average absolute deviation	79	116	142	154	173	206	202	206
Average deviation	-9	11	-32	-41	-39	-19	-130	-134
Std dev over work zone	94	143	168	185	203	252	187	190
Std dev of multiple runs	65	71	66	65	71	69	74	84
Radial bias of standard	6	6	7	7	8	8	9	10
Std dev of the standard	17	19	22	23	25	28	30	34
Uncertainty of single run	270	388	455	496	548	663	567	581
Uncertainty of three runs	248	370	442	484	535	654	554	565
Allowable deviation	485	566	668	712	782	872	922	1074

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Spatial allowable deviation.

Position	Spheres		Distance	Deviation	Position	Spheres		Distance	Deviation
1	8	19	10.600	462	1	16	23	7.184	-343
1	2	19	14.615	503	1	14	23	17.392	-439
1	4	16	9.000	392	1	15	23	12.070	-321
1	5	28	18.851	551	1	14	22	12.070	-319
1	3	16	10.600	379	2	9	23	14.368	-344
1	8	25	14.615	444	2	9	17	12.070	-309
1	9	27	13.500	425	2	15	23	12.070	-303
1	4	28	18.000	501	1	2	5	16.800	-362
1	3	28	18.851	513	2	10	17	7.183	-239
1	2	25	18.851	505	2	9	29	17.541	-361
1	11	28	14.615	435	1	5	8	17.392	-354
1	3	27	18.000	489	2	5	9	12.070	-285
1	17	28	10.600	347	2	9	11	11.200	-273
1	2	26	18.000	448	1	13	23	22.847	-407
1	5	29	18.000	448	2	10	11	5.599	-201

0 of 600 Total Radial Measurements exceed the Spatial Allowable Deviation.

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* CORDAX CALIBRATION WORKSHEET *

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Cordax data from both positions corrected for point-to-point and squareness errors.

16000 Ball plate Exp. date: 08-25-96

Software: Name PC1808, ID# CS-09P-144, Issue A, Revision 06/02/95

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.

The applied axial point-to-point corrections were as follows:

X axis = 4.6 ppm; Y axis = 5.7 ppm; Z-axis = 0

Axial Data Performance Specification = +/-(0.00035 inch + 17 ppm)

Inch Groups	≤5	5-12	>12
Number measured distances	40	100	60
Average absolute deviation	96	91	47
Average deviation	12	-5	-1
Std dev over work zone	116	106	59
Std dev of multiple runs	23	23	32
Radial bias of standard	6	7	8
Std dev of the standard	17	21	25
Uncertainty of single run	305	285	168
Uncertainty of three runs	303	283	160
Allowable deviation	427	503	580

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Axial allowable deviation.

Position	Spheres		Distance	Deviation	Position	Spheres		Distance	Deviation
2	4	16	9.000	254	2	13	19	4.500	-192
2	5	17	9.000	245	1	13	19	4.500	-192
2	1	13	9.000	216	1	15	21	4.500	-181
2	3	15	9.000	212	1	14	20	4.500	-180
2	4	10	4.500	170	2	13	25	9.000	-190
2	3	9	4.500	166	1	16	22	4.500	-154
2	5	11	4.500	164	1	17	23	4.500	-153
2	2	14	9.000	192	2	16	28	9.000	-179
2	2	8	4.500	155	2	17	29	9.000	-178
1	3	9	4.500	155	1	9	21	9.000	-172
1	5	11	4.500	149	2	16	22	4.500	-143
1	4	10	4.500	142	2	15	21	4.500	-141
1	1	13	9.000	167	2	17	23	4.500	-140
1	5	17	9.000	165	1	8	20	9.000	-163
1	3	15	9.000	164	2	15	27	9.000	-152

0 of 200 Single-axis measurements exceed the Axial Allowable Deviation.

The following data are an estimate of the CMM axial point-to-point errors:

X axis: average point-to-point error is 0.0 ppm.

Y axis: average point-to-point error is -0.0 ppm.

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* CORDAX CALIBRATION WORKSHEET *

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Cordax data from both positions corrected for point-to-point and squareness errors.

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.
The applied planar squareness corrections were as follows:
XY plane = -7.0 ppm; XZ plane = 0 ppm; YZ plane = 0 ppm

Planar Data Performance Specification = +/-(0.00035 inch + 25 ppm)

Inch Groups	≤5	5-6	6-10	10-12	12-17	≥17
Number measured distances	40	40	94	78	156	192
Average absolute deviation	96	59	113	113	91	79
Average deviation	12	-7	-6	-9	-3	7
Std dev over work zone	116	67	141	140	121	100
Std dev of multiple runs	23	18	26	26	32	35
Radial bias of standard	6	6	7	7	8	9
Std dev of the standard	17	18	21	23	25	29
Uncertainty of single run	305	185	368	365	311	268
Uncertainty of three runs	303	183	365	362	307	262
Allowable deviation	463	490	575	630	688	800

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Planar allowable deviation.

