CMM Measurement Report

Flight Model

Results of the CMM Measurements on the RICH mirror - Revision 2

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CMA
23 June 2005

I. Measurements:

The RICH mirror was measured 14 June on a coordinate measuring machine (CMM) at the Univ of Arizona shop. The mirror was mounted upside down, on tree points at the top rims of the mirror. This was the only configuration which would allow the probe to access the entire mirror surface. The following sets of measurements were made:

a) The plane of the metal mounting inserts and the location of the mounting holes.
b) The figure of the mirror surface was sampled by 5 rings of points with roughly 20 points per ring. The first and last rings were at (or near) the edge of the mirror surface. The rings were spaced in a roughly even manner through the cone height. The points along the rings were not in a regular grid since this CMM is driven manually.
c) The height of the mirror was measured.

The goal of these CMM measurements is to verify the conformity of the main dimensions to the specifications. These measurements do not address the surface accuracy of the mirror. The surface roughness will be addressed by TOPO measurements on samples of the mirror surface (witness samples).

II. Results:

1) The mounting plane formed by the bottom of the 4 metal inserts forms the reference surface for mounting the RICH mirror system. This plane is identified as surface "C" in the ICD drawing. The plane is verified to be flat (ie, the 4 inserts are co-planar) with a max deviation of 0.3mm.

2) The insert hole pattern was produced by using the shipping fixture for a template. The CMM measurements verify that bolt circle radius is 685 mm. The error is less than the measurement error. This is a difficult measurement since it involves locating the center of small, 6mm holes. The 4 holes form a cross which forms a right angle to within 0.08 degrees or better.

3) The bottom edge of the mirror surface is identified as "B" in the ICD. This measured to be about 0.5 mm above the reference mounting plane formed by the inserts. This allows the mirror mounting to be defined by the inserts rather than possible irregularities in the mirror edge. This conforms to the ICD specification.

4) The height of the mirror (referenced to the insert mounting plane) is 463.2 mm. This is specified as 462 mm in the ICD. CMA could reduce this height by grinding. However, re-measurement verification would be difficult. Our recommendation is to leave this if it does not interfere with

equipment. We also note that the ICD specification set of [lower mirror diameter, upper mirror diameter, and height] define a cone which is slightly different than the actual mandrel supplied by CGS. We have taken the shape defined by the mandrel to be the intended shape rather than the ICD specification when there is a conflict.

5) The diameter of the mirror at the bottom is measured to be 1340.1 mm in conformance to the ICD.

6) The hole pattern of the mounting inserts is concentric to the mirror to within about 0.3mm. The uncertainty of this value is about the same amount due to the reasons explained in (2) above.

7) The axis of the cone is measured to be within 0.04 degrees of perpendicular to the mounting plane of the inserts.

8) The taper angle of the cone is measured to be 8.47 degrees. The mandrel measurements supplied by CGS indicate that the mandrel taper angle is 8.465 degrees. We conclude that the mirror represents an accurate reproduction of the mandrel shape.

9) Each ring of measurements yields a center point. A best fit line of these center points (for the 5 measurement rings) agrees with the axis of the mirror cone. The max deviation (of a center point) from this line is 0.055 mm. The centering tolerance specification is 0.10 mm. Our measurements indicate that the mirror is about a factor of 2 better than this specification.

10) For the bottom 3 rings of measurement, the rms deviation of points from the best fit cone surface is roughly 0.10-0.14 mm. The measurements of the top rings have deformations in the shape caused by supporting the mirror on the top edge. Thus, these measurements are not included in this calculation. The greatest deviations of the mirror surface from the cone shape are at the seams between mirror sections. There is potentially some error at the top since these sections are not supported by structural ribs.

III. Recommendations:

These measurements indicate conformity with the specifications, except where noted. The measurements do not address any potential, large scale slope errors, particularly near the 3 seams of the mirror surface. The top areas of the seams are unsupported and we do not yet know if this is a problem.

After a reflective coat is applied to the mirror surface, CMA recommends that CGS makes some further simple measurements of the mirror surface as follows. The mirror can be mounted upside down above a level plane. The plane is covered with a regular lined, square grid paper. A photograph is then taken from above the mirror, along the central cone axis. This photographic view will allow at least a qualitative measurement of the conformity of the mirror surface with respect to large scale slope errors and any discontinuities at the mirror seams.

Roughness Measurement Report

FM/FS Coupons

Roughness Measurement Report
RICH FM Reflector
Serial Number FM-00102

The following is a Roughness Measurement Report for the RICH Flight Model Mirror (FM) for the AMS-02. The measurements were made using CMS's WYKO TOPO 3-D optical profiler.

Eight coupons were tested at f different locations for each coupon, for a total of 32 data points. Each data point was a measure of a 250 μm X 250 μm area on the FM/FS coupons. The data was compared to CMA's reference flat (glass), which measured between 1.1 nm and 1.3 nm (see attached data).

The results indicate measurements roughly 10 times smaller than the requirement. Most measurements lie between 3 nm and 7 nm, the maximum being 40 nm allowable based on the Procurement Specifications

The X and Y components of the slope error relating to each data point all fell below 1.0 mrad, which was specified in the procurement specifications.

The Coupon roughness measurements indicate that the FM and FS are within specifications for the roughness and slope error as required by the procurement specifications.

Roughness Measurements

WYKO TOPO 3-D

and

ZYGO Reference Flat

Data Points

zygo
Zygo Corporation and Subsidiaries
Advanced Metrology Systems
Laurel Brook Road
P.O. Box 448
Middlefield, CT 06455-0448
Telephone: 860-347-8
Fax: 860-347-6595

Customer : 190101
Forw Agent: United Parcel

: 12-22-
: 171

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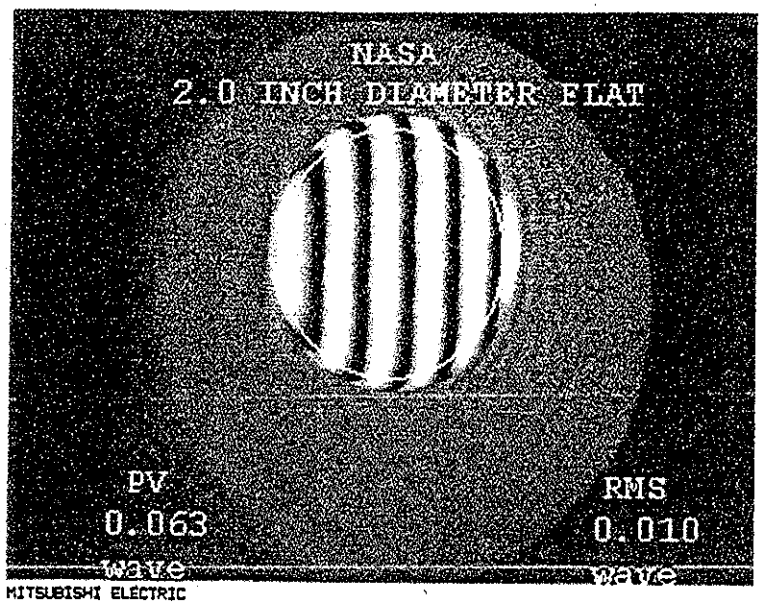

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Interferograms
Surface Roughness Grap
Certificate of Complia

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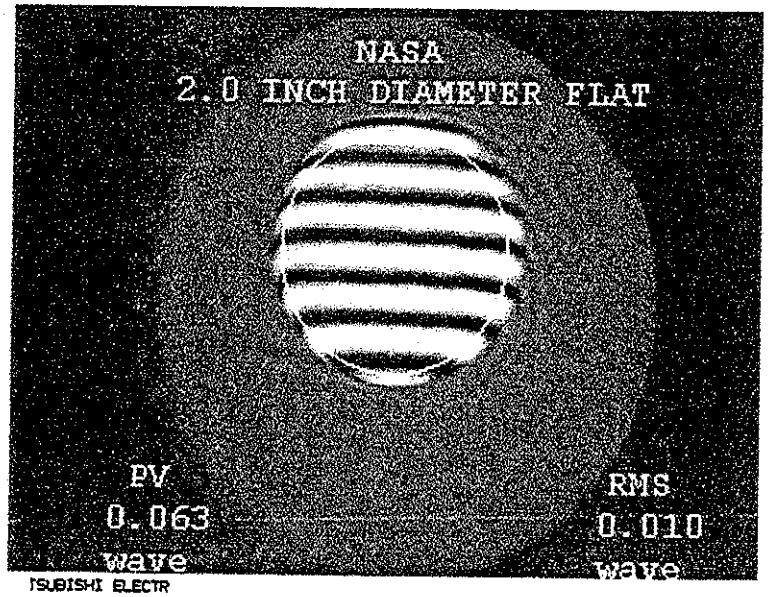

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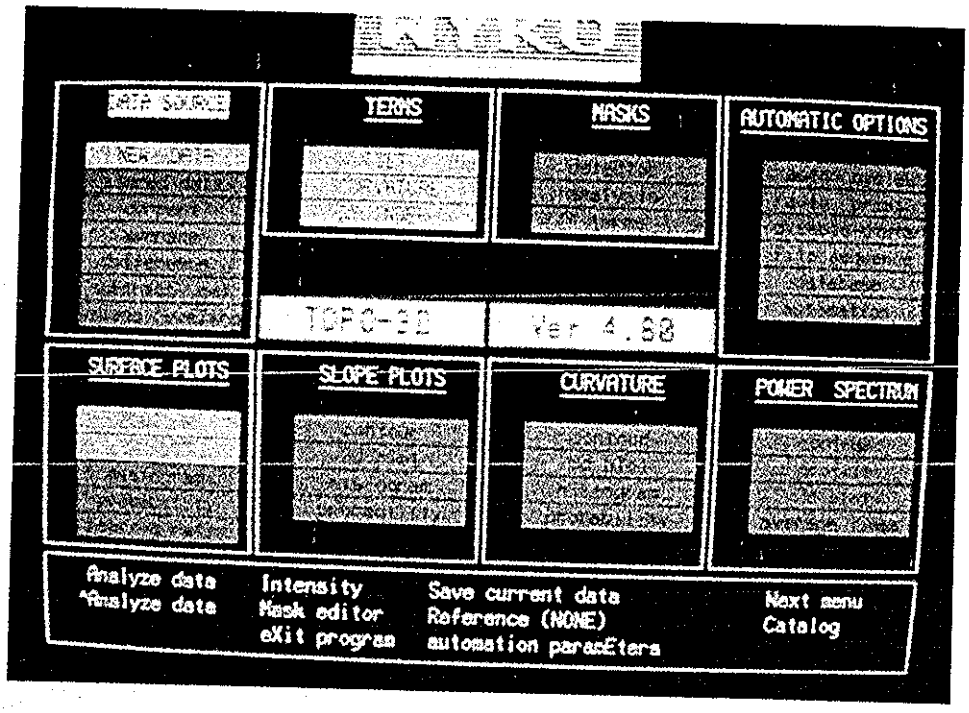
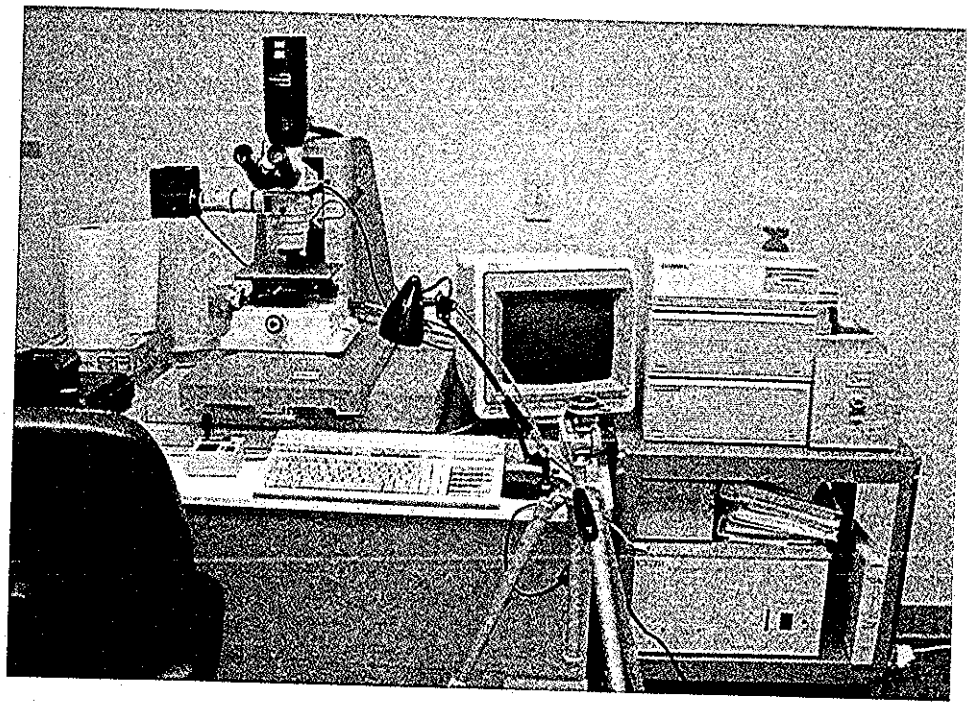
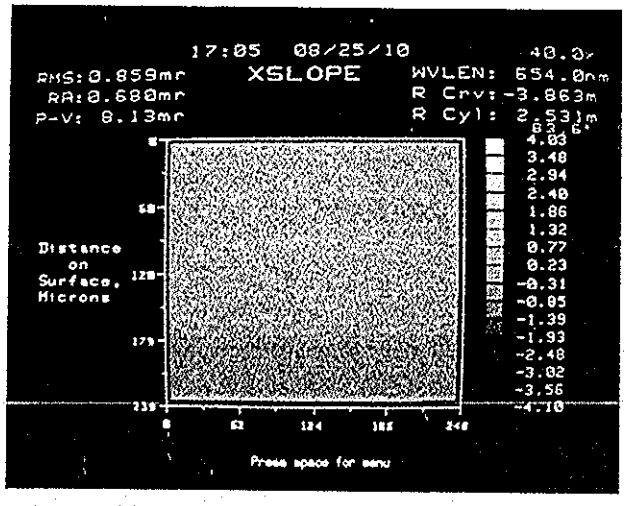




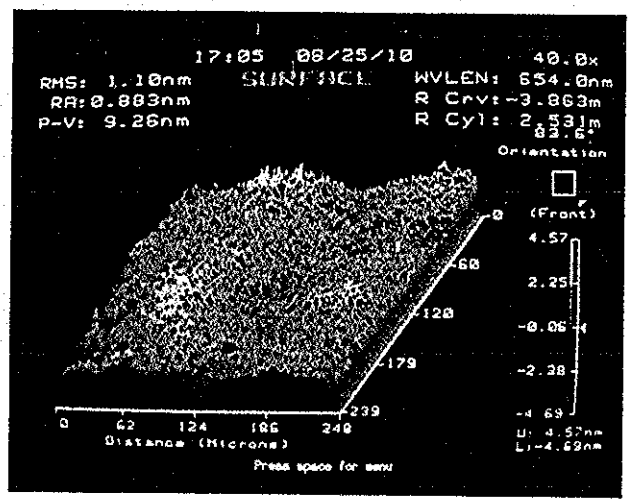
Top View Generic Menu screen for the analysis of the WYKO TOPO 3-D. For the FM measurements, Slope Plot Contours were selected to yield additional slope error data for each data point.

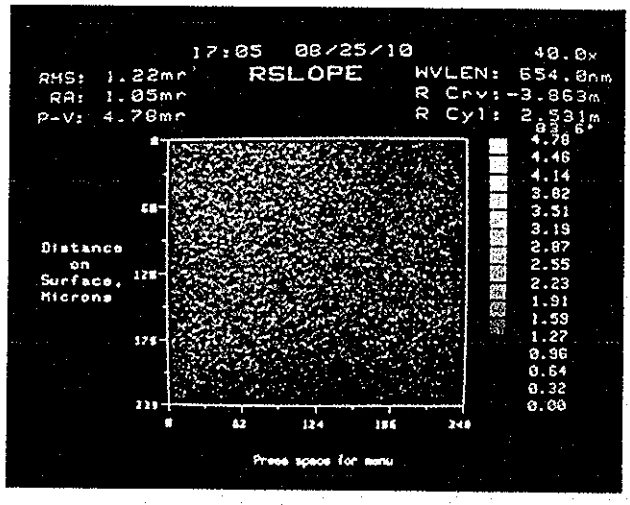
Bottom View WYKO TOPO 3-D instrument at CMA.