Position	Spheres		Distance	Deviation	Position	Spheres		Distance	Deviation
2	3	10	7.184	334	2	13	20	7.184	-373
2	3	16	10.600	387	1	13	20	7.184	-296
1	3	10	7.184	321	2	13	21	12.070	-352
2	2	16	14.368	344	2	16	23	7.184	-285
1	3	16	10.600	288	2	7	20	10.600	-325
2	21	28	7.184	247	2	13	26	10.600	-316
1	2	10	12.071	297	2	7	21	14.368	-354
2	4	16	9.000	254	1	7	20	10.600	-291
2	2	10	12.071	280	2	14	21	7.184	-233
2	5	17	9.000	245	1	16	23	7.184	-227
1	2	16	14.368	282	2	16	29	10.600	-256
1	21	28	7.184	206	2	13	19	4.500	-192
2	2	13	10.600	235	1	13	19	4.500	-192
2	1	13	9.000	216	1	7	21	14.368	-293
1	2	9	7.184	197	1	14	21	7.184	-217

0 of 600 1 and 2 Axis Measurements exceed the Planar Allowable Deviation.
The following data are an estimate of the CMM planar squareness errors:
The indicated XY plane squareness is 0.0 (0.01 arcseconds).
* May be affected by yaw, pitch, roll, and straightness of the included axes.

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* CORDAX CALIBRATION WORKSHEET *

****

Cordax data from both positions corrected for point-to-point and squareness errors.

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.

Spatial Data Performance Specification = +/-(0.00035 inch + 30 ppm)

Inch Groups	≤6	6-10	10-12	12 14	14-17	17 19	19 24	>24
Number measured distances	80	94	78	68	88	82	78	32
Average absolute deviation	78	113	113	98	85	82	77	80
Average deviation	2	-6	-9	4	-9	20	1	-13
Std dev over work zone	94	141	140	124	119	99	99	102
Std dev of multiple runs	21	26	26	30	33	33	34	39
Radial bias of standard	6	6	7	7	8	8	9	10
Std dev of the standard	17	19	22	23	25	28	30	34
Uncertainty of single run	249	367	365	324	302	269	263	276
Uncertainty of three runs	247	365	362	320	297	264	257	269
Allowable deviation	485	566	668	712	782	872	922	1074

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Spatial allowable deviation.

Position	Spheres		Distance	Deviation	Position	Spheres		Distance	Deviation
2	3	10	7.184	334	2	13	20	7.184	-373
2	3	16	10.600	387	1	13	20	7.184	-296
1	3	10	7.184	321	2	16	23	7.184	-285
2	2	16	14.368	344	2	13	21	12.070	-352
2	21	28	7.184	247	2	7	20	10.600	-325
1	3	16	10.600	288	2	13	26	10.600	-316
1	2	10	12.071	297	2	7	21	14.368	-354
2	4	16	9.000	254	1	7	20	10.600	-291
2	5	17	9.000	245	2	14	21	7.184	-233
2	2	10	12.071	280	1	16	23	7.184	-227
1	21	28	7.184	206	2	13	19	4.500	-192
1	2	16	14.368	282	1	13	19	4.500	-192
2	2	13	10.600	235	2	16	29	10.600	-256
2	4	10	4.500	170	1	14	21	7.184	-217
2	1	13	9.000	216	1	7	21	14.368	-293

0 of 600 Total Radial Measurements exceed the Spatial Allowable Deviation.

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* LDDM CALIBRATION WORKSHEET *

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LDDM Data Corrected for point-to-point and squareness errors. Both positions used for the analysis.

Software: Name PC1808, ID# CS-09P-144, Issue A, Revision 06/02/95

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.
The applied axial point-to-point corrections were as follows:
X axis = 7.5 ppm; Y axis = 52.7 ppm; Z-axis = 0

Axial Data Performance Specification = +/-(0.00035 inch + 17 ppm)

Inch Groups	≤5	5-12	≥12
Number measured distances	40	100	60
Average absolute deviation	55	42	33
Average deviation	8	-5	-3
Std dev over work zone	68	54	41
Std dev of multiple runs	41	33	38
Radial bias of standard	6	7	8
Std dev of the standard	17	21	25
Uncertainty of single run	191	154	133
Uncertainty of three runs	179	144	117
Allowable deviation	427	503	580

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Axial allowable deviation.

Position	Spheres		Distance	Deviation	Position	Spheres		Distance	Deviation
1	4	10	4.500	179	1	13	19	4.500	-136
1	4	16	9.000	203	2	15	21	4.500	-116
1	5	11	4.500	147	1	7	19	9.000	-119
1	5	17	9.000	122	1	16	28	9.000	-118
1	2	14	9.000	112	1	16	22	4.500	-99
1	1	2	5.601	99	1	14	20	4.500	-98
2	3	15	9.000	93	2	13	19	4.500	-97
1	4	22	13.500	104	2	8	20	9.000	-113
2	3	9	4.500	74	2	9	21	9.000	-97
1	2	8	4.500	71	1	11	23	9.000	-93
1	1	13	9.000	82	2	7	19	9.000	-91
2	21	27	4.500	66	1	14	26	9.000	-88
1	1	7	4.501	65	2	14	20	4.500	-74
2	13	15	11.200	82	2	16	22	4.500	-73
1	19	25	4.500	64	1	10	28	13.500	-94

0 of 200 Single-axis measurements exceed the Axial Allowable Deviation.
The following data are an estimate of the CMM axial point-to-point errors:
X axis: average point-to-point error is 0.0 ppm.
Y axis: average point-to-point error is 0.0 ppm.