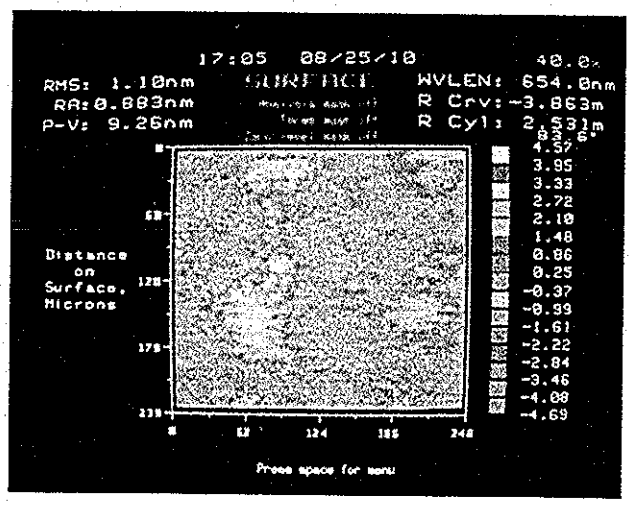


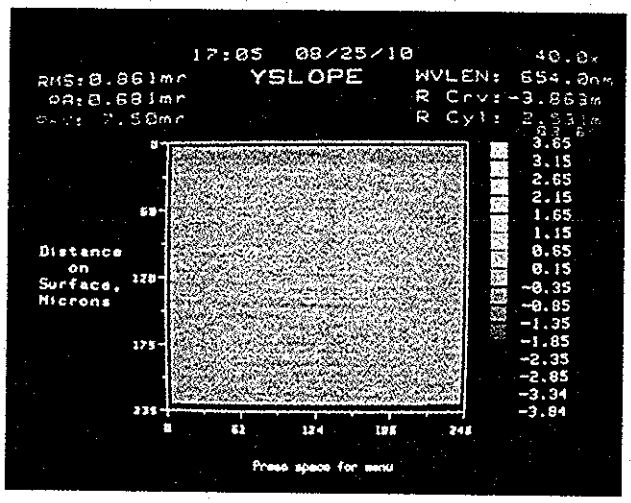
ZYGO Glass Reference Flat

Data Point	1
rms Roughness	1.1nm





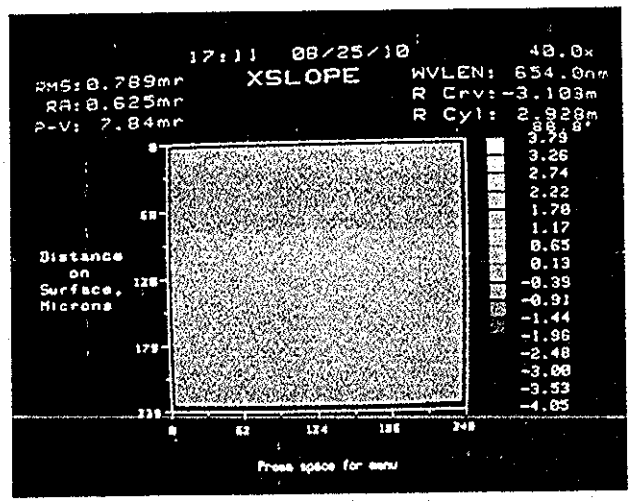


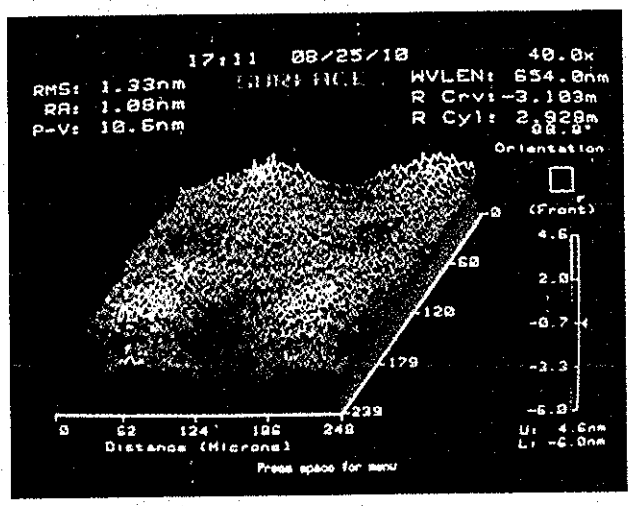


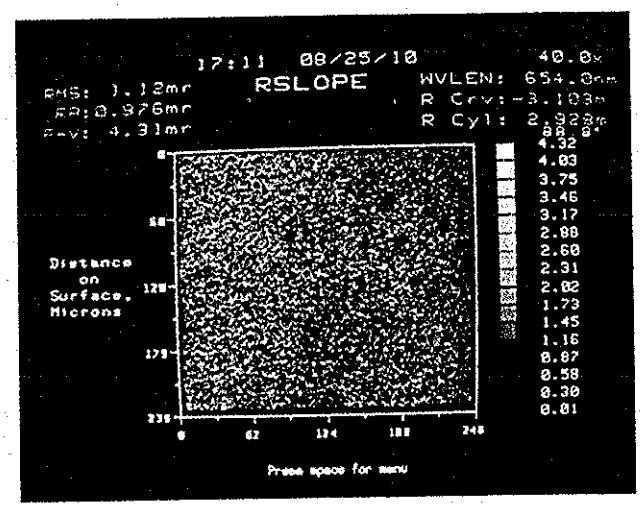
ZYGO Glass Reference Flat

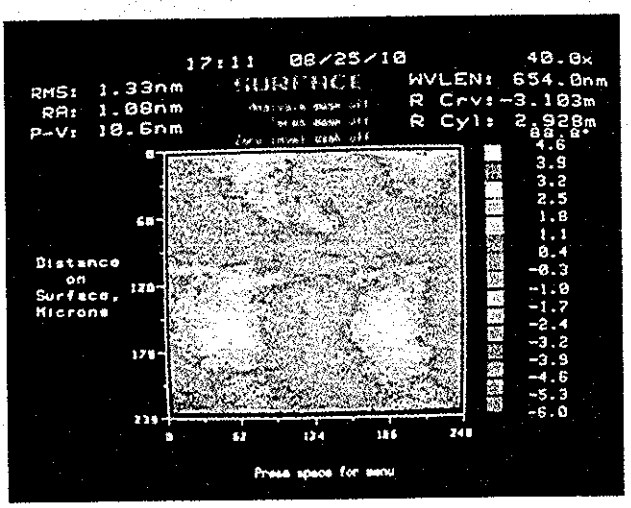
Data Point 2

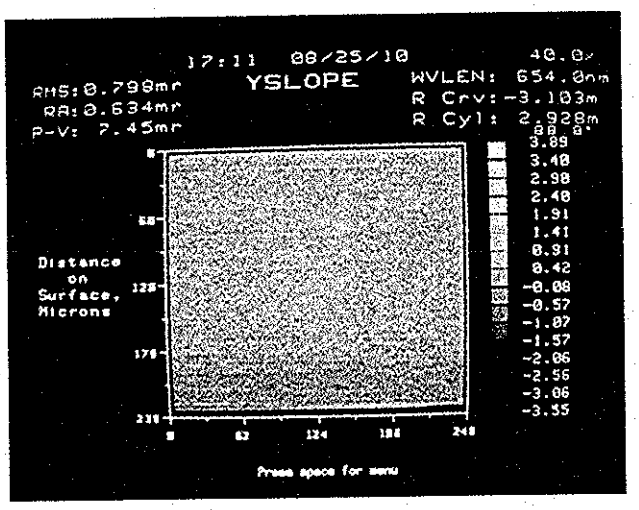
rms Roughness 1.33nm







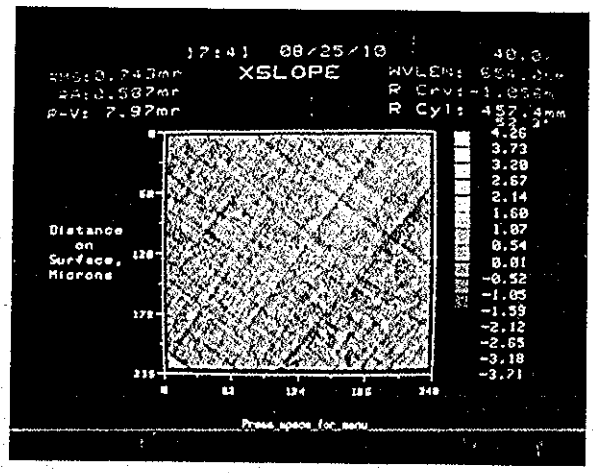




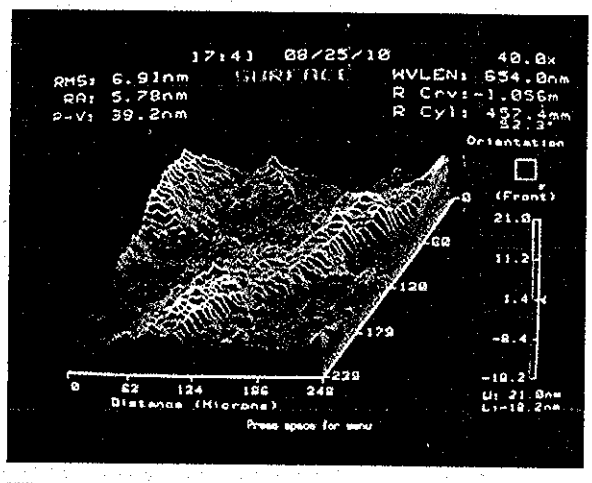
Roughness Measurements

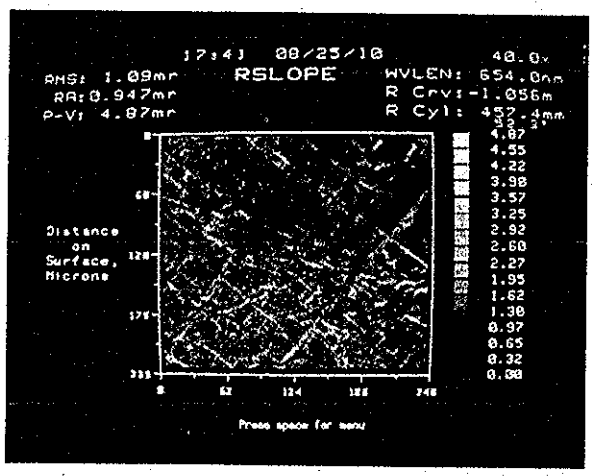
FM/FS Coupons

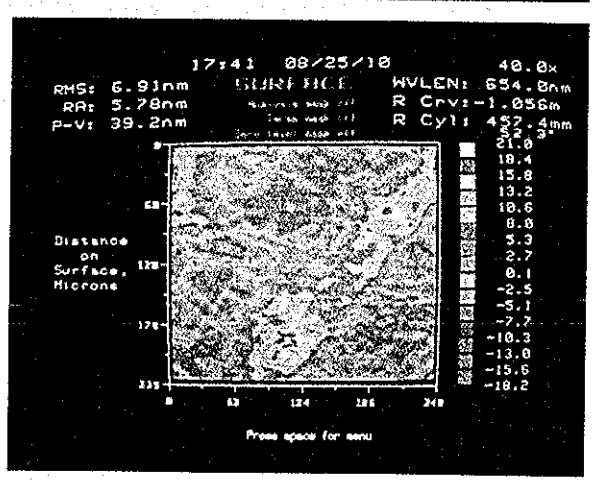
Data Points

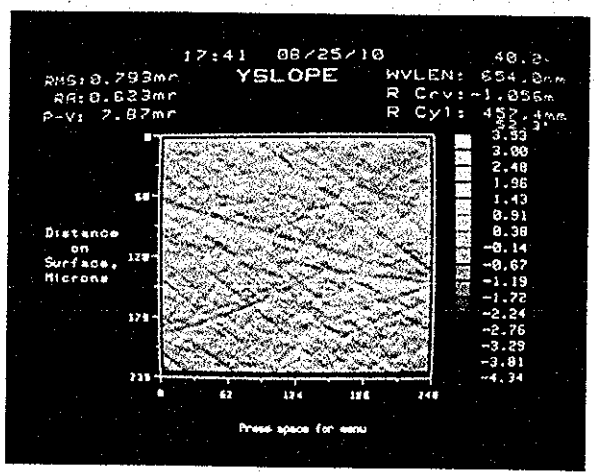


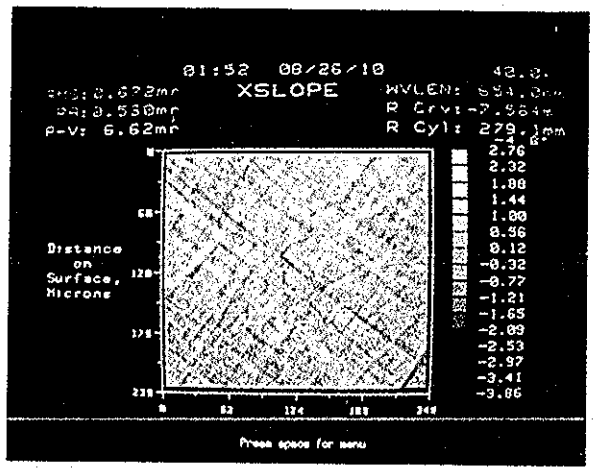
CGS FM/FS Coupons	
Sample	1
Data Point	1
rms Roughness	6.91nm



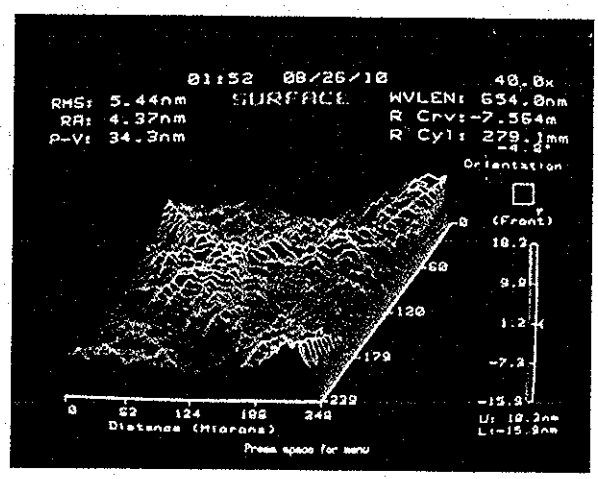


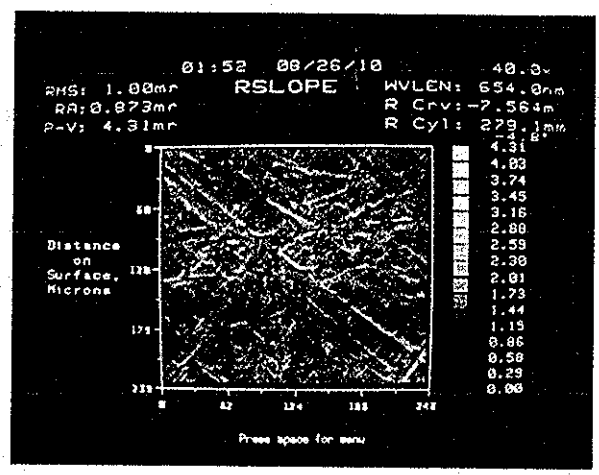


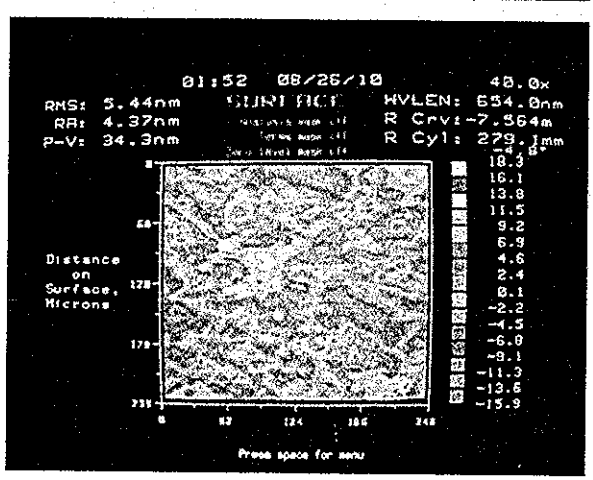


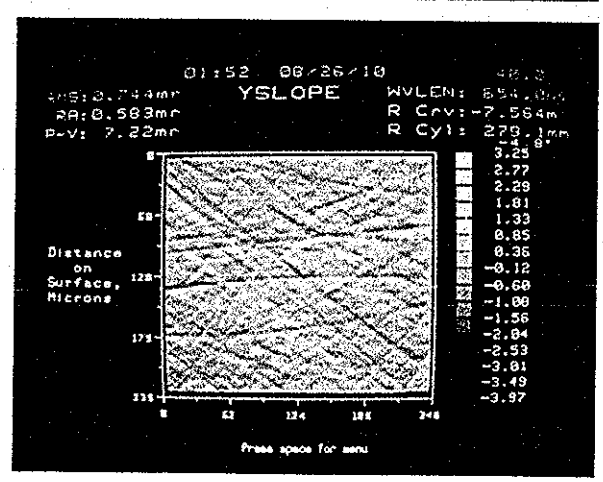


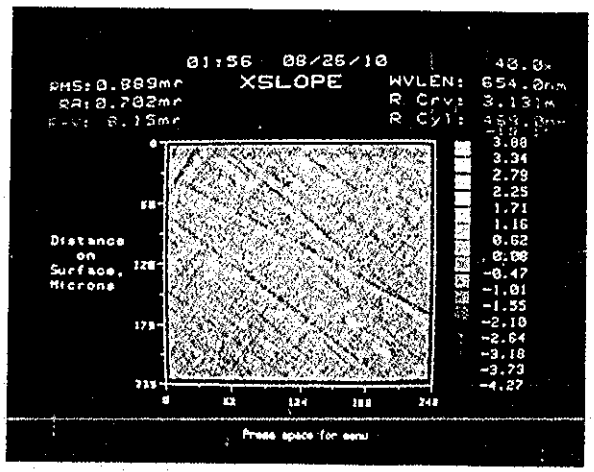
CGS FM/FS Coupons	
Sample	2
Data Point	2
Rms Roughness	5.44nm



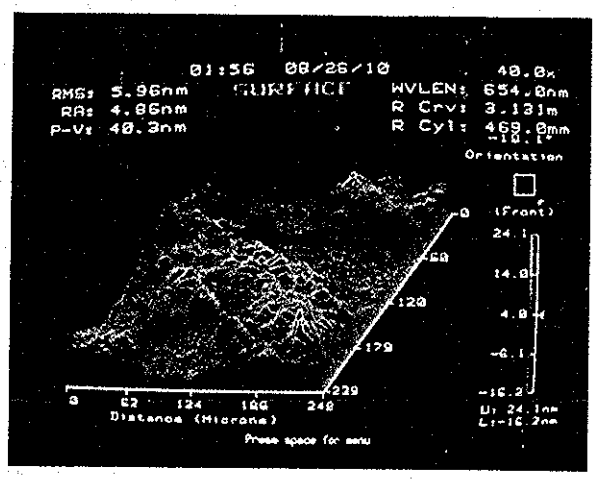


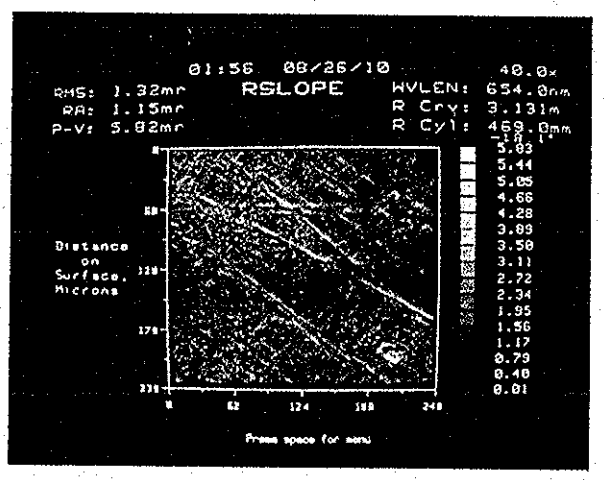


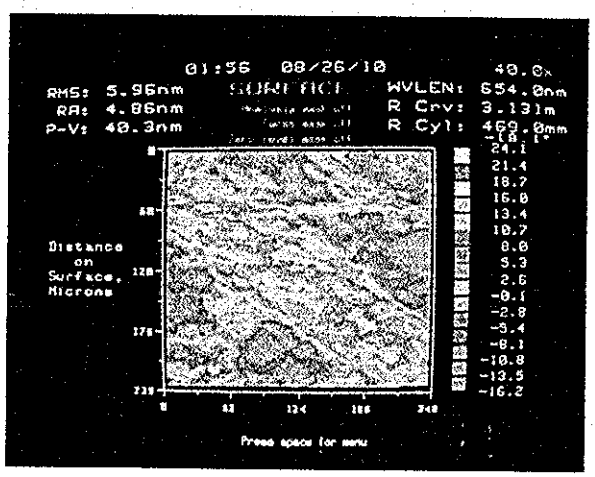


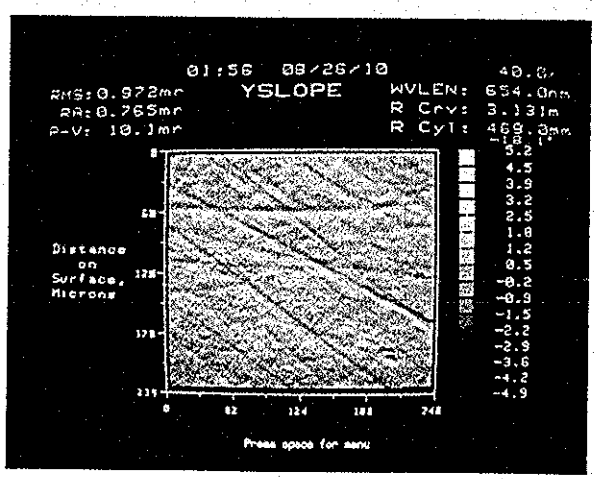


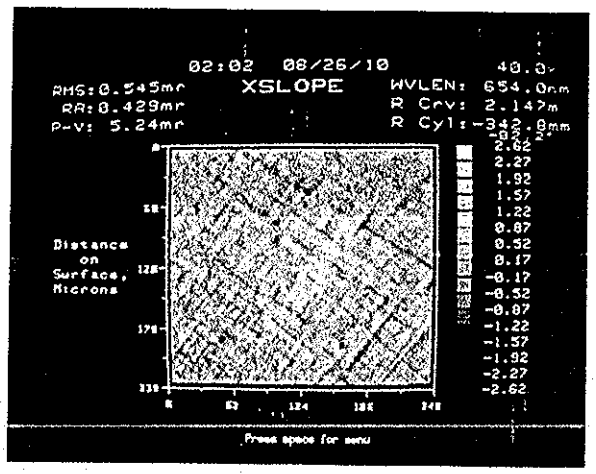
CGS FM/FS Coupons	
Sample	1
Data Point	3
Rms Roughness	5.96nm



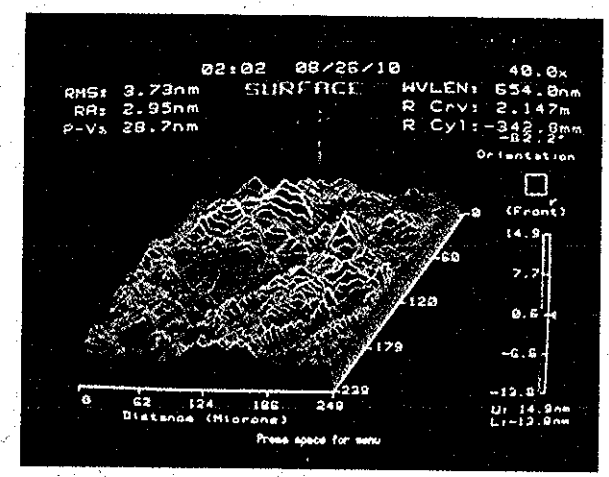


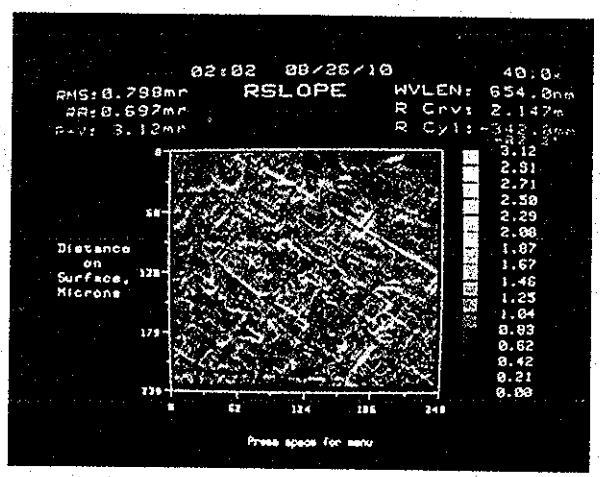


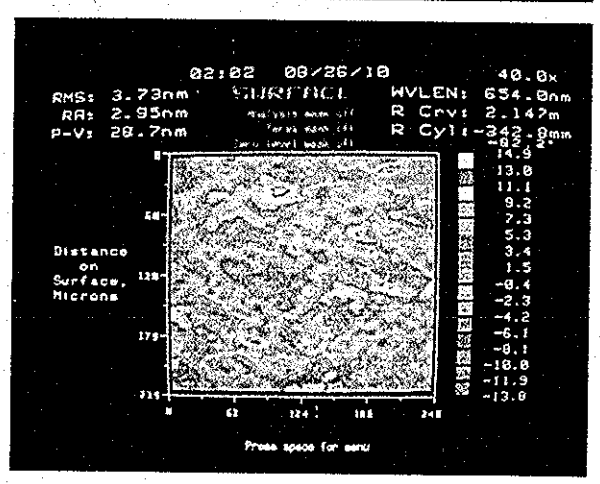


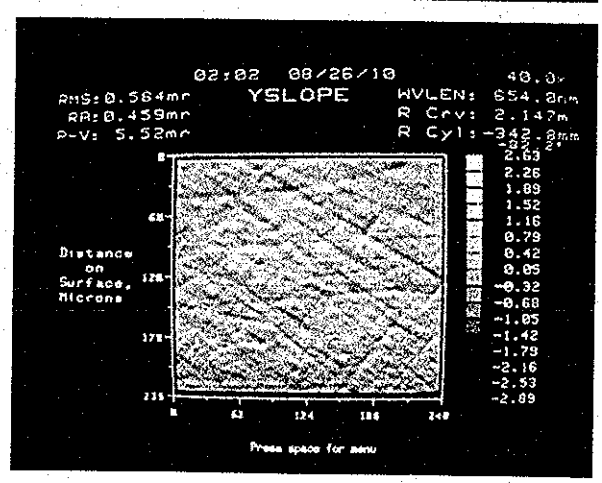


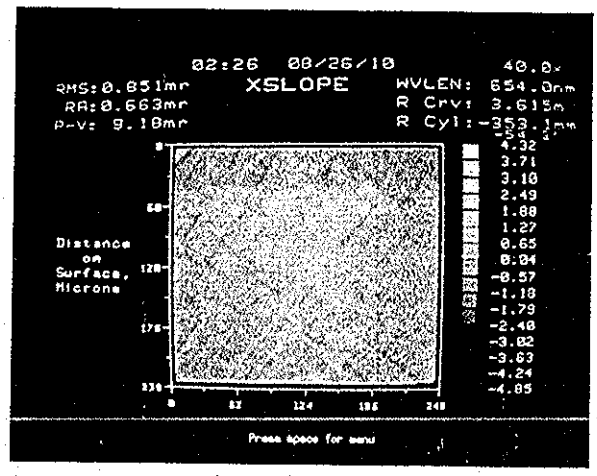
CGS FM/FS Coupons	
Sample	1
Data Point	4
rms Roughness	3.73nm



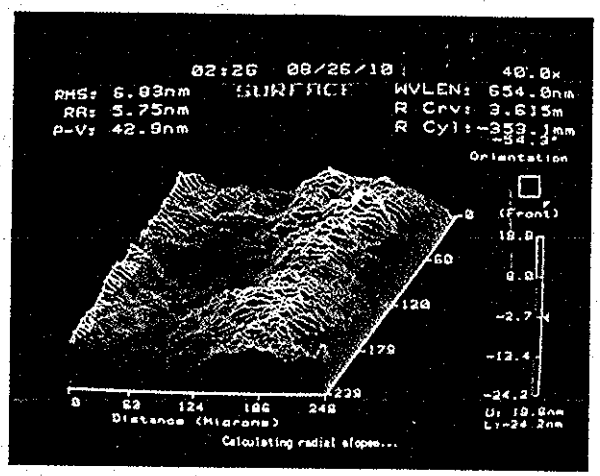


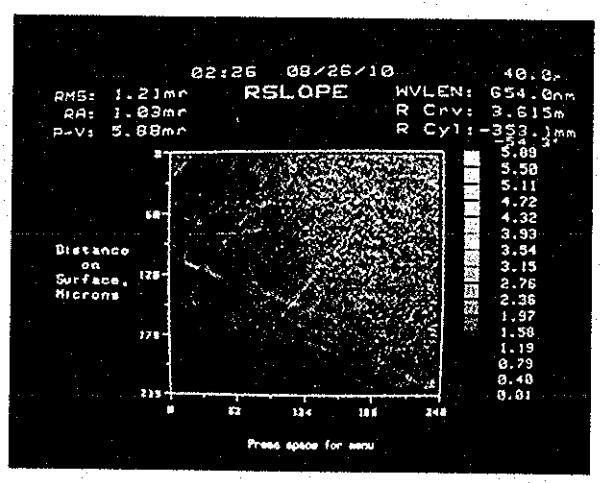


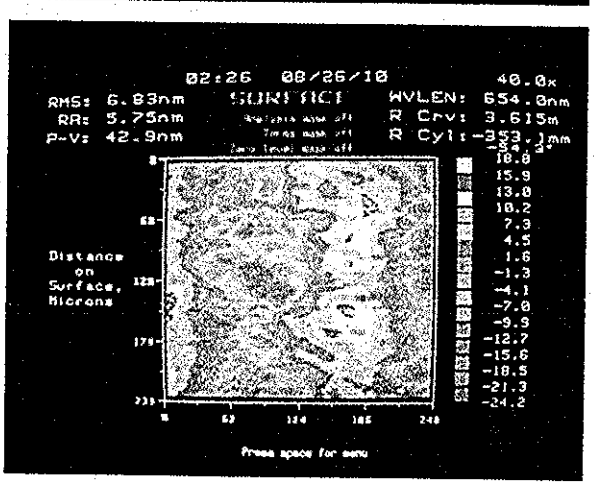


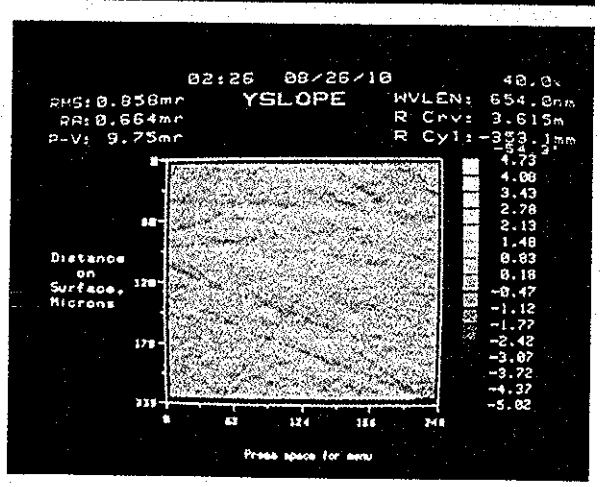


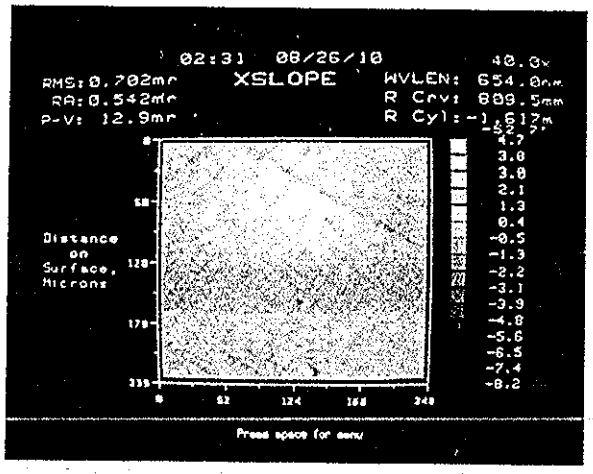
CGS FM/FS Coupons	
Sample	2
Data Point	1
Rms Roughness	6.83nm



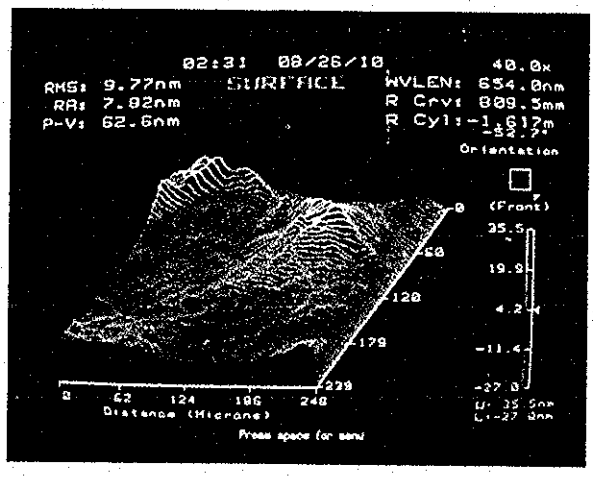


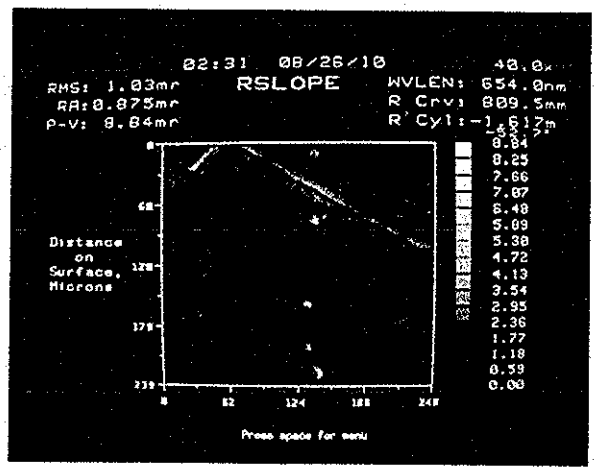


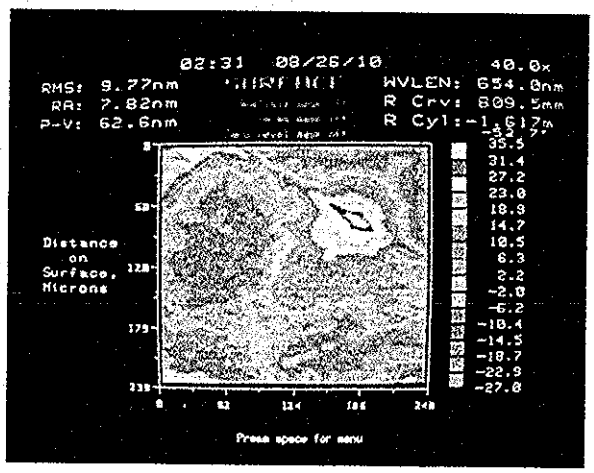


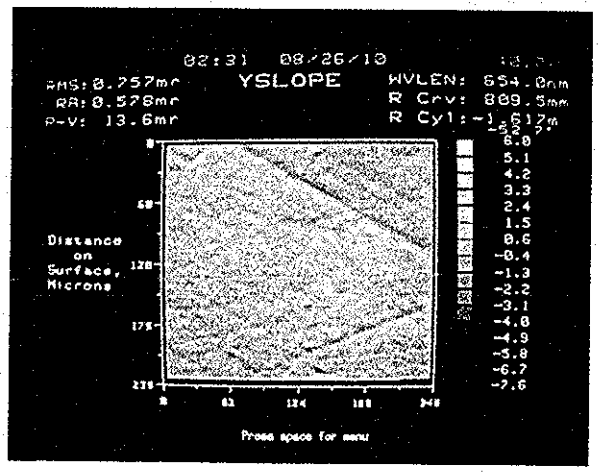


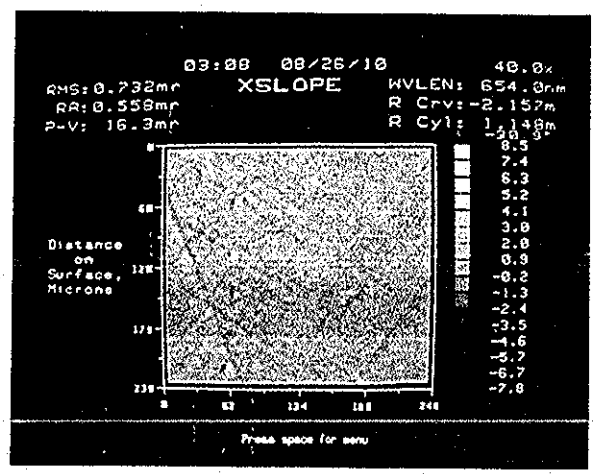
CGS FM/FS Coupons	
Sample	2
Data Point	2
Rms Roughness	9.77nm



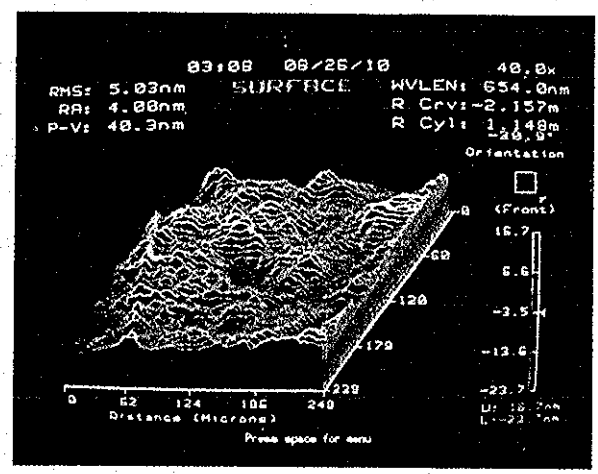


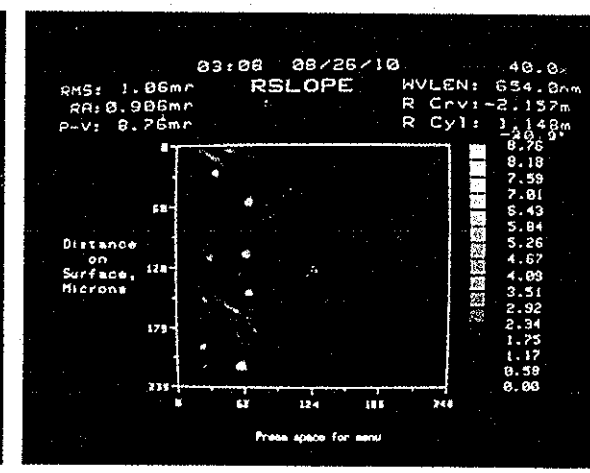


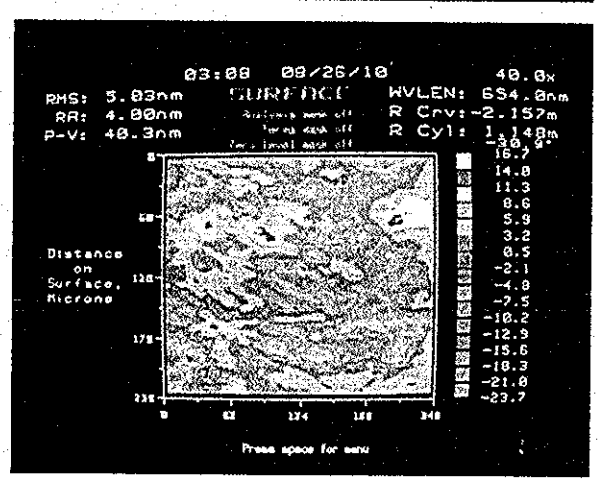


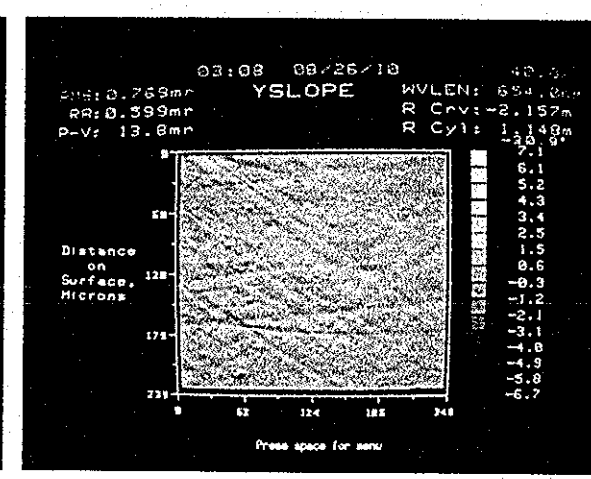


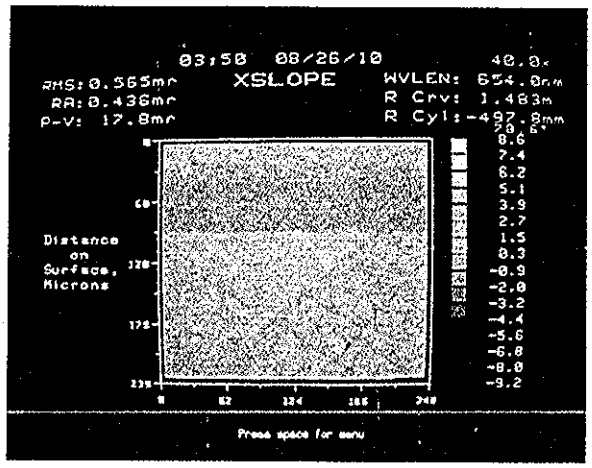
CGS FM/FS Coupons	
Sample	2
Data Point	3
Rms roughness	5.03nm



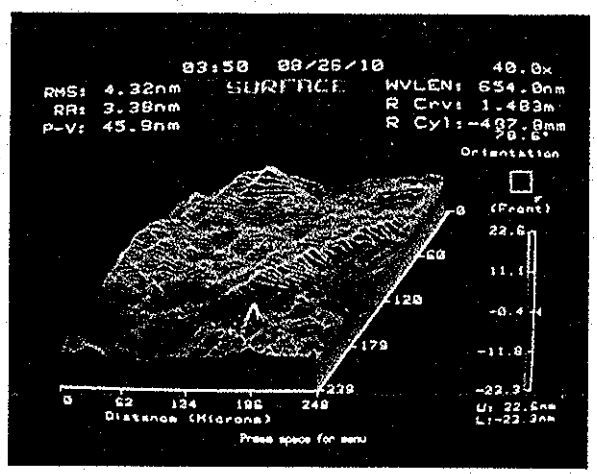


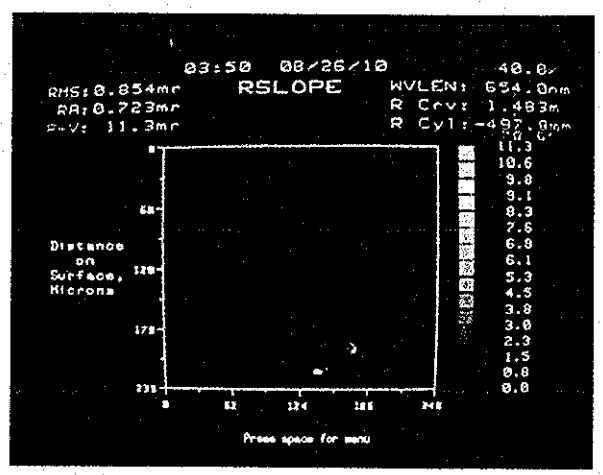


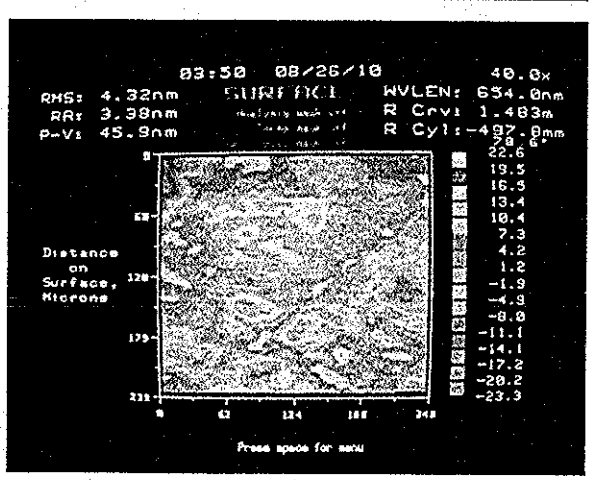


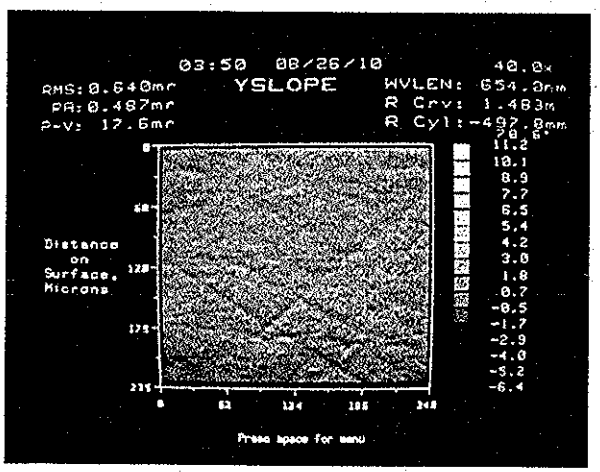


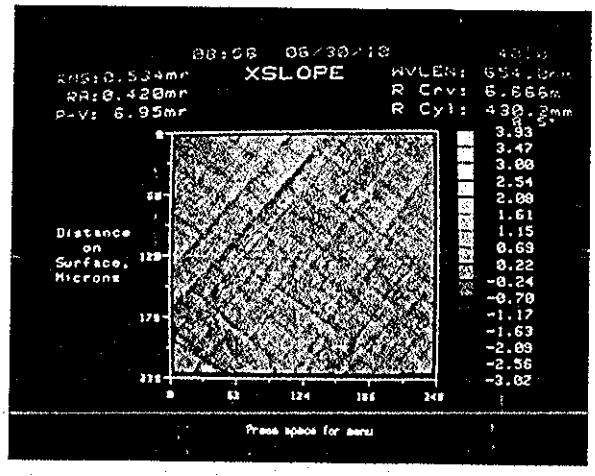
CGS FM/FS Coupons	
Sample	2
Data Point	4
rms Roughness	4.32nm





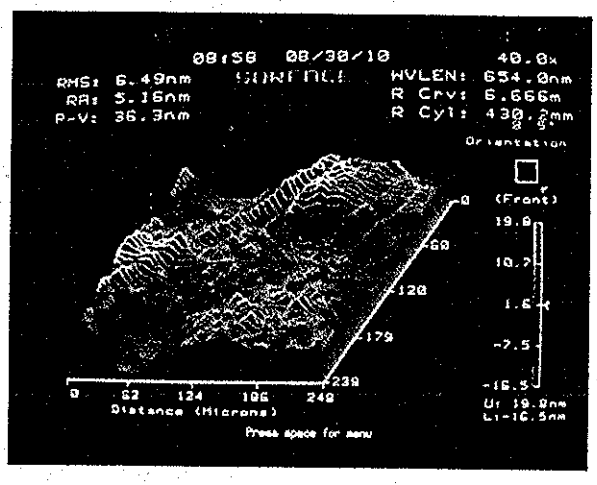


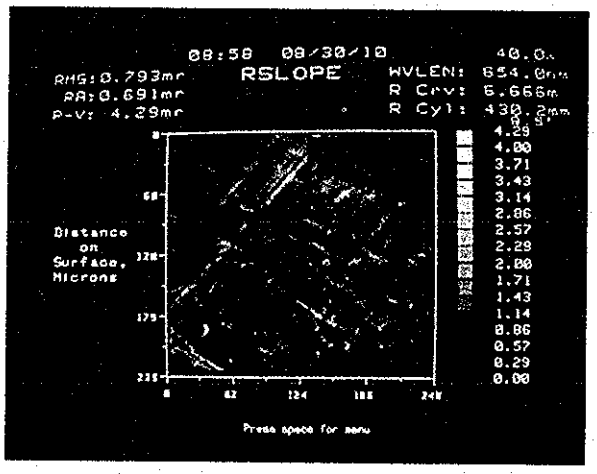


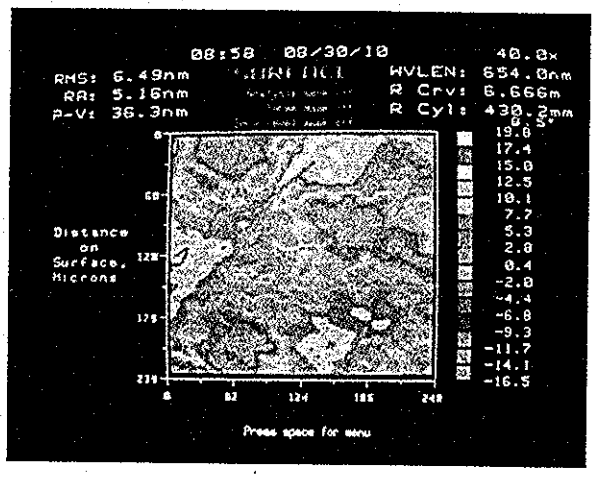


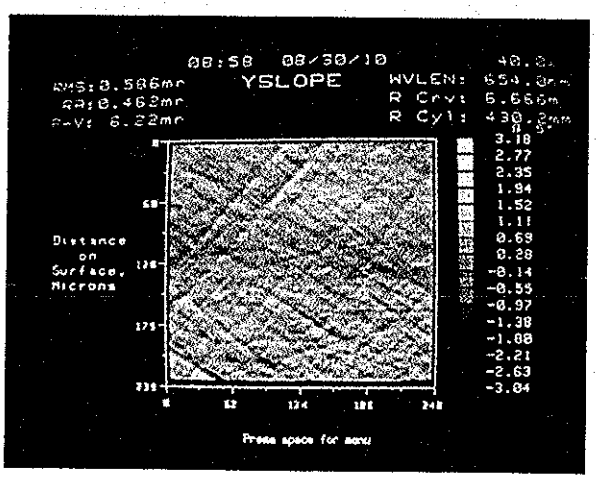
CGS FM/FS Coupons

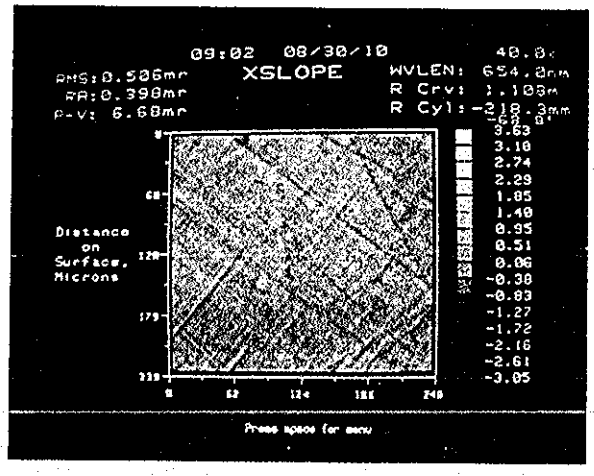
Sample	3
Data Point	1
Rms Roughness	6.49nm



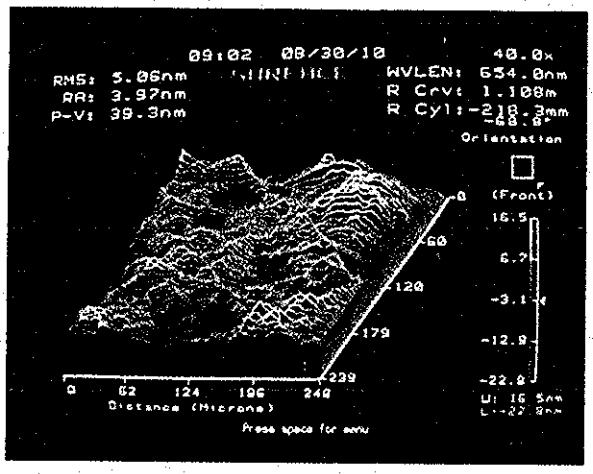


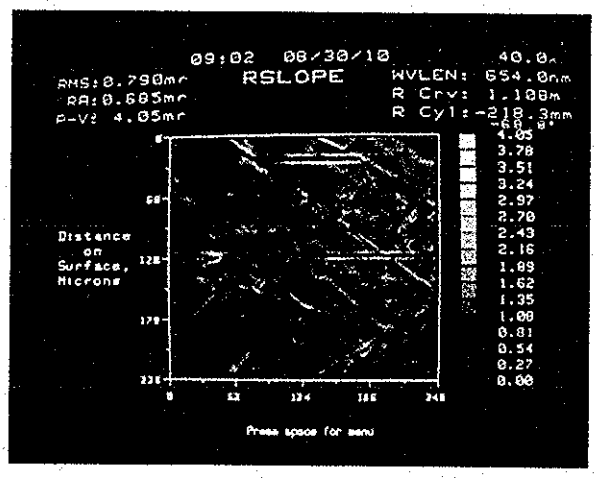


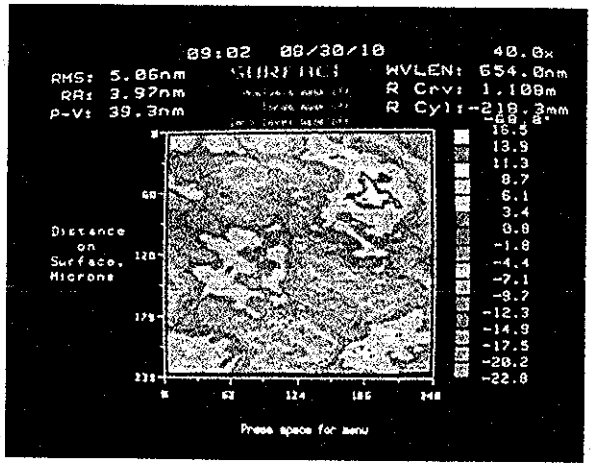


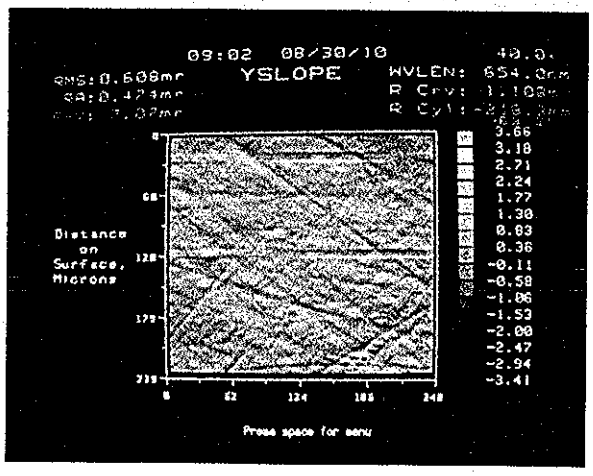


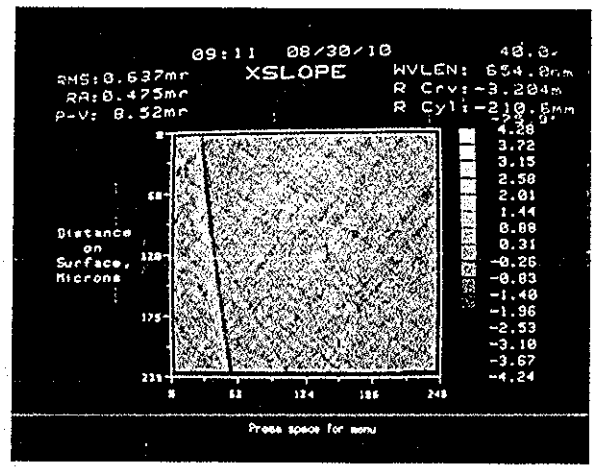
CGS FM/FS Coupons	
Sample	3
Data Point	2
Rms Roughness	5.05nm