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* LDDM CALIBRATION WORKSHEET *

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LDDM Data Corrected for point-to-point and squareness errors. Both positions used for the analysis.

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.
The applied planar squareness corrections were as follows:
XY plane = 6.3 ppm; XZ plane = 0 ppm; YZ plane = 0 ppm

Planar Data Performance Specification = +/-(0.00035 inch + 25 ppm)

Inch Groups	≤5	5-6	6-10	10-12	12-17	≥17
Number measured distances	40	40	94	78	156	192
Average absolute deviation	55	25	85	71	75	69
Average deviation	8	1	-0	-8	-10	2
Std dev over work zone	68	32	101	93	94	85
Std dev of multiple runs	41	25	38	38	38	39
Radial bias of standard	6	6	7	7	8	9
Std dev of the standard	17	18	21	23	25	29
Uncertainty of single run	191	99	275	247	253	236
Uncertainty of three runs	179	90	268	239	245	227
Allowable deviation	463	490	575	630	688	800

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Planar allowable deviation.

Position	Spheres		Distance	Deviation	Position	Spheres		Distance	Deviation
1	4	10	4.500	179	1	16	23	7.184	-252
1	3	10	7.184	204	1	13	20	7.184	-233
1	3	16	10.600	236	1	10	23	10.599	-259
1	4	16	9.000	203	1	7	20	10.600	-256
2	2	9	7.184	171	2	7	20	10.600	-200
1	2	13	10.600	198	2	13	20	7.184	-170
1	5	11	4.500	147	1	7	21	14.368	-225
1	8	13	7.184	168	1	14	21	7.184	-166
1	21	28	7.184	164	1	22	26	12.070	-196
2	3	10	7.184	162	1	13	19	4.500	-136
1	15	19	12.070	195	2	16	23	7.184	-154
1	2	16	14.368	207	1	22	27	7.184	-154
1	5	16	10.600	178	1	13	26	10.600	-176
1	14	19	7.184	147	1	13	21	12.070	-182
2	20	27	7.184	146	1	15	23	12.070	-182

0 of 600 1 and 2 Axis Measurements exceed the Planar Allowable Deviation.
The following data are an estimate of the CMM planar squareness errors:
The indicated XY plane squareness is -0.3 (-0.07 arcseconds).
* May be affected by yaw, pitch, roll, and straightness of the included axes.

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* LDDM CALIBRATION WORKSHEET *

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LDDM Data Corrected for point-to-point and squareness errors. Both positions used for the analysis.

Inspected by XXX Department XXX Inspection Date: 01-25-1996

The distances are in inches and deviations in microinches.

Spatial Data Performance Specification = +/-(0.00035 inch + 30 ppm)

Inch Groups	≤6	6-10	10-12	12 14	14-17	17 19	19 24	≥24
Number measured distances	80	94	78	68	88	82	78	32
Average absolute deviation	40	85	71	84	68	72	67	65
Average deviation	5	-0	-8	-5	-13	5	-1	1
Std dev over work zone	53	101	93	101	88	88	84	83
Std dev of multiple runs	34	38	38	38	38	39	38	42
Radial bias of standard	6	6	7	7	8	8	9	10
Std dev of the standard	17	19	22	23	25	28	30	34
Uncertainty of single run	149	274	247	275	237	243	232	233
Uncertainty of three runs	138	267	239	267	229	235	224	222
Allowable deviation	485	566	668	712	782	872	922	1074

These data are the 15 most positive and 15 most negative deviations with their ball plate position, sphere pair and nominal distance; respectively ranked as a percentage of the Spatial allowable deviation.

Position	Spheres		Distance	Deviation	Position	Spheres		Distance	Deviation
1	4	10	4.500	179	1	16	23	7.184	-252
1	3	10	7.184	204	1	13	20	7.184	-233
1	3	16	10.600	236	1	10	23	10.599	-259
1	4	16	9.000	203	1	7	20	10.600	-256
2	2	9	7.184	171	2	13	20	7.184	-170
1	5	11	4.500	147	2	7	20	10.600	-200
1	8	13	7.184	168	1	14	21	7.184	-166
1	2	13	10.600	198	1	7	21	14.368	-225
1	21	28	7.184	164	1	13	19	4.500	-136
2	3	10	7.184	162	1	22	26	12.070	-196
1	15	19	12.070	195	2	16	23	7.184	-154
1	5	16	10.600	178	1	22	27	7.184	-154
1	2	16	14.368	207	1	13	26	10.600	-176
1	14	19	7.184	147	1	13	21	12.070	-182
2	20	27	7.184	146	1	15	23	12.070	-182

0 of 600 Total Radial Measurements exceed the Spatial Allowable Deviation.