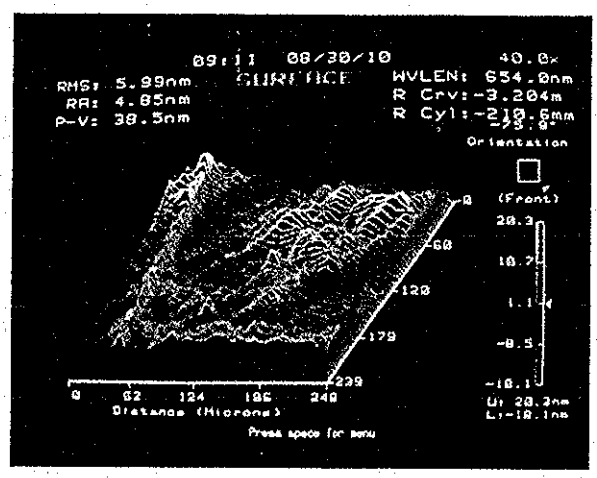


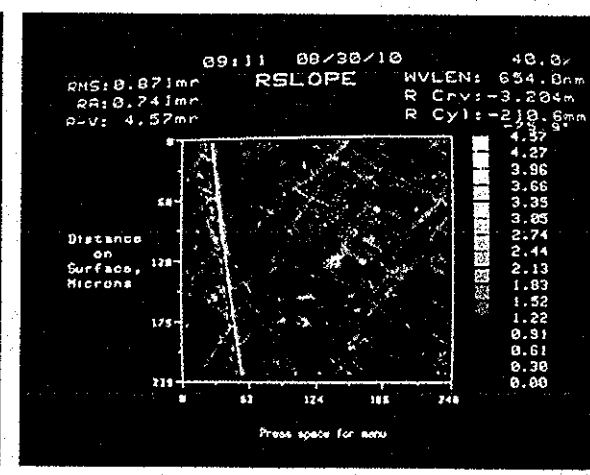


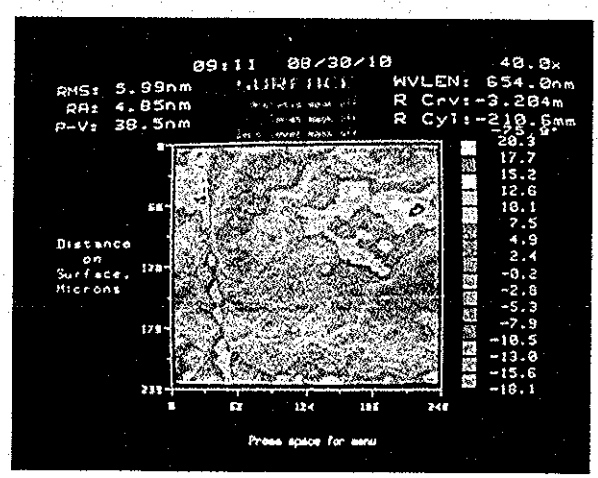


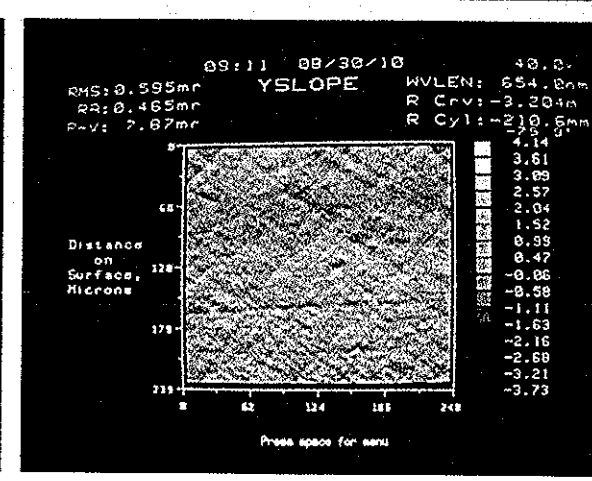


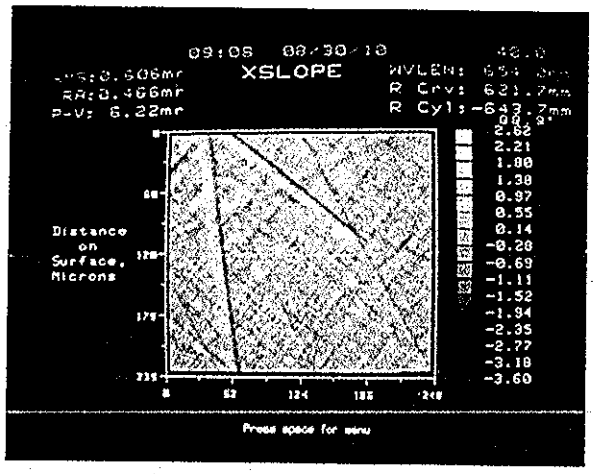
CGS FM/FS Coupons	
Sample	3
Data Point	3
Rms Roughness	5.99nm





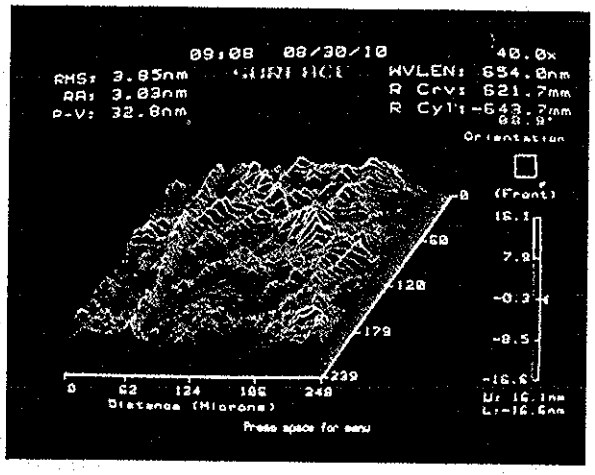


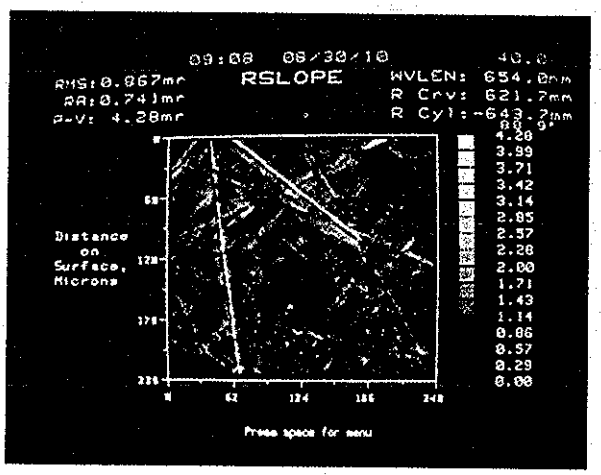


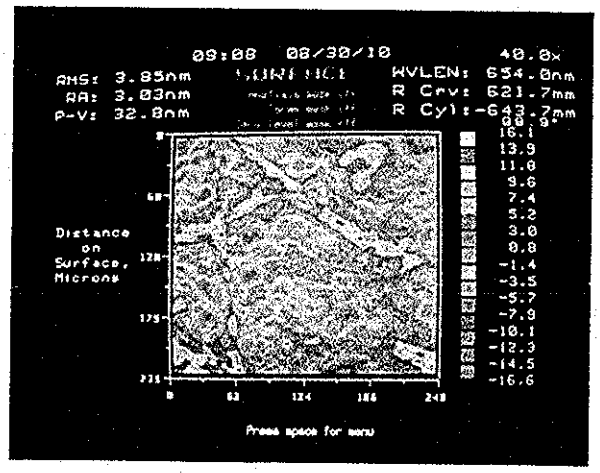


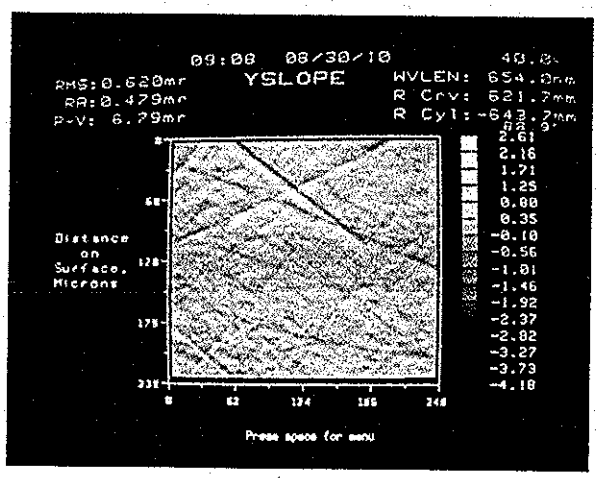
CGS FM/FS Coupons

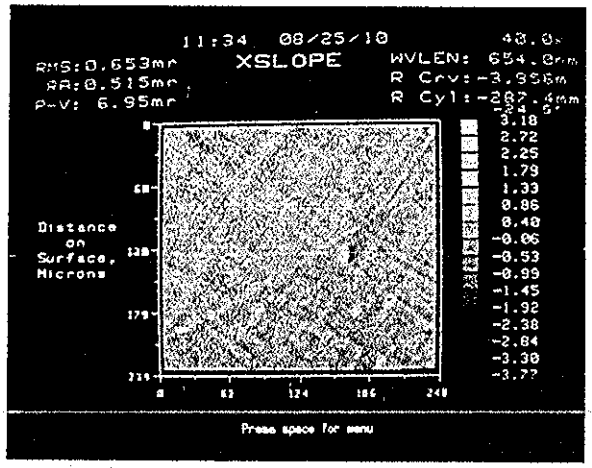
Sample	3
Data Point	4
Rms Roughness	3.85nm



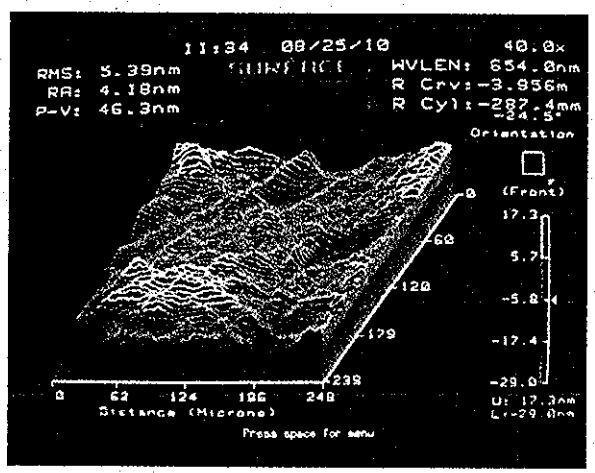


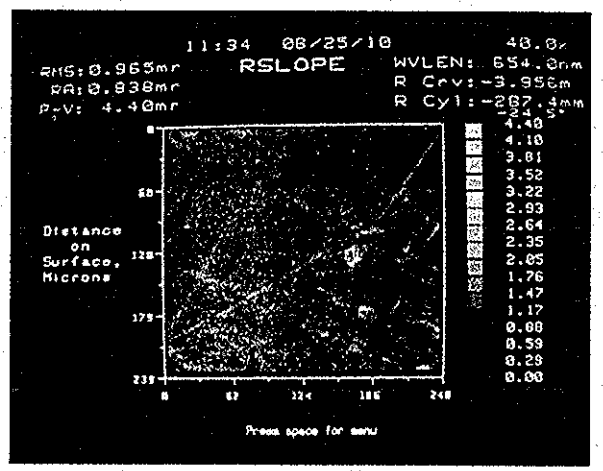


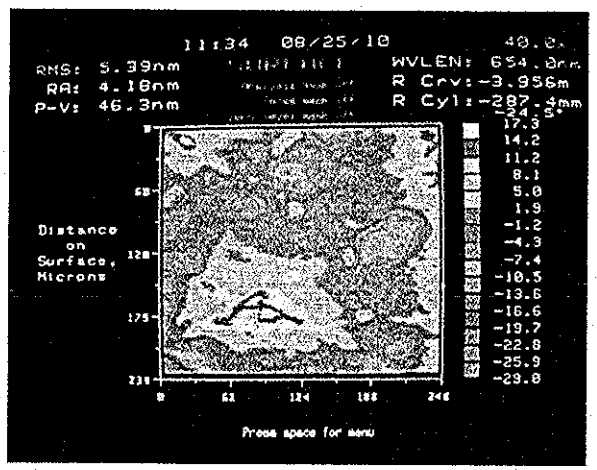


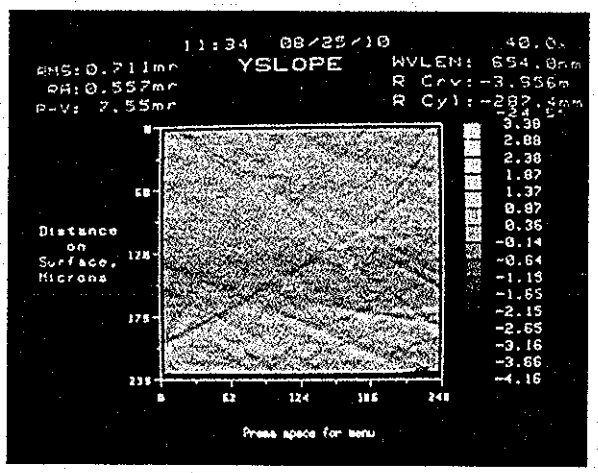


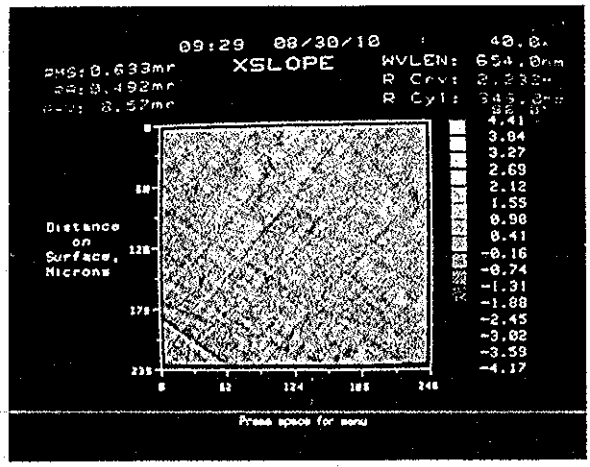
CGS FM/FS Coupons	
Sample	4
Data Point	1
Rms Roughness	5.39nm



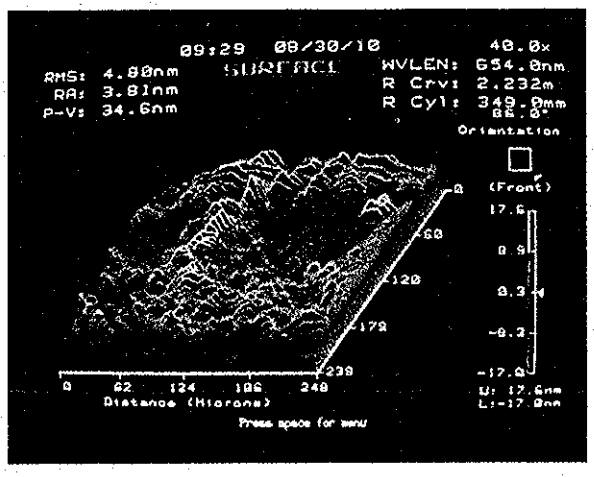


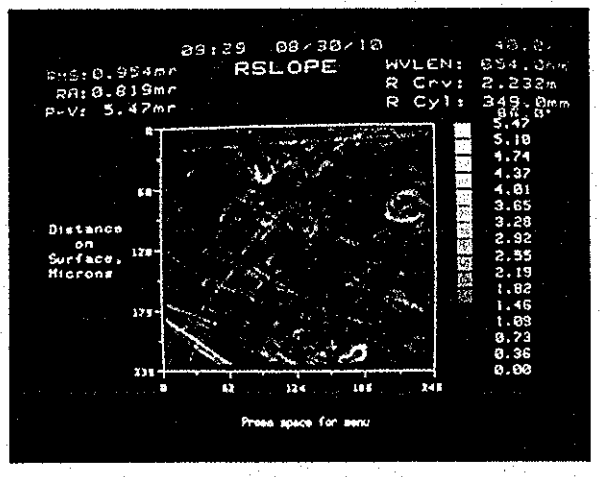


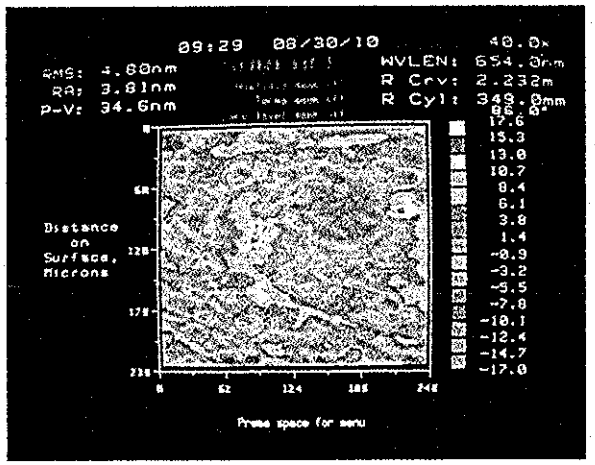


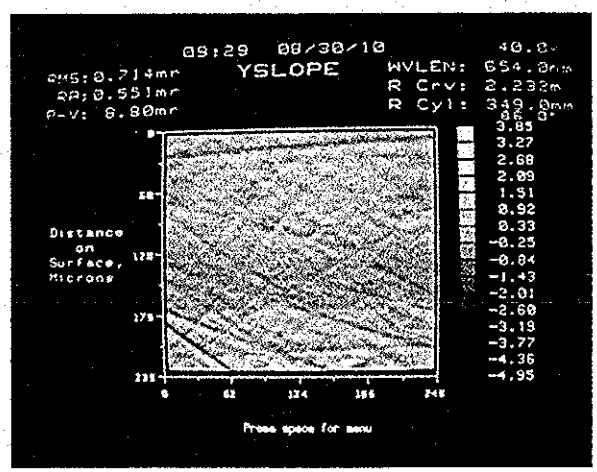


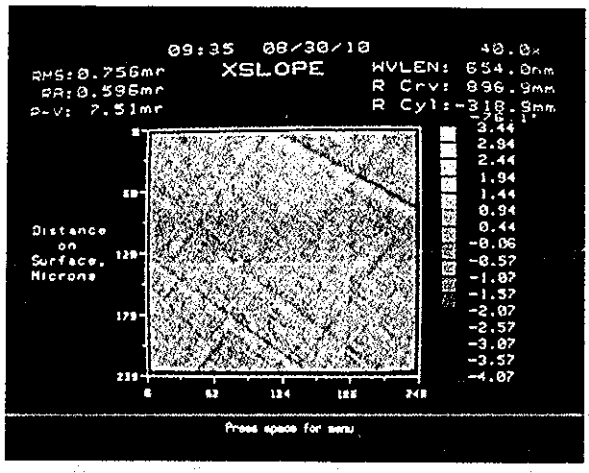
CGS FM/FS Coupons	
Sample	4
Data Point	3
Rms Roughness	4.80nm



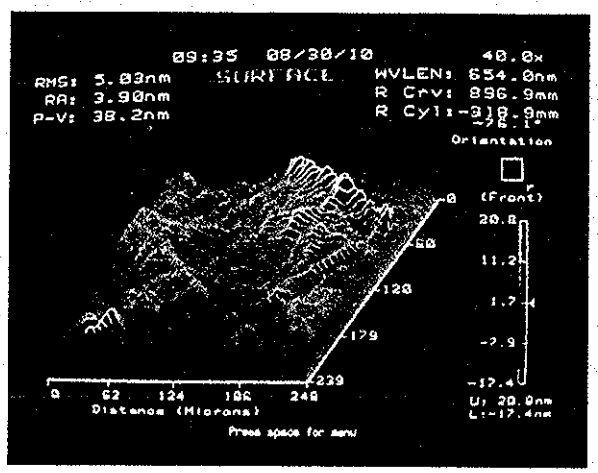


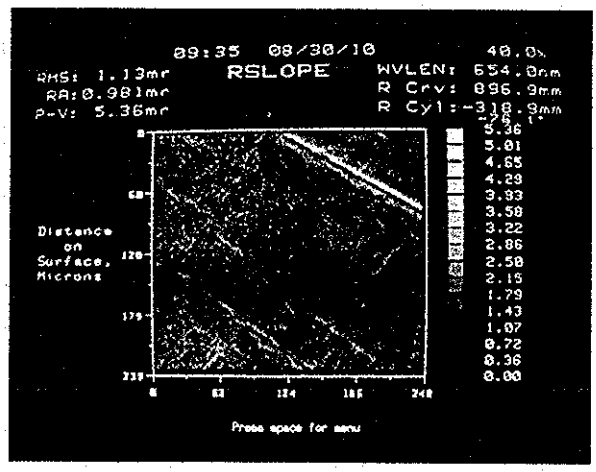


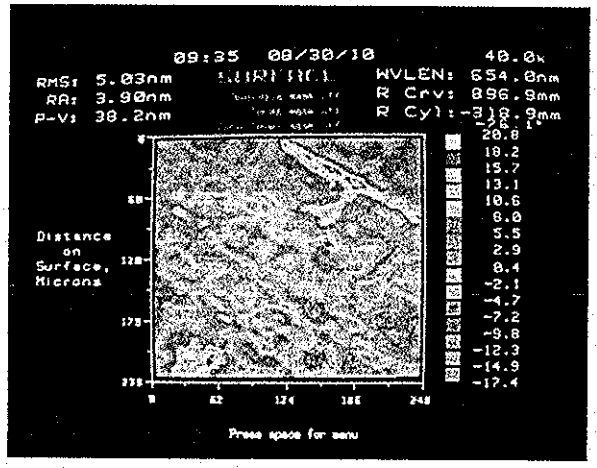


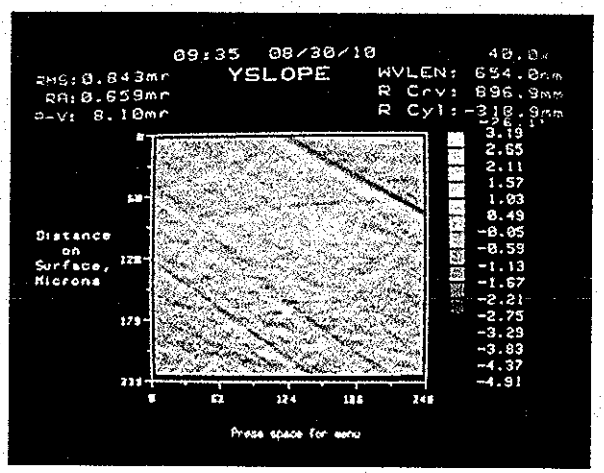


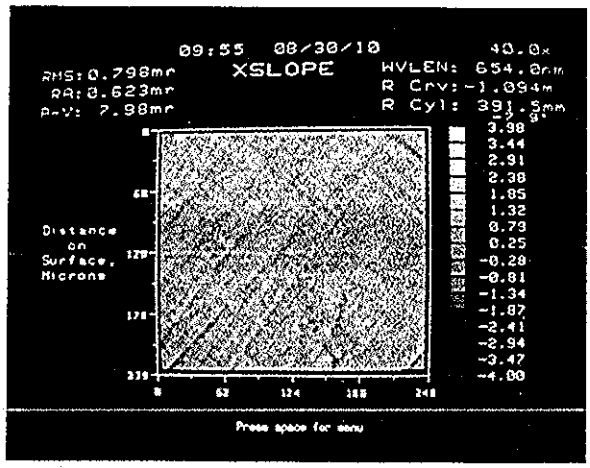
CGS FM/FS Coupons	
Sample	4
Data Point	4
Rms Roughness	5.03nm



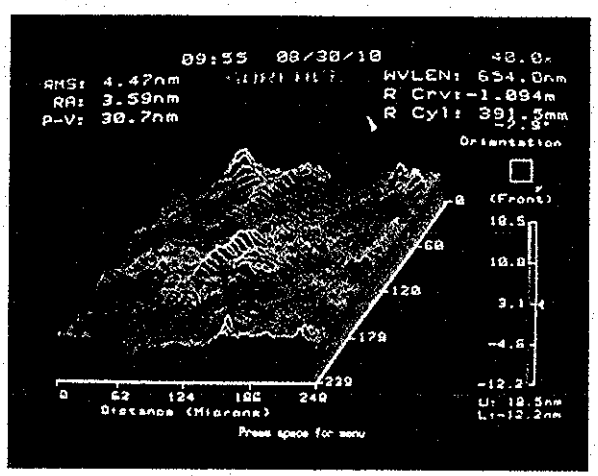


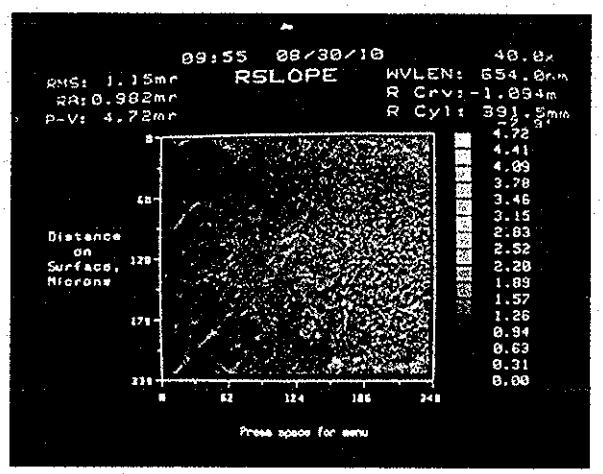


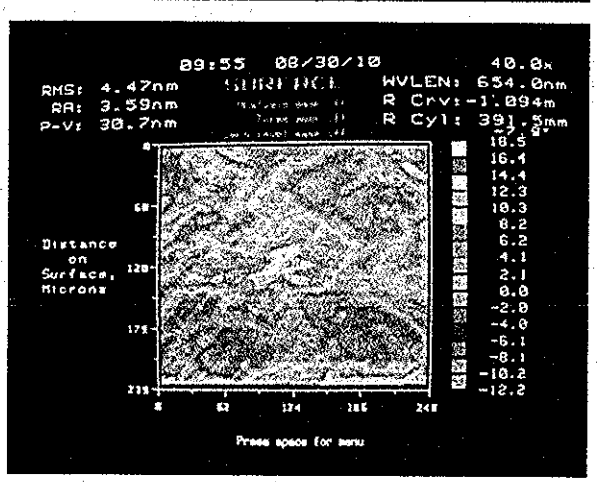


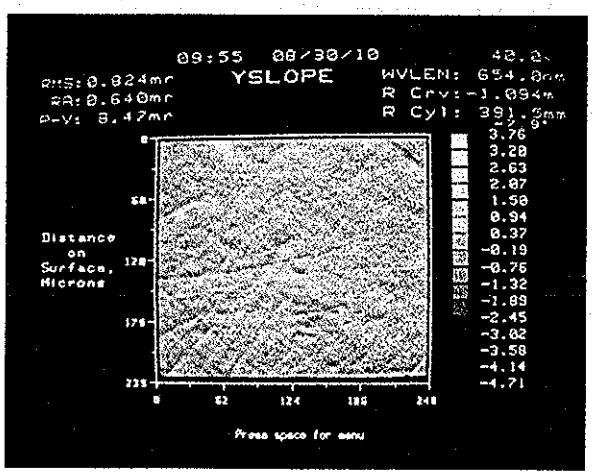


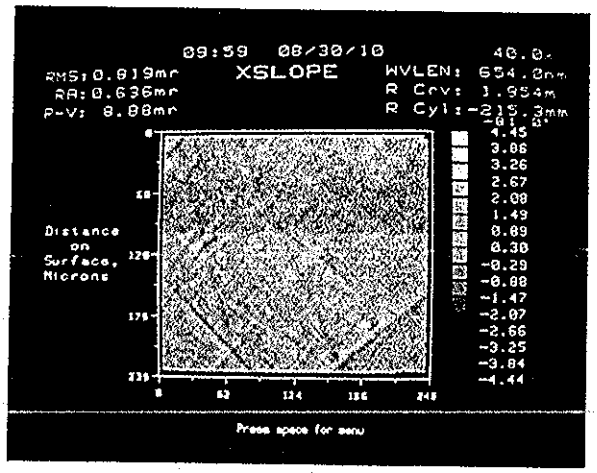
CGS FM/FS Coupons	
Sample	5
Data Point	1
Rms Roughness	4.47nm



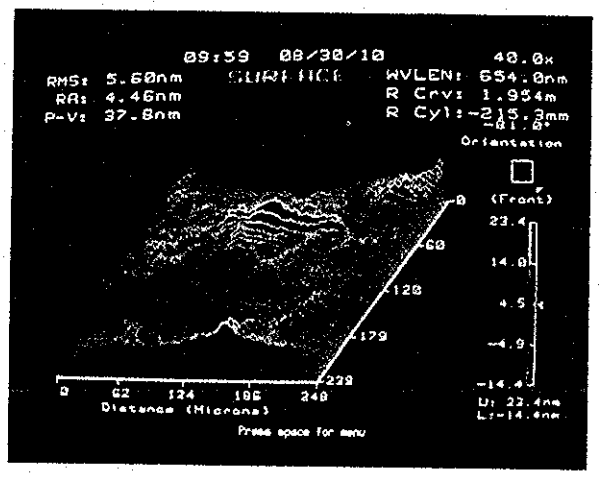


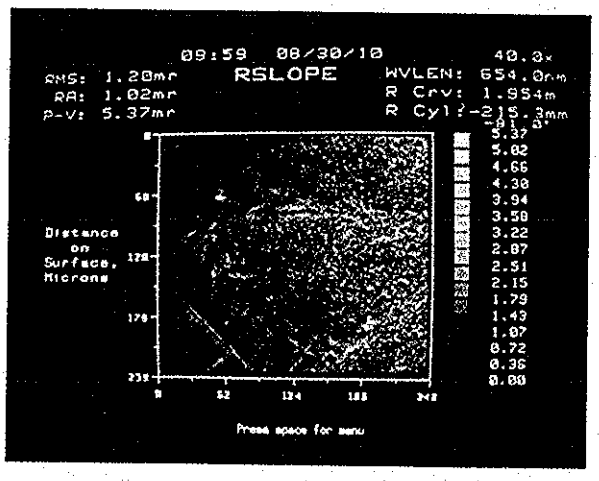


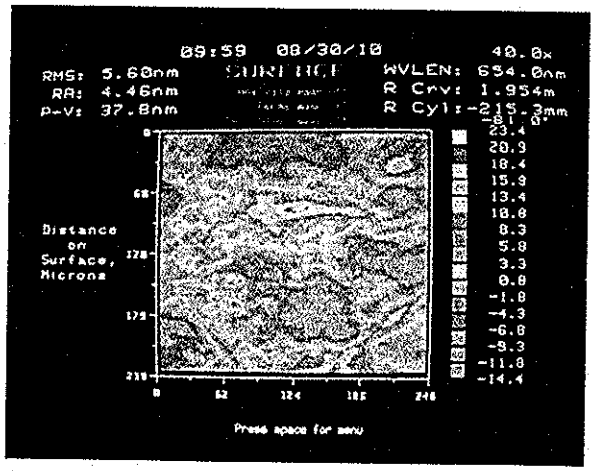


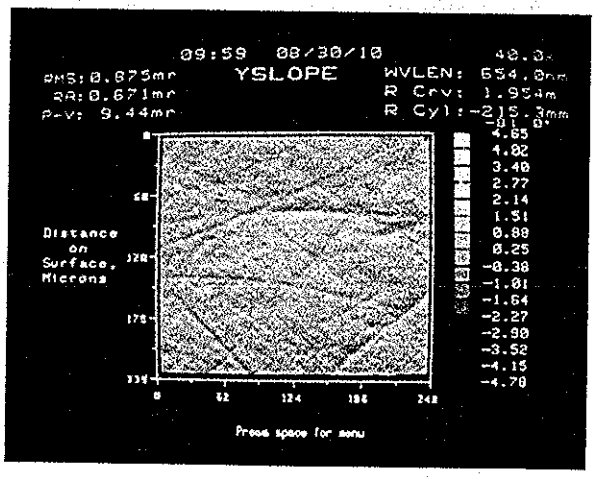


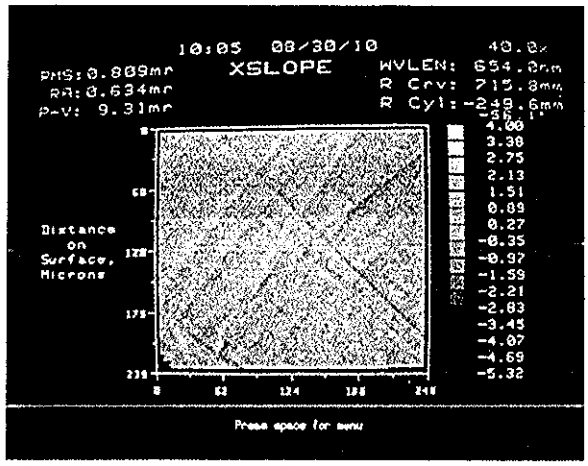
CGS FM/FS Coupons	
Sample	5
Data Point	2
Rms Roughness	5.60nm



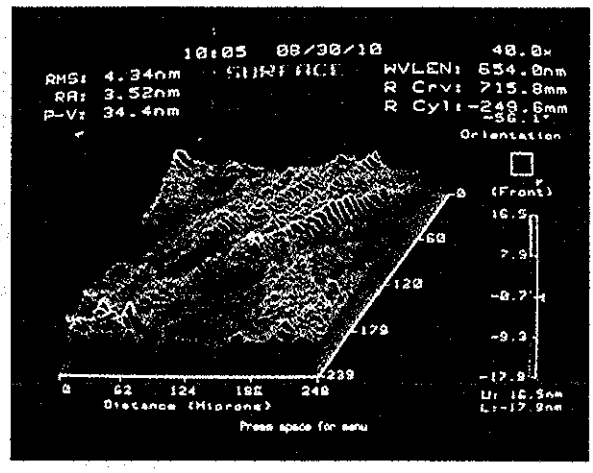


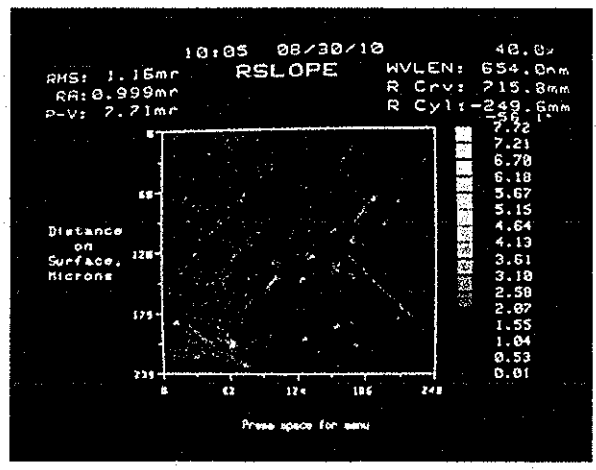


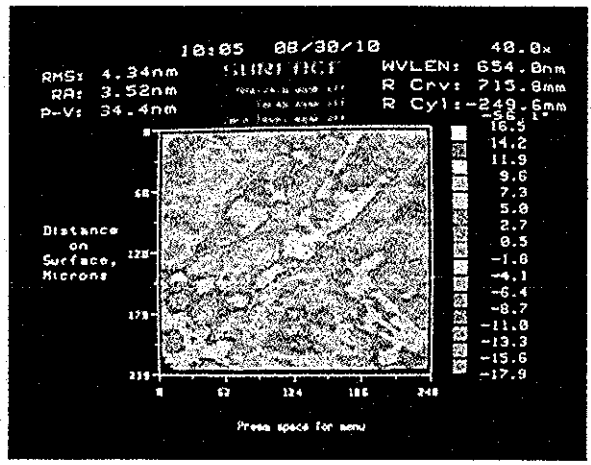


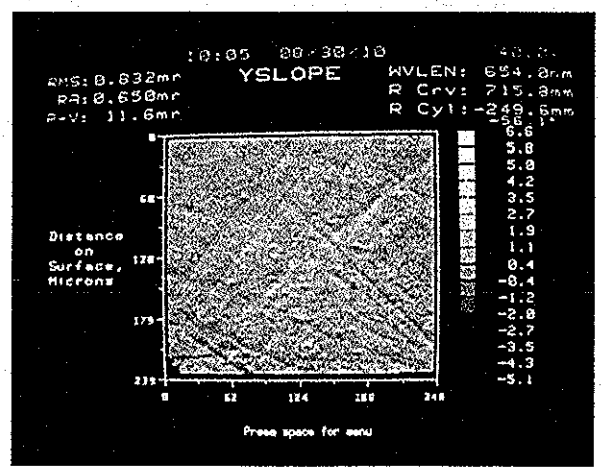


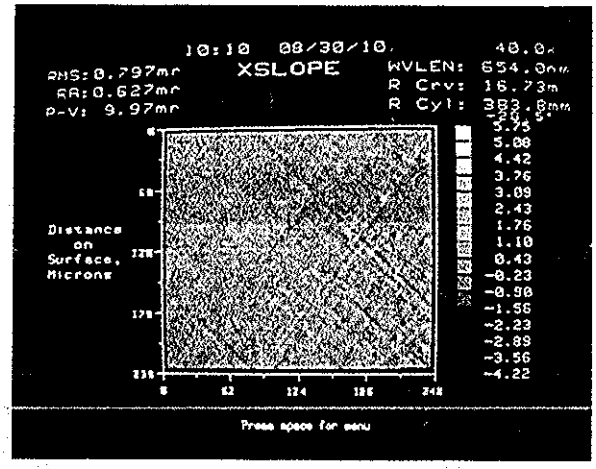
CGS FM/FS Coupons	
Sample	5
Data Point	3
Rms Roughness	4.34nm



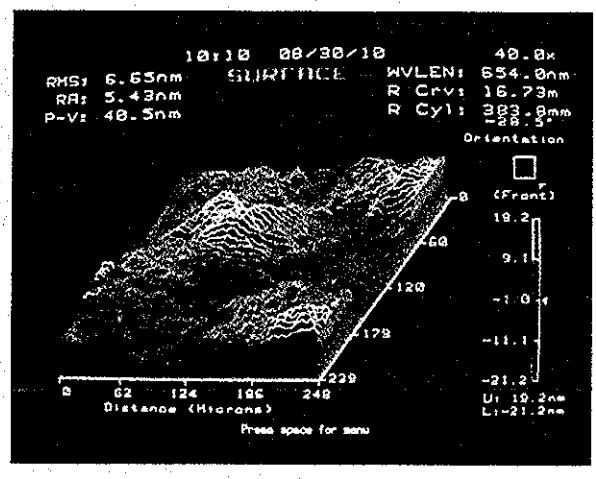


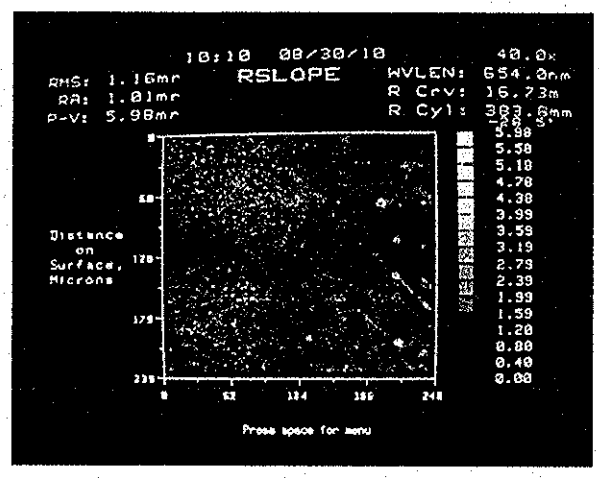


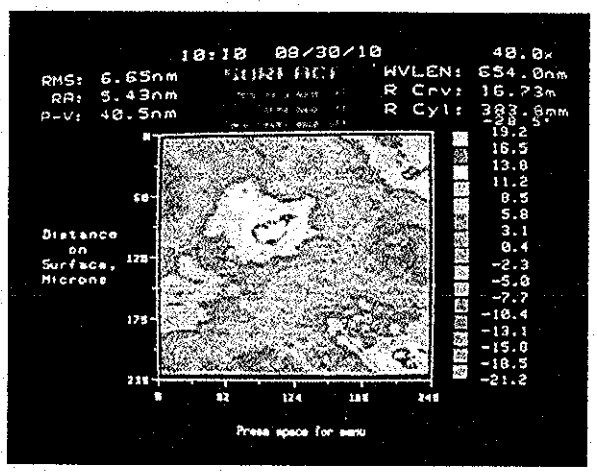


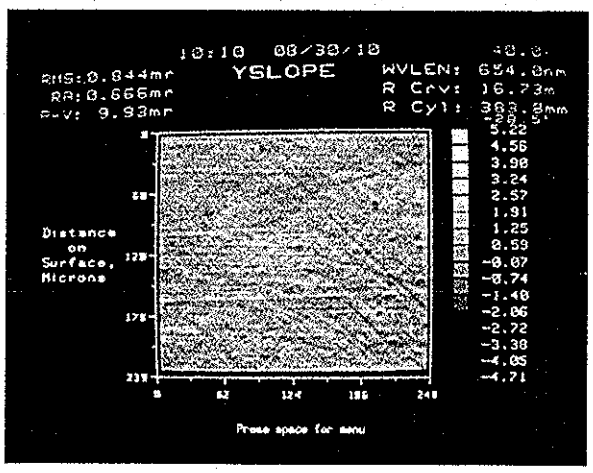


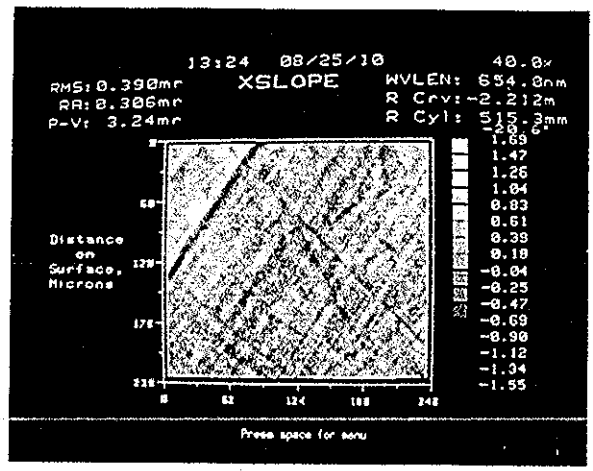
CGS FM/FS Coupons	
Sample	5
Data Point	4
Rms Roughness	6.65nm



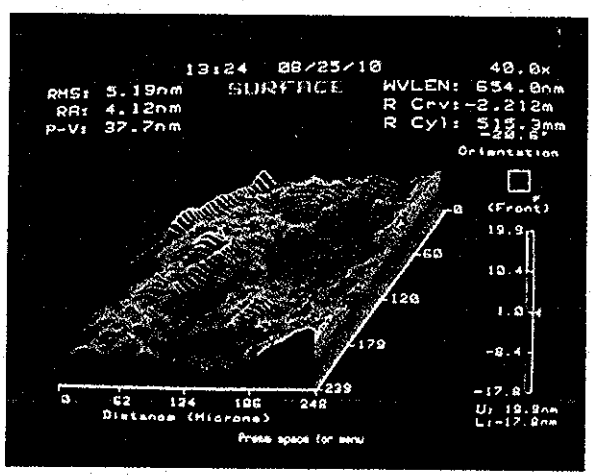


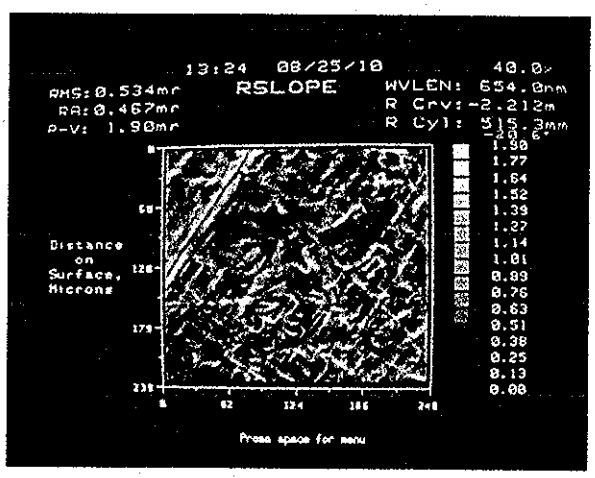


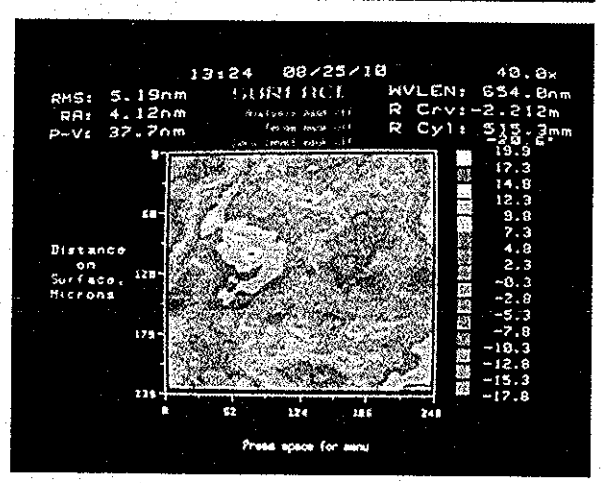


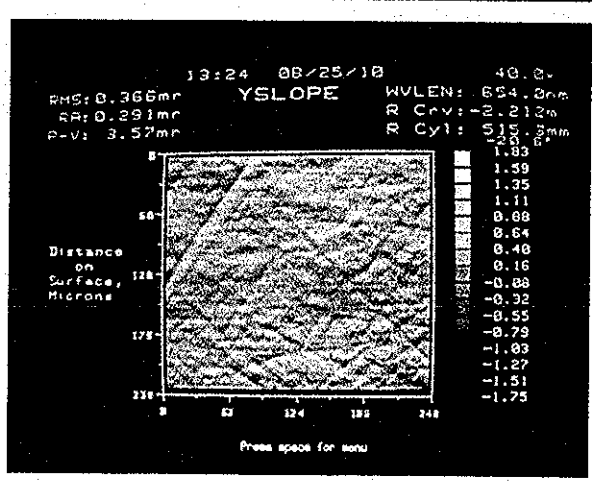


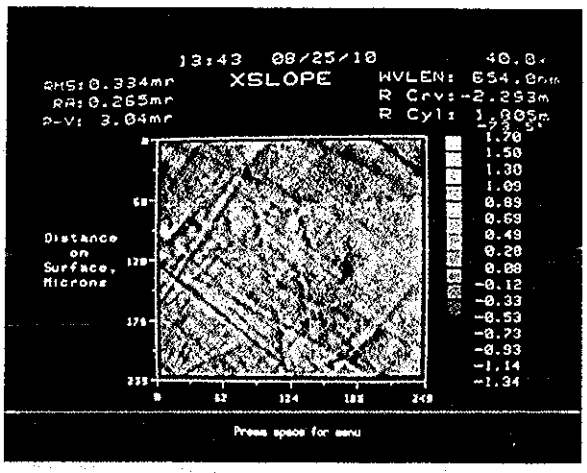
CGS FM/FS Coupons	
Sample	6
Data Point	1
Rms Roughness	5.19nm



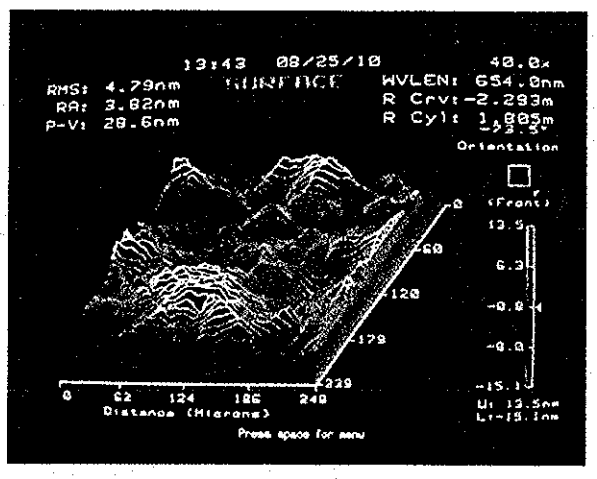


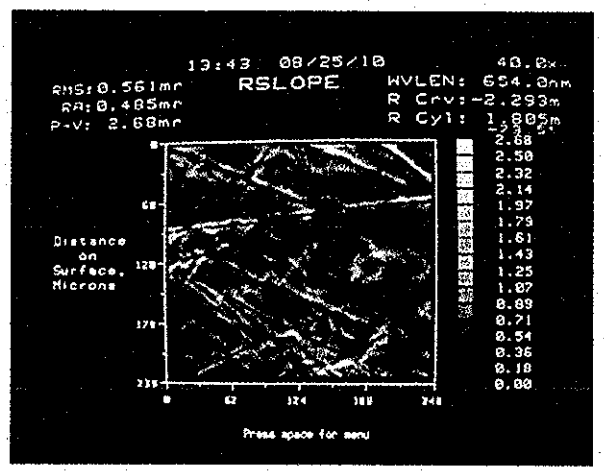


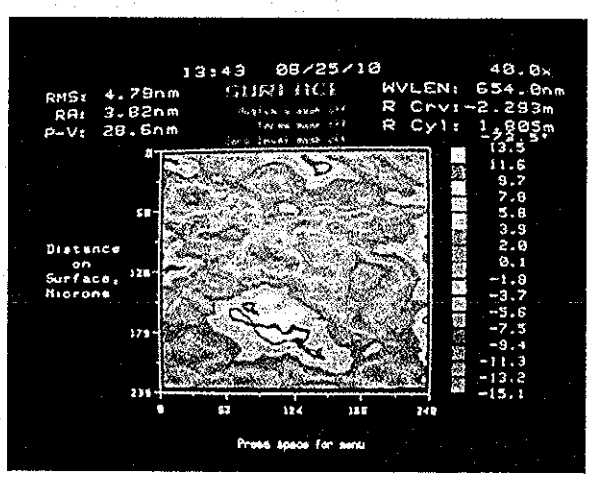


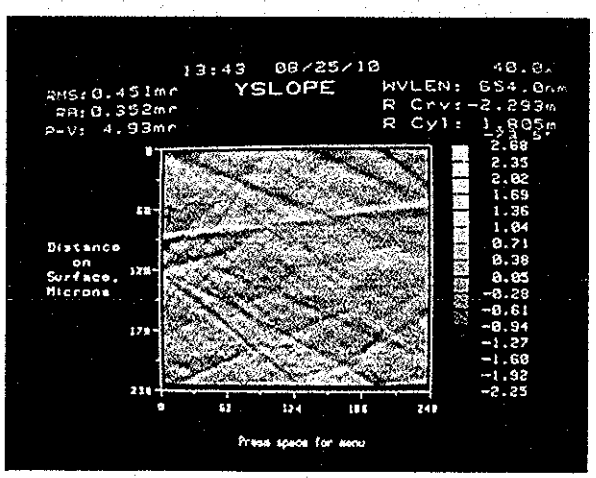


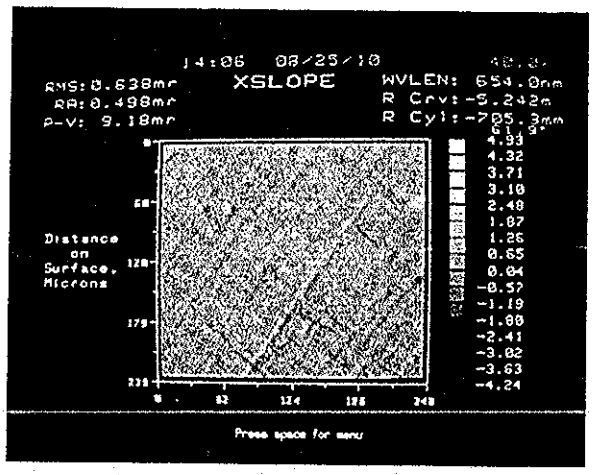
CGS FM/FS Coupons	
Sample	6
Data Point	2
Rms Roughness	4.79nm



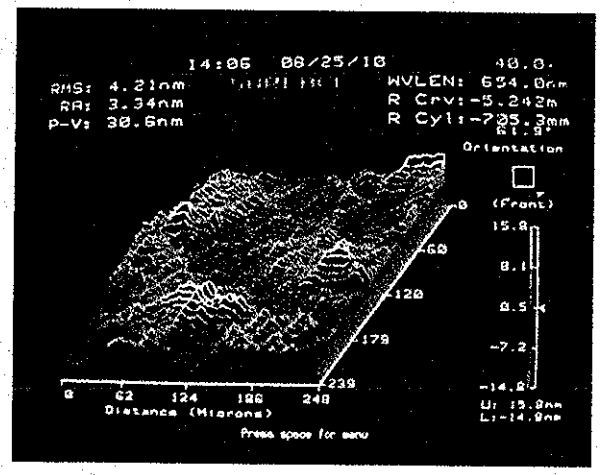


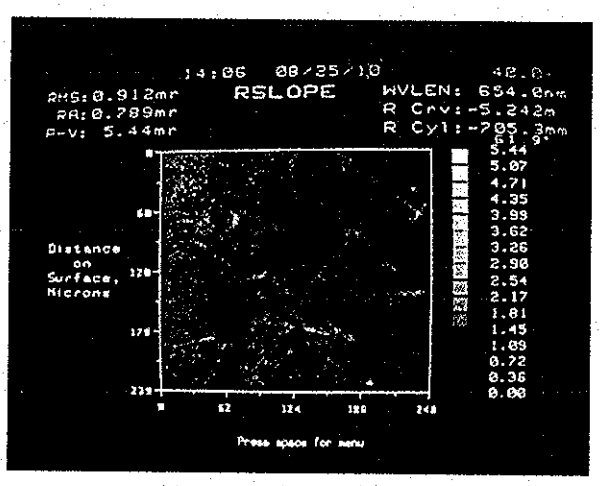


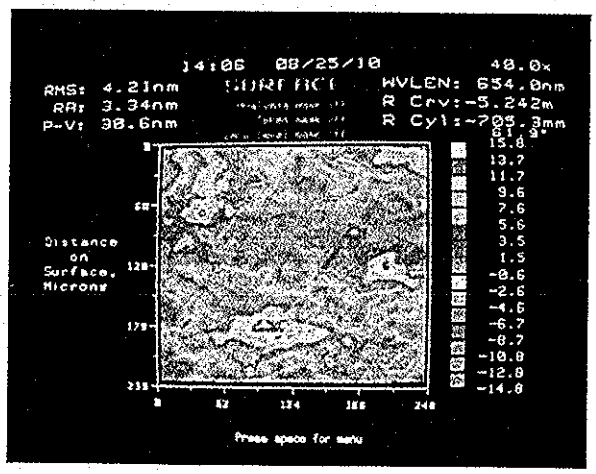


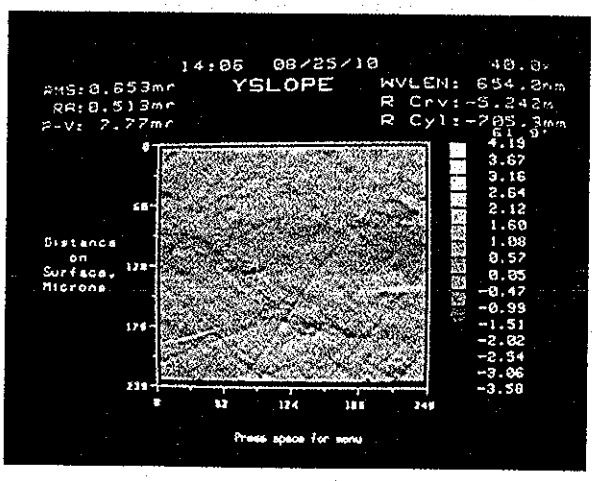


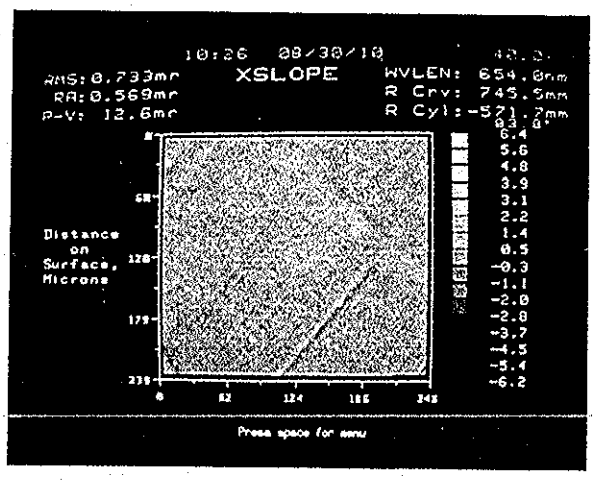
CGS FM/FS Coupons	
Sample	6
Data Point	3
Rms Roughness	4.21nm



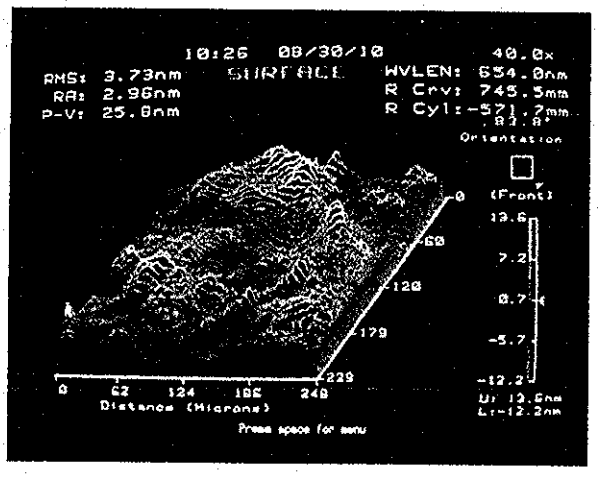


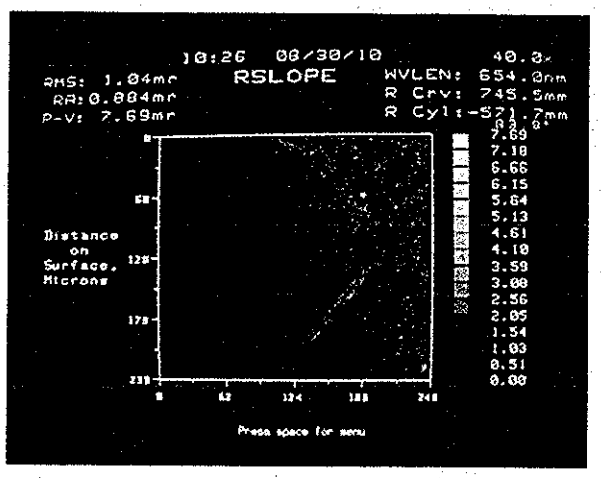


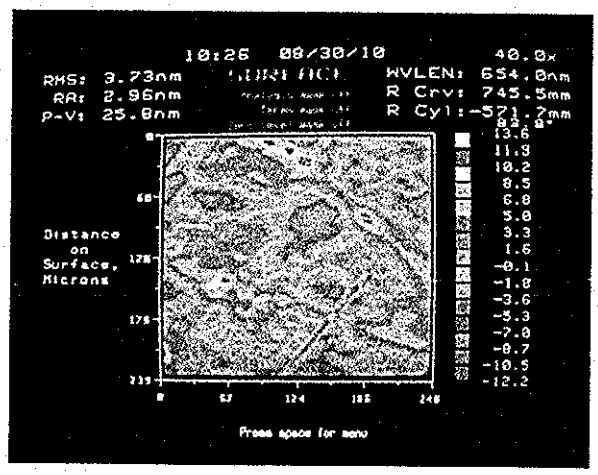


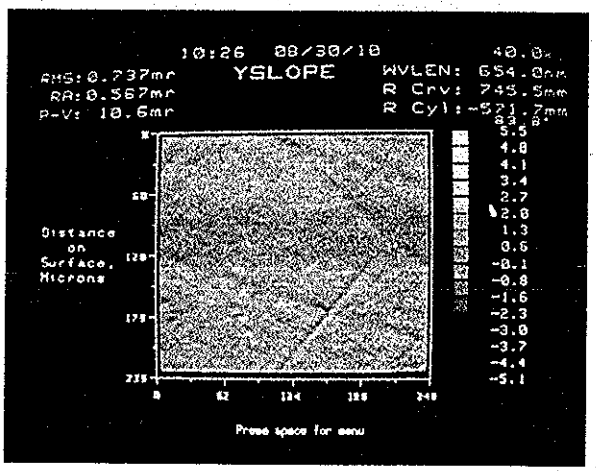


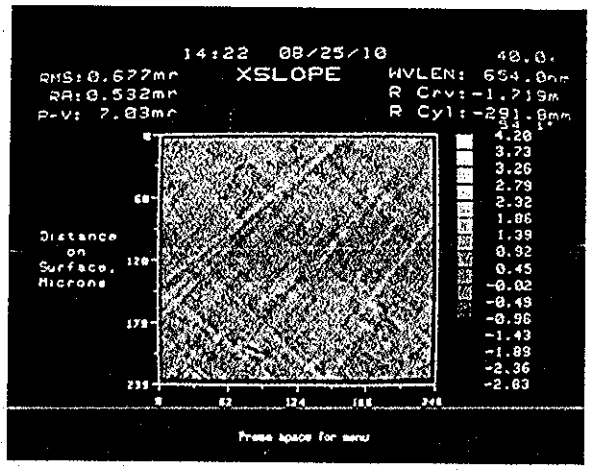
CGS FM/FS Coupons	
Sample	6
Data Point	4
Rms Roughness	3.73nm



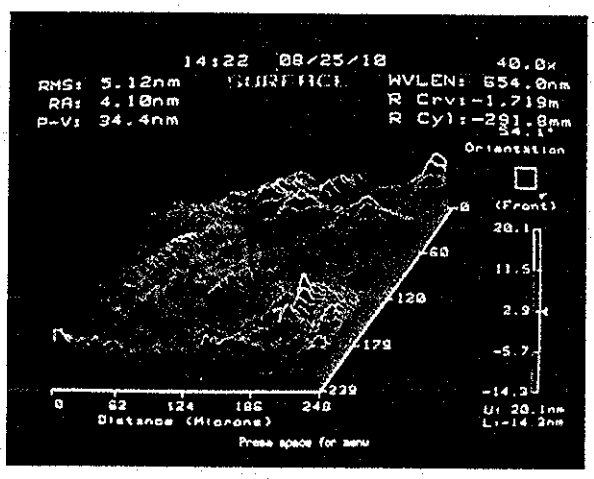


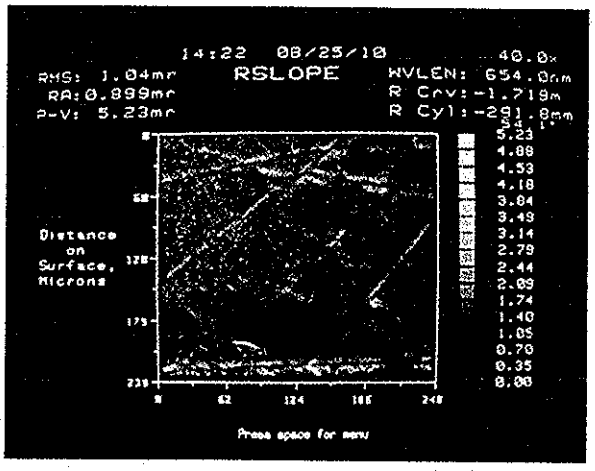


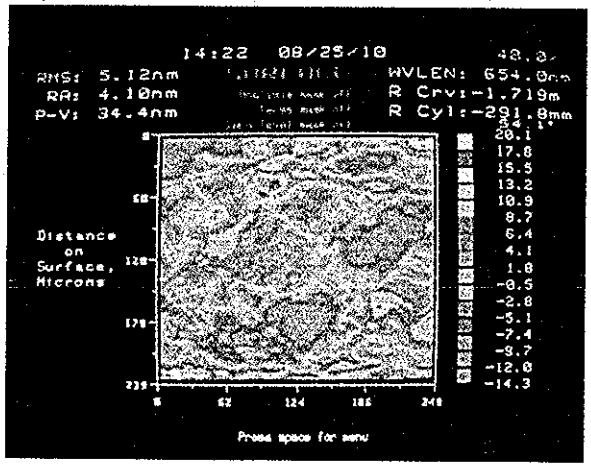


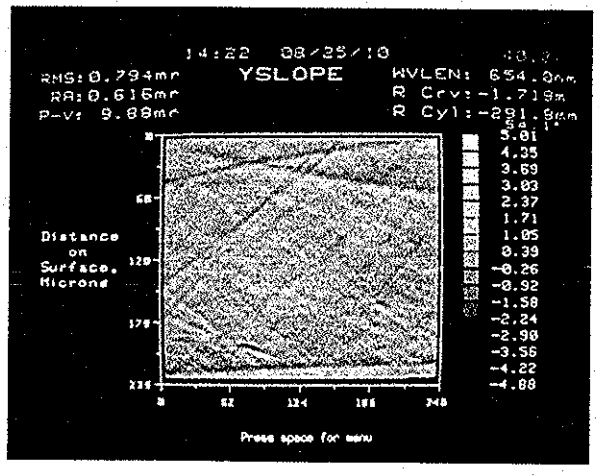


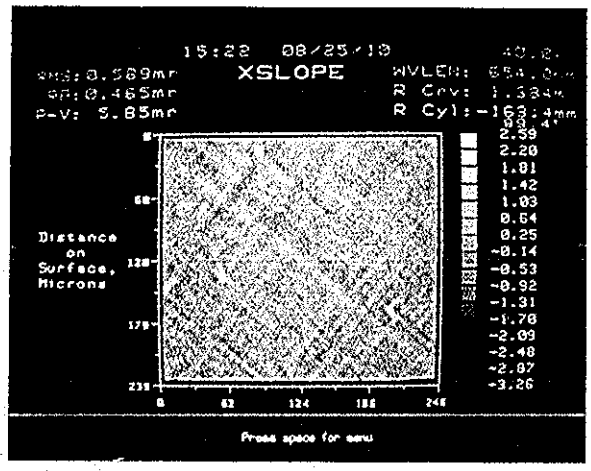
CGS FM/FS Coupons	
Sample	7
Data Point	1
Rms Roughness	5.12nm





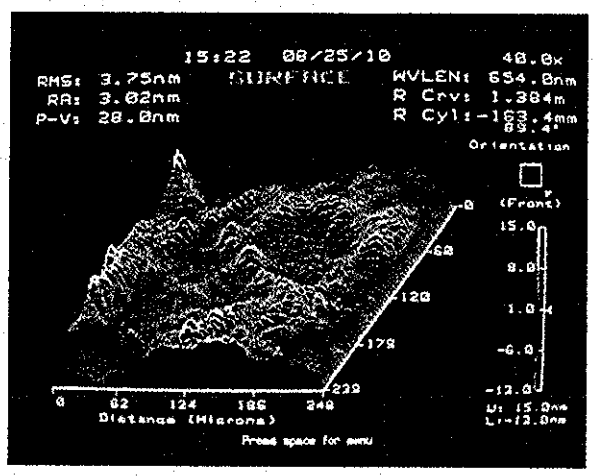


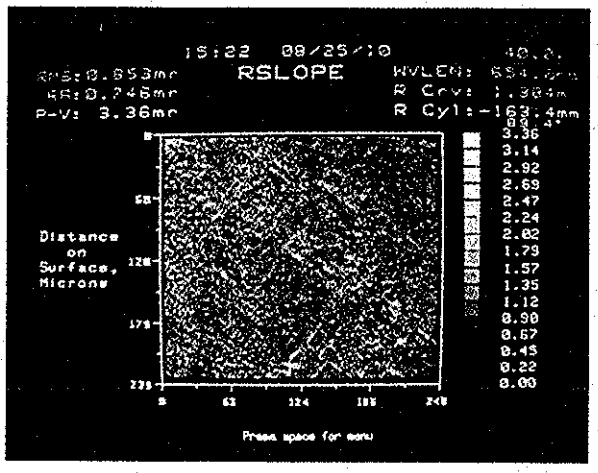


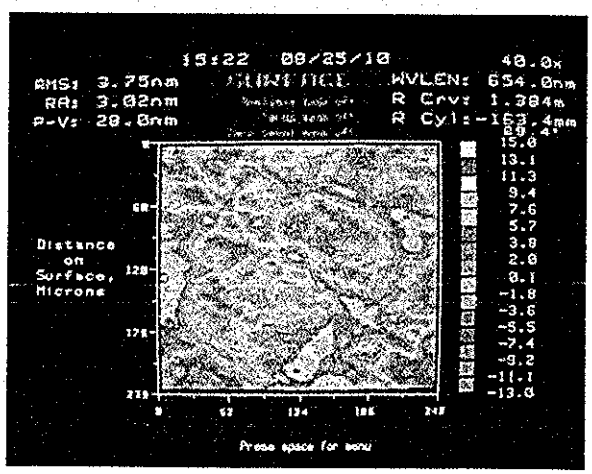


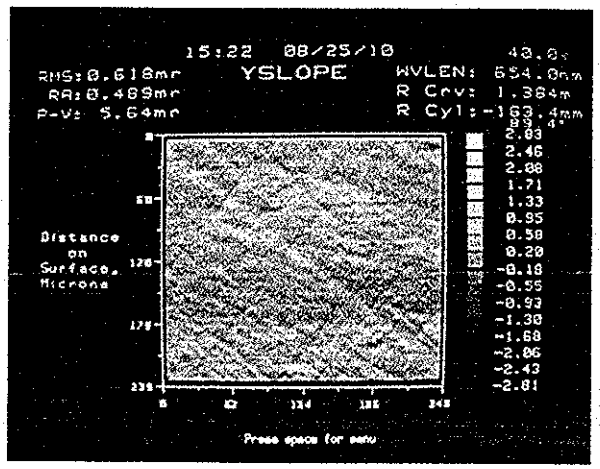
CGS FM/FS Coupons

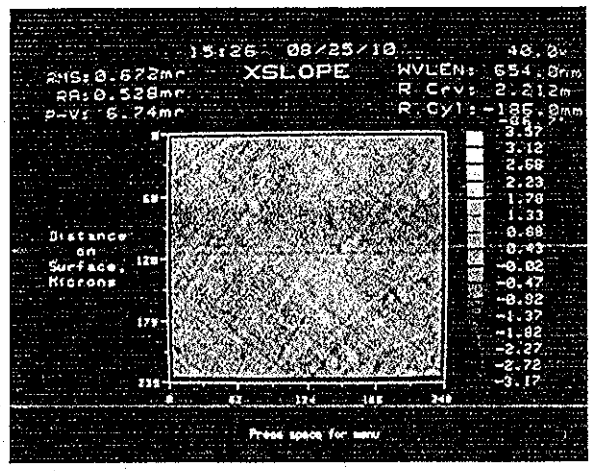
Sample	7
Data Point	2
Rms Roughness	3.75nm



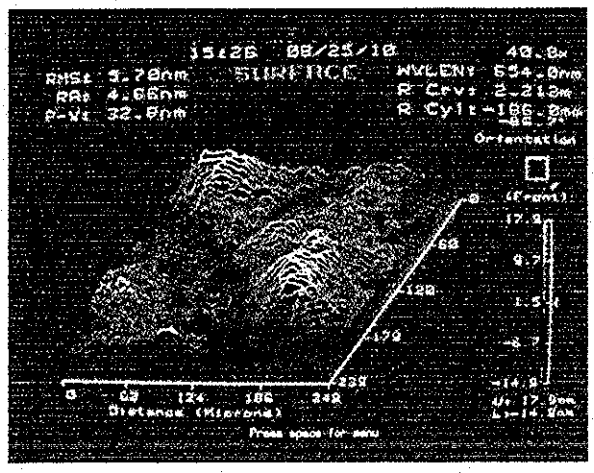


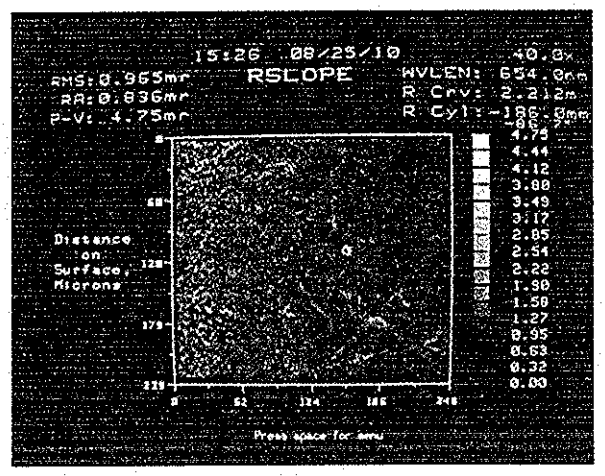


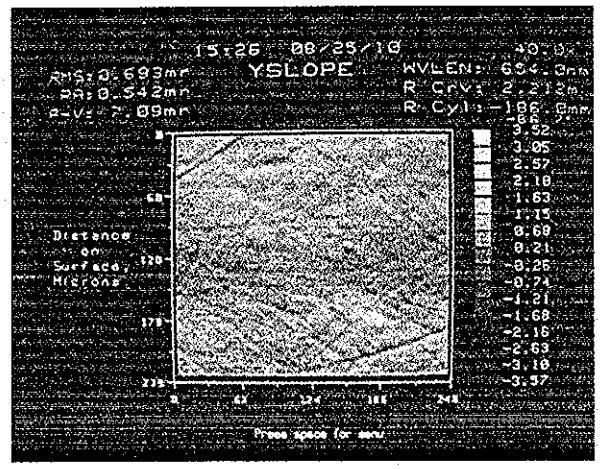


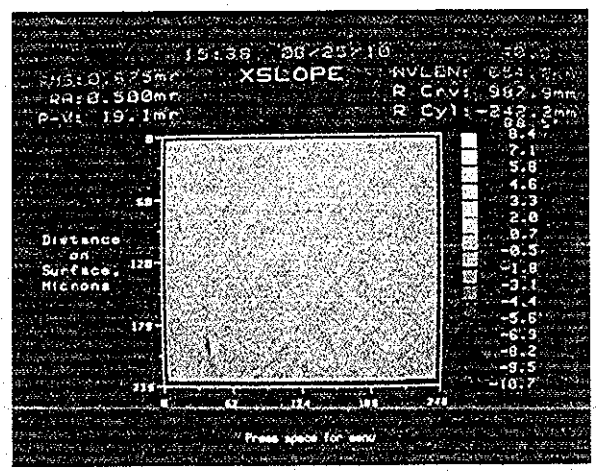


CGS FM/FS Coupons	
Sample	7
Data Point	3
Rms Roughness	5.70nm



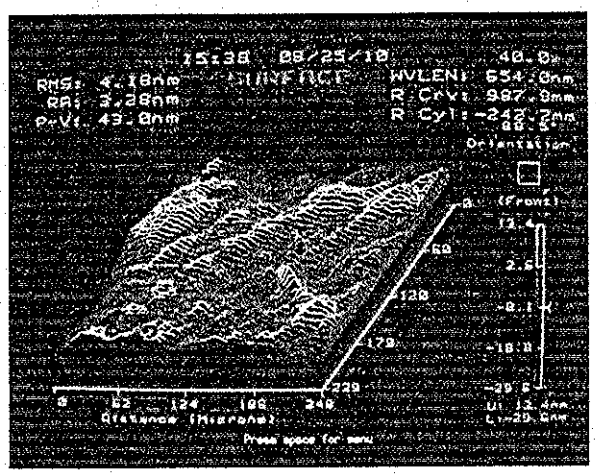


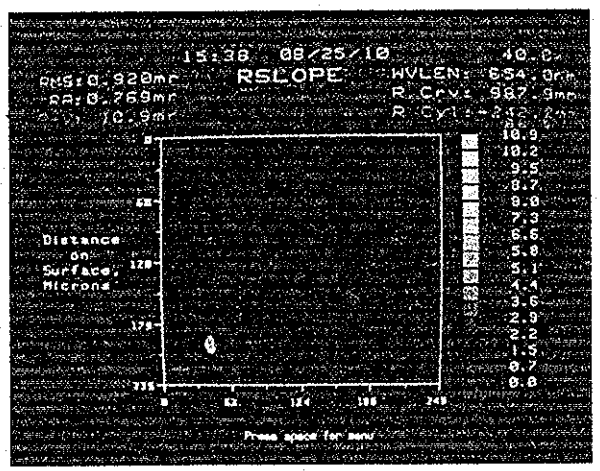


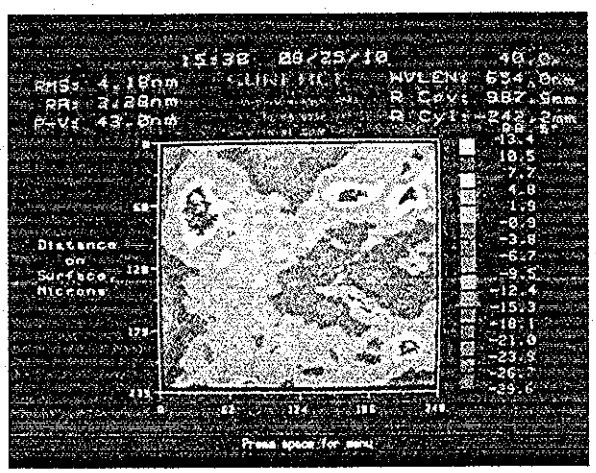


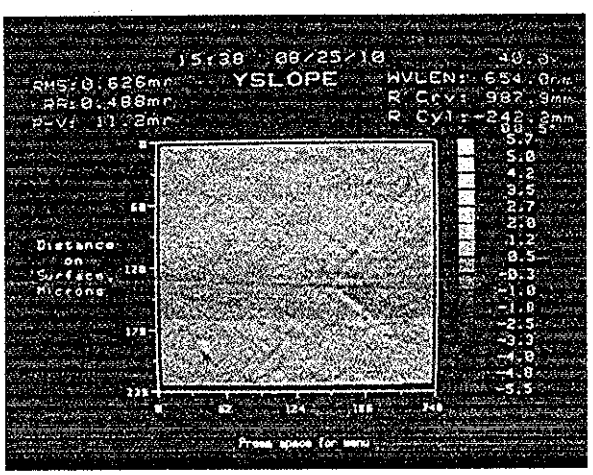
CGS FM/FS Coupons

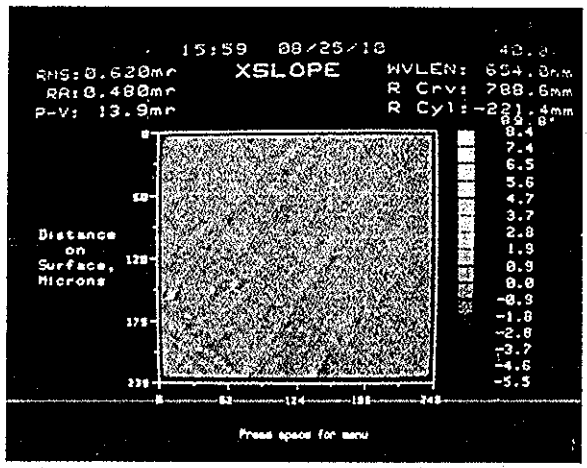
Sample	7
Data Point	4
Rms Roughness	4.16nm





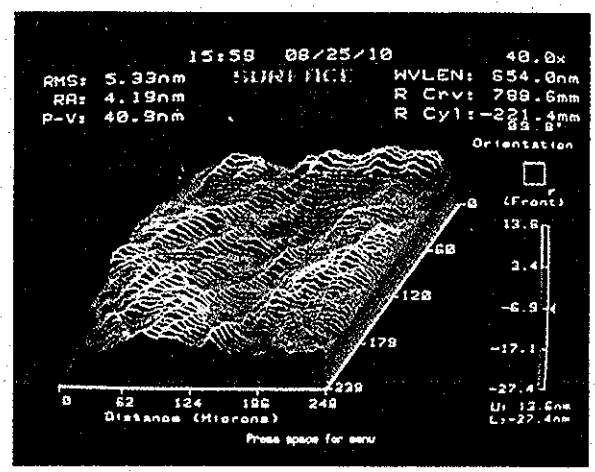


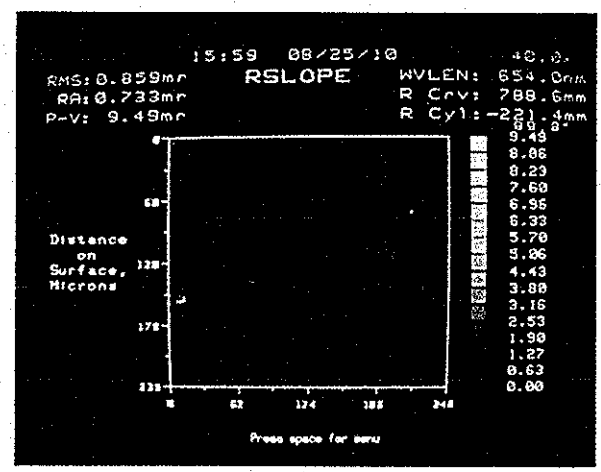


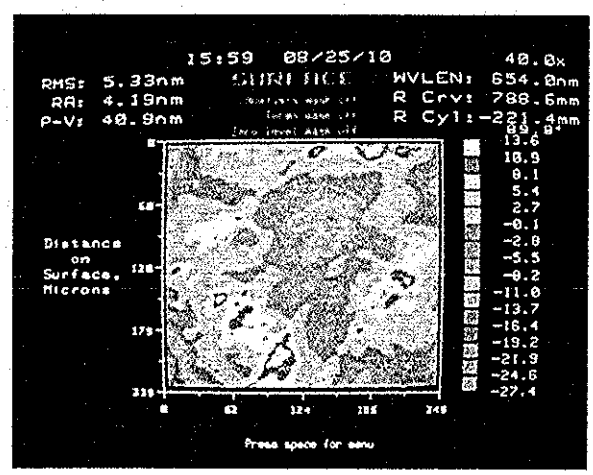


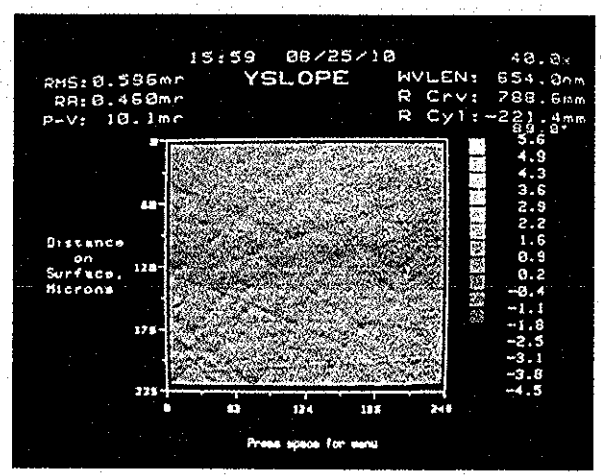
CGS FM/FS Coupons

Sample	8
Data Point	1
Rms Roughness	5.33nm









CMM Measurement

Calibration Data

CMM TECHNOLOGY INC.

Coordinate Measuring Machine Sales & Service
1230 Puerta del Sol • San Clemente, CA 92673
1-800/648-6944 • 949/366-0707

Calibration Certificate

ACCREDITED Cert No 2061.01

CALIBRATION #: 28848 PAGE 1 OF 1

TEMP 76° HUMIDITY 31%

For details of service repair and adjustment, see WO # 28848

- ☑ Pass: Accepted to manufacturer's specifications. Spec .001
- ☐ Pass: Accepted to customer's specifications. Spec _____
- ☐ Limitation: Accepted with limitations See customer's specification.

Calibration Interval: 1 Year

COMPANY University of Arizona
ADDRESS 1040 East 4th St
CITY Tucson STATE AZ ZIP 85721
PHONE (520) 621-6764 FAX (520) 621-6333

CMM Calibrated

MFG ELM Systems
MODEL # Bridge
SIZE X 48 Y 96 Z 20"
S/N 6832

This CMM has been calibrated according to appropriate parts of the following specifications: ISO/IEC 17025:1999; ASME B89 4.1-1997; ISO 10012-1; ANSI/NCSL Z540-1-1994 and the forme MIL STD 45662A. Calibration was performed using written procedures developed by CMM Technology, Inc. (CMMT-27.1 CMM Calibration Procedures©) The uncertainty of measurement involved in the calibration process comprises many components. CMM Technology, Inc has determined their cumulative effect to be 130 in maximum up to 48 inches and (130 + 0.5L) in maximum for 48 to 120 inches. This uncertainty represents an expanded uncertainty expressed at approximately the 95% confidence level using a coverage factor of k=2. This certification shall not be reproduced except in full without the written approval of CMM Technology, Inc. The calibration results recorded on this certificate apply only to the CMM listed above. Calibration is traceable to NIST through documents on file at CMM Technology, Inc.

SQUARENESS	ACCURACY	DISTANCE 1	DISTANCE 2
XY	.0001"	12"	
ZX	.0002"	12"	
ZY	.0001"	12"	

ALL READINGS .XXXX" 1 = .0001" 2 = .0002" 3 = .0003"

LINEAR ACCURACY													
X Axis POSITION:	0	3	6	9	12	15	18	21	24	27	30	33	36
	0	0	0	1	1	0	-1	-1	1	1	1	2	2
X Axis POSITION:	39	42	45	48									
	1	0	-1	-1									
Y Axis POSITION:	0	4	8	12	16	20	24	28	32	36	40	44	48
	0	1	1	-2	-2	-1	-1	0	0	1	0	-1	1
Y Axis POSITION:	52	56	60	64	68	72	76	80	84	88	92	96	
	1	1	2	2	0	0	0	1	2	2	3	3	
Z Axis POSITION:	0	2	4	6	8	10	12	14	16	18	20	22	
	0	-1	1	0	0	1	0	0	-1	-2	1		
Z Axis POSITION:													

LINEAR DISPLACEMENT ACCURACY			SQUARENESS ACCURACY			MEASURING REPEATABILITY			PARALLELISM (Beam/Plate Parallelism)	
Current Displacement Error	Axis	Before Adjustment Displacement Error	Current Squareness Error	Axis	Before Adjustment Squareness Error	Current Repeatability	Axis	Before Adjustment Repeatability	Current Parallelism	Before Adjustment Parallelism
.0003"	X	.0008"	.0001"	XY	.0007"	.0001"	X	.0001"	.0001"	.0001"
.0004"	Y	.0008"	.0002"	ZX	.0005"	.0001"	Y	.0001"		
.0002"	Z	.0002	.0001"	ZY	.0001"	.0001"	Z	.0001"		

Condition of CMM: ☑ Good ☐ Fair ☐ Poor

EQUIPMENT USED FOR CALIBRATION

DESCRIPTION	MANUFACTURER	SERIAL NUMBER	NIST TRACEABILITY NIST NUMBER	TEST DATE	DUE DATE
Tepmaster	Mitutoyo	80056	821/261216-02	7/30/04	7/30/05
Ball-Bar	Ball-Tek	000487	821/270460-04	3/3/05	3/3/06
Temp/Humidity Gage	Col-Parmer	0215	Test # 2049	2/20/05	2/20/06
				/ /	/ /
				/ /	/ /

Calibrated by and responsible for ensuring the correctness of this recorded information.

Pat Lauer
Service Engineer

Date calibrated: 7/13/05

Next calibration due on: 7/13/06

CMM-11-D

CMM TECHNOLOGY INC.

Coordinate Measuring Machine Sales & Service

1230 Puerta del Sol • San Clemente, CA 92673
1-800/648-6944 • 949/366-0707

ACCREDITED Cert No. 2061.01

CALIBRATION # 28848 PAGE 1 OF 1

TEMP 76° HUMIDITY 31%

CMM Calibrated

COMPANY UNIVERSITY of ARIZONA MFG. Elm

ADDRESS 1040 EAST 4TH ST MODEL # Bridge

CITY TUCSON STATE AZ ZIP 85721 SIZE X 48" Y 96" Z 20"

PHONE (520) 621-6764 FAX (520) 621-6333 S/N 6832

WO # 28848

☑ Pass: Accepted to manufacturer's specifications. Spec ± .0015

☐ Pass: Accepted to customer's specifications. Spec ±

☐ Limitation: Accepted with limitations See customer's specification.

Calibration Interval

1 YEAR

the correctness of this recorded information.

Pat Lawrence
Service Engineer

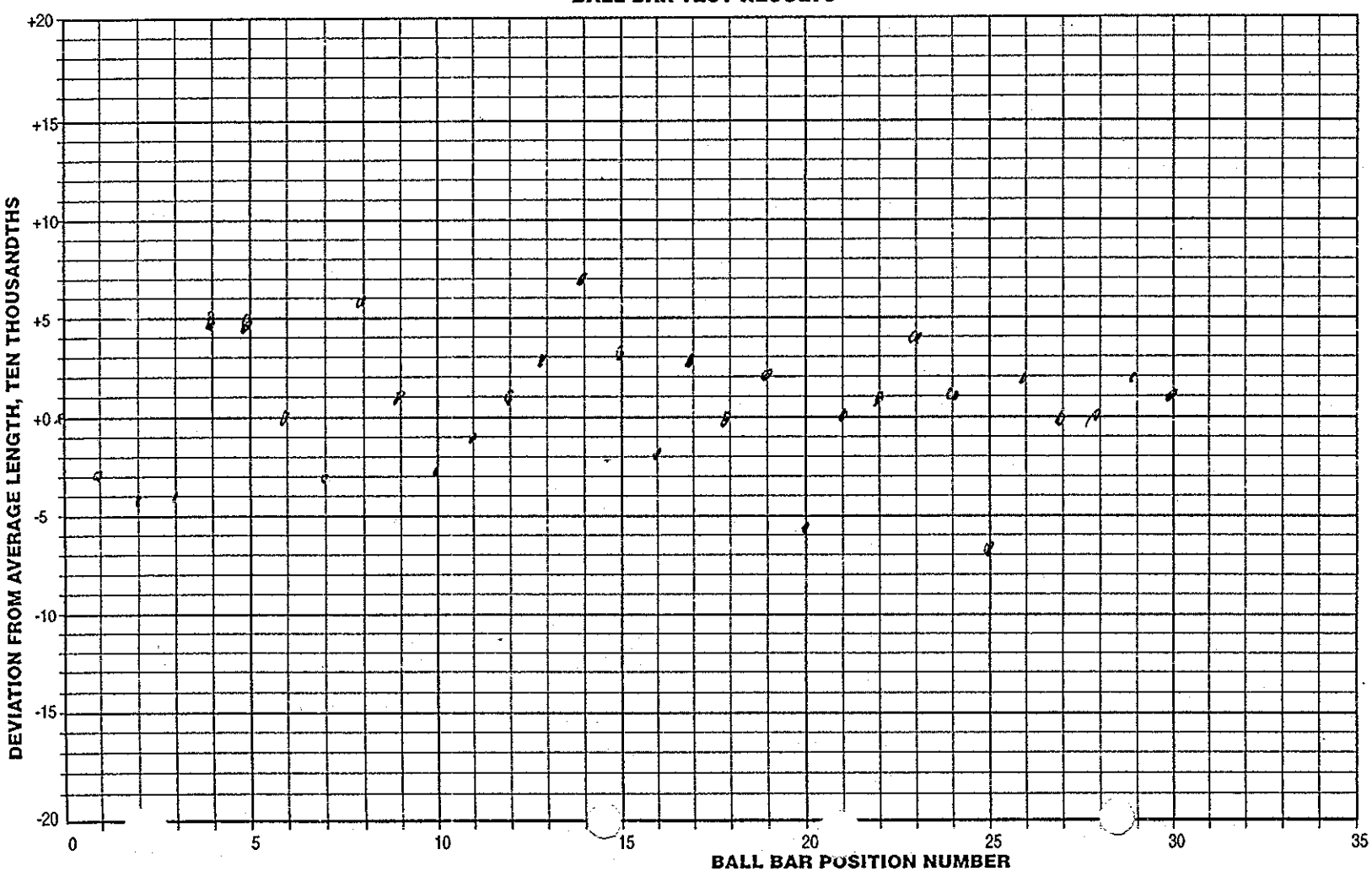
Date calibrated: 7, 13, 05

Next calibration due on: 7, 13, 06

This CMM has been calibrated according to appropriate parts of the following specifications: ISO/IEC 17025:1999; ASME B89.4.1-1997; ISO 10012-1; ANSI/NCSL Z540-1-1994 and the former MIL STD 45662A. Calibration was performed using written procedures developed by CMM Technology, Inc. (CMMT-27.1 CMM Calibration Procedures©). The uncertainty of measurement involved in the calibration process comprises many components. CMM Technology, Inc. has determined their cumulative effect to be 180 µin maximum up to 120". This uncertainty represents an expanded uncertainty expressed at approximately the 95% confidence level using a coverage factor of k=2. This certification shall not be reproduced except in full, without the written approval of CMM Technology, Inc. The calibration results recorded on this certificate apply only to the CMM listed above. Calibration is traceable to NIST through documents on file at CMM Technology, Inc.

This Volumetric Perfomance Test was performed in conjunction with CMM Technology Inc.'s calibration number 28848. See Page 1.

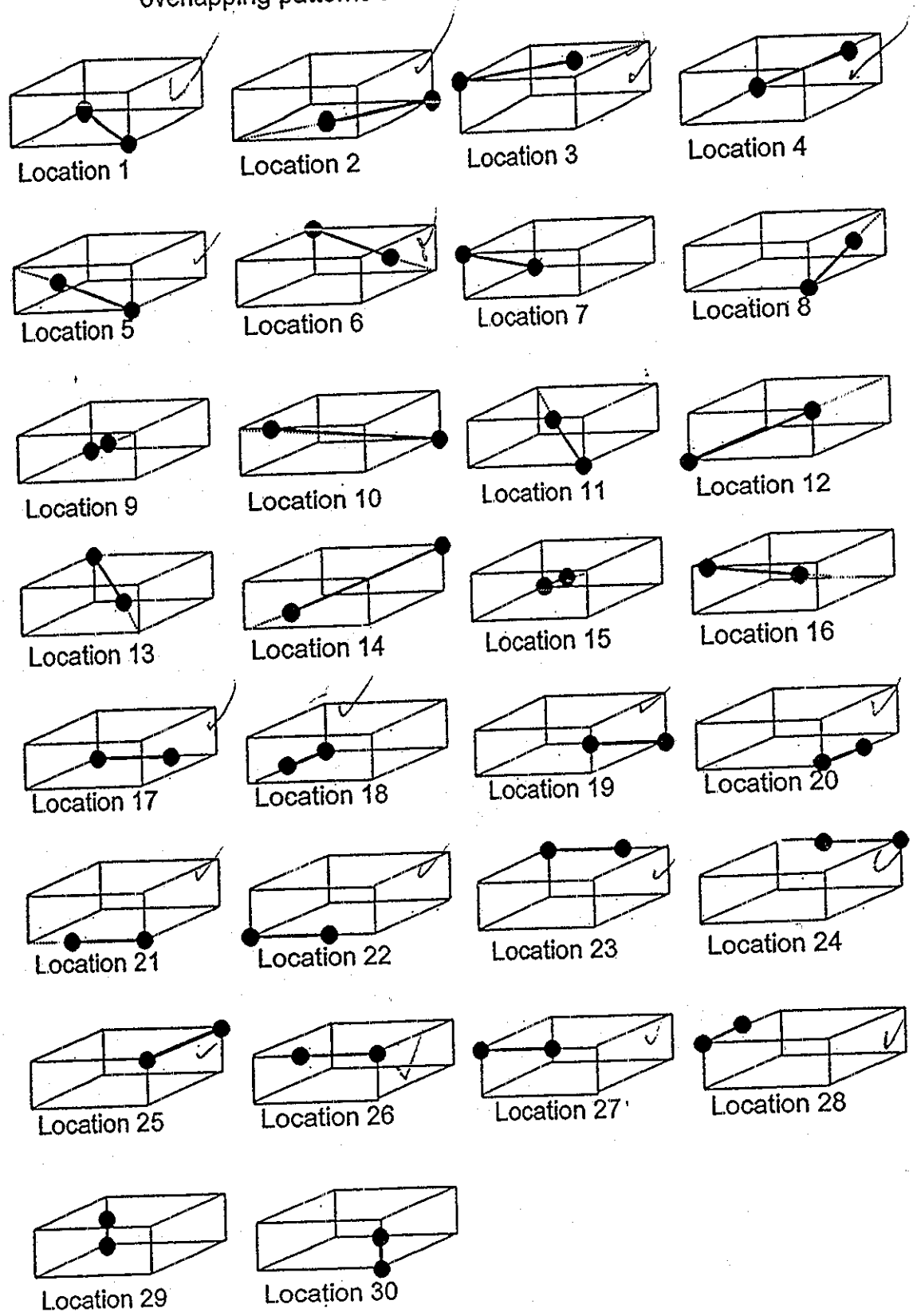
BALL BAR TEST RESULTS



Total Volumetric	
Basic Ball Bar Length	19.500
Pos. 1 Deviation	-.0003
Pos. 2 Deviation	-.0004
Pos. 3 Deviation	-.0004
Pos. 4 Deviation	.0005
Pos. 5 Deviation	.0005
Pos. 6 Deviation	-0-
Pos. 7 Deviation	-.0003
Pos. 8 Deviation	.0006
Pos. 9 Deviation	.0001
Pos. 10 Deviation	-.0002
Pos. 11 Deviation	-.0001
Pos. 12 Deviation	.0001
Pos. 13 Deviation	.0003
Pos. 14 Deviation	.0007
Pos. 15 Deviation	.0003
Pos. 16 Deviation	-.0002
Pos. 17 Deviation	.0003
Pos. 18 Deviation	-0-
Pos. 19 Deviation	.0002
Pos. 20 Deviation	-.0006
Pos. 21 Deviation	-0-
Pos. 22 Deviation	.0001
Pos. 23 Deviation	.0004
Pos. 24 Deviation	.0001
Pos. 25 Deviation	-.0007
Pos. 26 Deviation	-0-
Pos. 27 Deviation	-0-
Pos. 28 Deviation	.0002
Pos. 29 Deviation	.0001
Pos. 30 Deviation	
Pos. 31 Deviation	
Pos. 32 Deviation	
Pos. 33 Deviation	
Pos. 34 Deviation	
Pos. 35 Deviation	

CMM-15-B

Fig. 27 **Recommended Ball Bar Positions for Machines with a Single Long Axis.** (The axis ratio here is 2:1:1. On machines with slightly different ratios, overlapping patterns are recommended.)



WORK ORDER

CMM TECHNOLOGY INC.

Coordinate Measuring Machine Sales & Service

1230 Puerta del Sol • San Clemente CA 92673
Tel 800/648-6944 • 949/366-0707

CMM MFG: E/W
MODEL:
SIZE X 48" Y 96" Z 20"
S/N 6832

COMPANY: UNIVERSITY OF ARIZONA
ADDRESS: 1040 E 4TH ST.
CITY: TUCSON AZ
STATE: AZ ZIP: 85721
PHONE: 520-621-6764
CONTACT: Robert Kingsley

WORK ORDER # 28548

P.O. # P170507 TERMS NET 10 DAYS

CALIBRATION AND TUNE-UP PACKAGE

We recommend a 6-month calibration interval for all CMMs over 5 years old

AMOUNT

- [ ] Inspect and clean X, Y and Z scales
- [ ] Check and adjust all reader heads
- [ ] Check X, Y and Z fine adjustment
- [ ] Inspect and adjust beam/plate parallelism
- [ ] Perform probe evaluation
- [ ] Inspect and adjust perpendicularity
- [ ] Inspect and adjust linearity
- [ ] Check volumetric performance
- [ ] Check repeatability in X, Y and Z axis
- [ ] Issue an official Calibration Report

REPAIR LABOR 5 HOUR MINIMUM

	HRS.	RATE	AMOUNT
			696.00

NOTES: TRAINING ON THE QC5000

PARTS AND ACCESSORIES

QTY	PART NUMBER	DESCRIPTION	PRICE

TOTAL PARTS ▶

SALES TAX

TOTAL 696.00

100% SATISFACTION GUARANTEED OR YOU DON'T PAY PERIOD

President

[X] All work stated on this work order was completed to my satisfaction. Please invoice.

[ ] I am not satisfied. Please DO NOT invoice.

SIGNATURE

TITLE

7/14/08

DATE

CMM TECHNOLOGY RECOMMENDS THE FOLLOWING:

SERVICE ENGINEER Pat Jones DATE 7-14-08

CMM-10-B

WORK ORDER

CMM TECHNOLOGY INC.

Coordinate Measuring Machine Sales & Service

1230 Puerta del Sol • San Clemente, CA 92673
Tel 800/648-6944 • 949/366-0707

CMM MFG: E/M
MODEL:
SIZE X 48' Y 96" Z 20'
S/N 6832

COMPANY: UNIVERSITY of ARIZONA
ADDRESS: 1040 EAST 4TH ST
CITY: TUCSON
STATE: AZ ZIP: 85721
PHONE: (520) 621-6764
CONTACT:

WORK ORDER # 28848

P.O. # P170502 TERMS NET 10 DAYS

CALIBRATION AND TUNE-UP PACKAGE

We recommend a 6-month calibration interval for all CMMs over 5 years old

- [x] Inspect and clean X, Y and Z scales
- [x] Check and adjust all reader heads
- [x] Check X, Y and Z fine adjustment
- [x] Inspect and adjust beam/plate parallelism
- [x] Perform probe evaluation
- [x] Inspect and adjust perpendicularity
- [x] Inspect and adjust linearity
- [x] Check volumetric performance
- [x] Check repeatability in X, Y and Z axis
- [x] Issue an official Calibration Report

AMOUNT: 660 00

REPAIR LABOR 5 HOUR MINIMUM

HRS.	RATE

NOTES:

100% SATISFACTION GUARANTEED OR YOU DON'T PAY PERIOD

Gail Tagart
President

- [x] All work stated on this work order was completed to my satisfaction. Please invoice
- [ ] I am not satisfied. Please DO NOT invoice

SIGNATURE: [signature]
TITLE: Director
DATE: 7/12/05

PARTS AND ACCESSORIES

QTY	PART NUMBER	DESCRIPTION	PRICE

TOTAL PARTS ▶

CMM TECHNOLOGY RECOMMENDS THE FOLLOWING:

SALES TAX

TOTAL 660 00

SERVICE ENGINEER: Pat Lawrence DATE: 7-13-05

CMM-10-B

CMM TECHNOLOGY INC.

Coordinate Measuring Machine Sales & Service
1230 Puerta del Sol • San Clemente, CA 92673
1-800/648-6944 • 949/366-0707

Calibration Certificate

ACCREDITED Cert No. 2061.01

CALIBRATION #: 26604 PAGE 1 OF 2

TEMP 71° HUMIDITY 23%

For details of service, repair and adjustment see

WO # 26604

- ☐ Pass: Accepted to manufacturer's specifications Spec ±
- ☒ Pass: Accepted to customer's specifications. Spec ± .0010"
- ☐ Limitation: Accepted with limitations See customer's specification

Calibration Interval

12 MONTHS

CMM Calibrated

COMPANY Univ. of Arizona URIC
ADDRESS 1040 E 4TH ST Room 235
CITY Tucson STATE AZ ZIP 85721
PHONE 520-621-6764 FAX 520-621-6333

MFG ELM
MODEL # BRIDGE
SIZE X 48 Y 96 Z 20
S/N 6832

This CMM has been calibrated according to appropriate parts of the following specifications: ISO/IEC 17025:1999; ASME B89.4.1-1997; ISO 10012-1; ANSI/NCSL Z540-1-1994 and the form MIL STD 45662A. Calibration was performed using written procedures developed by CMM Technology Inc (CMMT-27.1 CMM Calibration Procedures©). The uncertainty of measurement involved in the calibration process comprises many components. CMM Technology, Inc has determined their cumulative effect to be 130 µin maximum up to 48 inches and (130 + 0.5L) µin maximum for 48 to 120 inches. This uncertainty represents an expanded uncertainty expressed at approximately the 95% confidence level using a coverage factor of k=2. This certification shall not be reproduced except in full, without the written approval of CMM Technology, Inc. The calibration results recorded on this certificate apply only to the CMM listed above. Calibratio is traceable to NIST through documents on file at CMM Technology, Inc.

SQUARENESS	ACCURACY	DISTANCE	
XY	0.00018"	31.51313	/ 31.51331
ZX	0.00005"	15.75770"	/ 15.75778
ZY	0.00009"	15.75778"	/ 15.75719"

ALL READINGS .XXXX" 1 = .0001" 2 = .0002" 3 = .0003"

LINEAR ACCURACY														
X Axis POSITION:	0	4	8	12	16	20	24	28	32	36	40	44	48
	0	-1.3	-1.2	-1.0	-0.3	0.9	0.1	-0.7	0.7	-2.0	-0.8	-0.5	-0.1
Y Axis POSITION:	0	4	8	12	16	20	24	28	32	36	40	44	48
	0	0.8	-0.1	0.9	-2.0	0.2	0.9	0.5	0.5	1.5	0.3	1.4	0.4
	52	56	60	64	68	72	76	80	84	88	92	95	
	-0.5	0.6	2.3	1.4	-0.4	1.0	-1.2	-1.6	0.3	-1.7	-0.5	0.2	
Z Axis POSITION:	0	2	4	6	8	10	12	14	16	18	19		
	0	-0.1	1.0	0	-0.4	-1.3	-0.2	0	0.2	1.3	-0.7		

LINEAR DISPLACEMENT ACCURACY

Current Displacement Error	Axis	Before Adjustment Displacement Error
2.0	X	10.9
2.3	Y	16.6
1.3	Z	8.8

SQUARENESS ACCURACY

Current Squareness Error	Axis	Before Adjustment Squareness Error
1.8	XY	21.8
0.5	ZX	3.8
0.9	ZY	16.6

MEASURING REPEATABILITY

Current Repeatability	Axis	Before Adjustment Repeatability
1.1	X	1.8
1.3	Y	1.1
1.8	Z	4.3

PARALLELISM

Beam/Plate Parallelism

Current Parallelism	Before Adjustment Parallelism
9.4	9.4

Condition of CMM

☒ Good ☐ Fair ☐ Poor

EQUIPMENT USED FOR CALIBRATION

DESCRIPTION	MANUFACTURER	SERIAL NUMBER	NIST TRACEABILITY NIST NUMBER	TEST DATE	DUE DATE
REF BAR	STARRETT	120187.8	821/266717-02	10/09/03	10/09/04
				/ /	/ /
BALL BAR	BALTEC	392/408	821/265364-01	03/11/04	03/11/05
				/ /	/ /
THERM	RADIOSHACK	0158	277225	10/17/03	10/17/04

Calibrated by and responsible for ensuring the correctness of this recorded information.

Service Engineer

Date calibrated: 06/16/2004

Next calibration due on: 06/16/2005

CMM TECHNOLOGY INC.

Coordinate Measuring Machine Sales & Service

1230 Puerta del Sol • San Clemente, CA 92673
1-800/648-6944 • 949/366-0707

ACCREDITED Cert No. 2061.01

CALIBRATION # 26604 PAGE 2 OF 2

TEMP 71° HUMIDITY 23%

CMM Calibrated

COMPANY UNIV OF ARIZONA

ADDRESS 1040 E. 4TH ST Room 235

CITY TUCSON STATE AZ ZIP 85721

PHONE 520-621-6764 FAX 520-621-6333

MFG. ELM

MODEL # BRIDGE

SIZE X 48 Y 96 Z 20

S/N 6832

WO # 26604

- ☐ Pass: Accepted to manufacturer's specifications. Spec ±
- ☒ Pass: Accepted to customer's specifications. Spec ± .0015"
- ☐ Limitation: Accepted with limitations See customer's specification.

Calibration Interval

12 MONTHS

Service Engineer

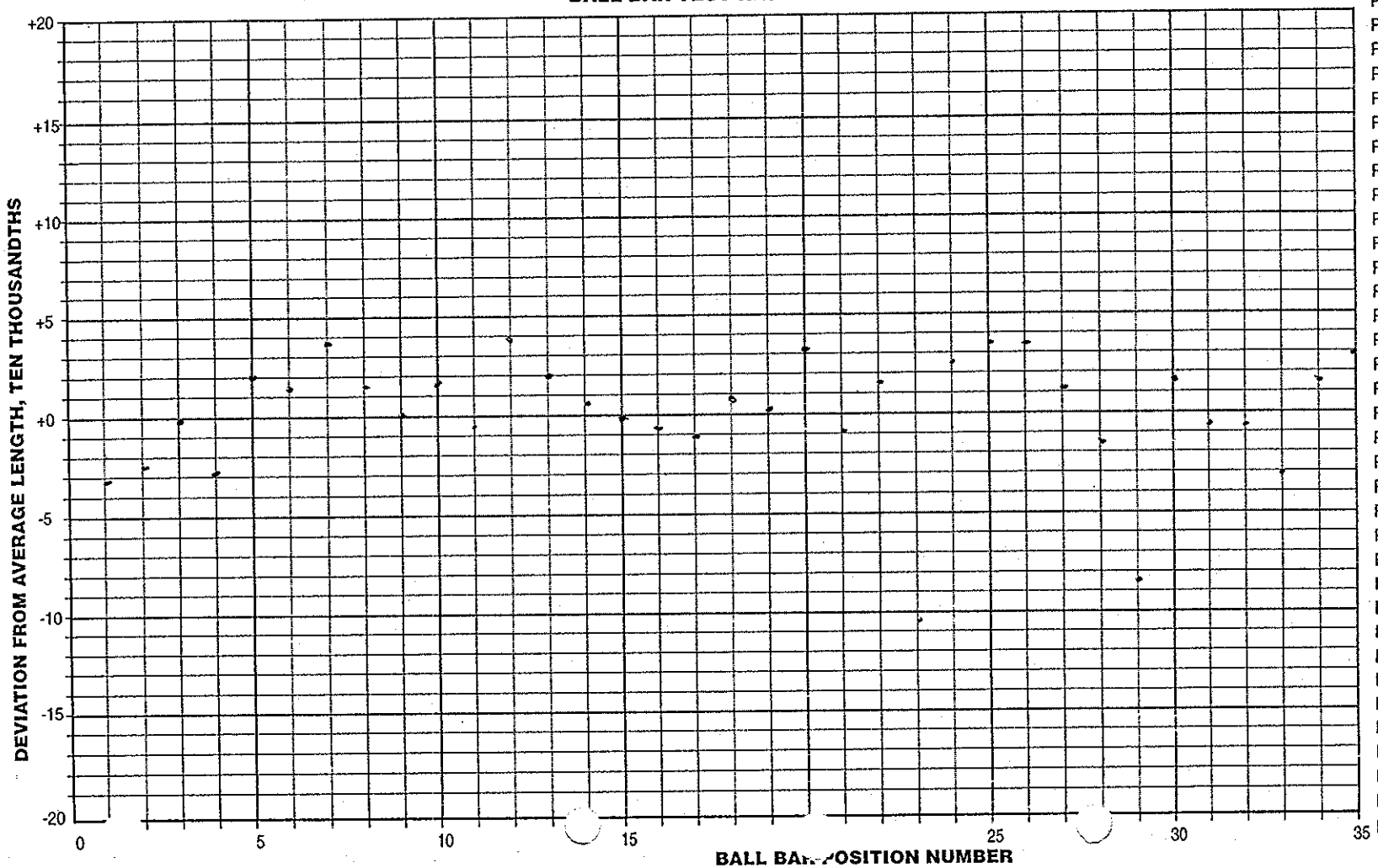
Date calibrated: 06, 16, 2004

Next calibration due on: 06, 16, 2005

This CMM has been calibrated according to appropriate parts of the following specifications: ISO/IEC 17025:1999; ASME B89.4.1-1997; ISO 10012-1; ANSI/NCSL Z540-1-1994 and the former MIL STD 45662A. Calibration was performed using written procedures developed by CMM Technology, Inc. (CMMT-27.1 CMM Calibration Procedures©). The uncertainty of measurement involved in the calibration process comprises many components. CMM Technology, Inc. has determined their cumulative effect to be 180 µin maximum up to 120°. This uncertainty represents an expanded uncertainty expressed at approximately the 95% confidence level using a coverage factor of k=2. This certification shall not be reproduced except in full, without the written approval of CMM Technology, Inc. The calibration results recorded on this certificate apply only to the CMM listed above. Calibration is traceable to NIST through documents on file at CMM Technology, Inc.

This Volumetric Perfomance Test was performed in conjunction with CMM Technology Inc.'s calibration number 26604, See Page 1.

BALL BAR TEST RESULTS



Total Volumetric	.00162"
Basic Ball Bar Length	15.75733
Pos. 1 Deviation	-.00032"
Pos. 2 Deviation	-.00026"
Pos. 3 Deviation	-.00001"
Pos. 4 Deviation	-.00029"
Pos. 5 Deviation	.00020"
Pos. 6 Deviation	.00014"
Pos. 7 Deviation	.00047"
Pos. 8 Deviation	.00014"
Pos. 9 Deviation	.00000"
Pos. 10 Deviation	.00016"
Pos. 11 Deviation	-.00004"
Pos. 12 Deviation	.00038"
Pos. 13 Deviation	.00020"
Pos. 14 Deviation	.00005"
Pos. 15 Deviation	-.00001"
Pos. 16 Deviation	-.00008"
Pos. 17 Deviation	-.00011"
Pos. 18 Deviation	.00009"
Pos. 19 Deviation	.00001"
Pos. 20 Deviation	.00031"
Pos. 21 Deviation	-.00009"
Pos. 22 Deviation	.00017"
Pos. 23 Deviation	-.00115"
Pos. 24 Deviation	.00026"
Pos. 25 Deviation	.00035"
Pos. 26 Deviation	.00034"
Pos. 27 Deviation	.00011"
Pos. 28 Deviation	-.00015"
Pos. 29 Deviation	-.00085"
Pos. 30 Deviation	.00014"
Pos. 31 Deviation	-.00006"
Pos. 32 Deviation	-.00008
Pos. 33 Deviation	-.00031"
Pos. 34 Deviation	.00015"
Pos. 35 Deviatio	.00029"

CMM-15-B

CMM TECHNOLOGY INC.
Coordinate Measuring Machine Sales & Service
1230 Puerta del Sol • San Clemente, CA 92673
Tel 800/648-6944 • Fax 949/366-6503
info@cmmtechnology.com

Probe Repeatability Evaluation Report

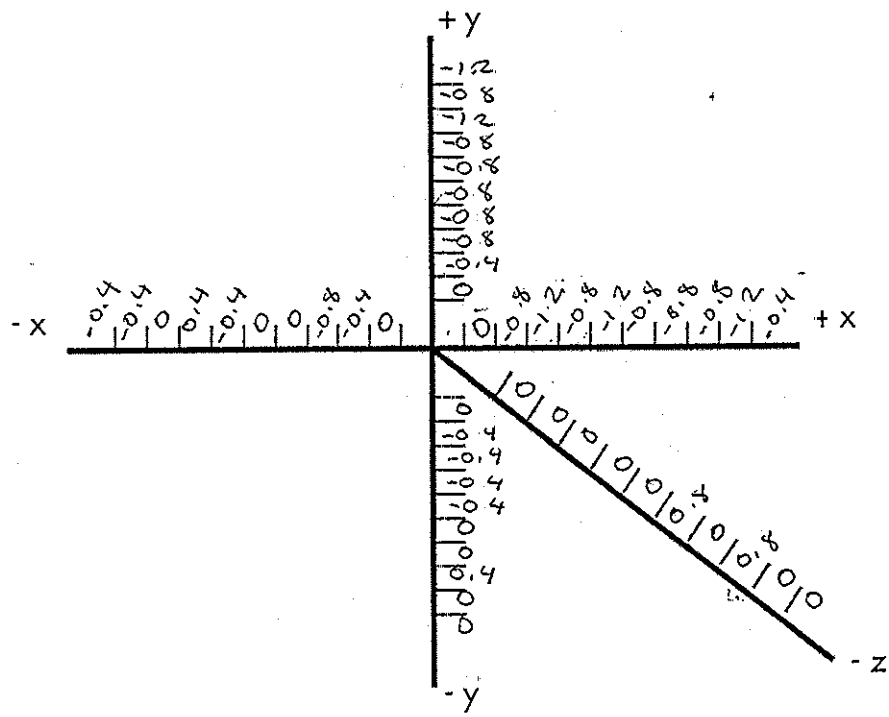
W.O. # 26604 Date

Company: UNIV. OF ARIZONA
Address: 1040 E. 4TH ST. Room 235
City: TUCSON State: AZ Zip: 85721
Phone: 520-621-6764 Fax: 520-621-6333
Contact: ROBERT KINGSLEY

Probe Evaluated
Mfg: RENISHAW
Probe Head: PH 1
Probe: TP6
S/N: D08531

ALL READINGS .XXXX"

1=.0001"
2=.0002"
3=.0003"



Repeatability Range		# of No Hits	# of Sticks
+X axis	.00012"	0	0
-X axis	.00012"	0	0
+Y axis	.00012"	0	0
-Y axis	.00008"	0	0
-Z axis	.00008"	0	0

☒ Pass: Accepted to customers' and/or manufacturer's specifications.

☐ Fail: Recommend Replacement

Comments:

Note: A "No Hit" is when the probe is deflected, but no point is recorded
A "Stick" is when the probe is deflected, but does not return to its neutral position. (i.e. the light remains out)

CMM-14-B