INDIAN POINT UNIT NO. 2
VISUAL FUEL INSPECTION
CYCLE 3/4 REFUELING

This report was prepared with the participation of Nuclear Assurance Corporation of Atlanta, Georgia

Consolidated Edison Company of New York, Inc.

Docket No. 50-247

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FUEL INSPECTION REPORT

Consolidated Edison Company

Indian Point Unit 2

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SUMMARY

A visual fuel inspection of the two [illegible]d burnup assemblies from each region in the core at Indian Point Unit No. 2 was completed on July 27, 1979 during the third refueling outage. The following assemblies listed with their approximate burnups at the end of cycle 3 were inspected:

Assembly	Burnup (MWD/MTU)
B-49	36000
B-41	36000
C-23	37000
C-06	37000
D-11	25000
D-71	25000
E-49	13000
E-38	13000

The television examination of the peripheral rods of these fuel assemblies indicated that the overall condition was excellent, with light to medium patchy oxide covering the active fuel cladding surfaces. The crud layer on the peripheral rods' surface appeared to be thin; however, some crud spalling was observed.

A partial fret of insignificant amount was seen in the end cap area of a rod in D-11. A few rods mostly in "B" and "C" assemblies were observed to be either touching or almost touching both upper and lower nozzles. One assembly (B-41)

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contained two rods that were bowed (interference bowing) sufficiently to be touching their adjacent rods.

Dimensional measurements were performed on 7* of the 8 assemblies inspected employing a camera capable of high magnification mounted on a movable carriage. With the exceptions previously noted, minimal rod closure of the peripheral rods was observed. Rod closure measurements (defined as the minimum projected spacing or gap between two adjacent fuel rods and two successive grids) were performed on a predetermined random basis to get a good statistical representation of the typical rod closure seen in these fuel assemblies. The average rod closure for the 172 slots examined was 0.1182 inches, which would indicate a 16% closure between the two rods. Since the measured average rod closures for Regions B,C,D, and E assemblies were 0.1135, 0.1184, 0.1208, and 0.1211 inches respectively, no burnup dependence of the rod closure was seen in this inspection. Dimensional measurements of rod lengths, guide thimble length, assembly bow, and assembly twist were made. Analysis of the dimensional results indicated that (1) average rod growth from as-built of the "B", "C", "D", and "E" assemblies were 0.928, 0.791, 0.665, and 0.497 inches, respectively, (2) the maximum assembly bow was 0.185 inches, (3) the average guide-thimble length for "B", "C", "D", and "E" assemblies were 150.499, 150.557, 150.558, and 150.858 inches, respectively, and (4) the maximum assembly twist was 5.11°.

*Dimensional measurements were not taken on E-49 due to technical difficulties.

In conclusion, no evidence of fuel cladding failure or any other condition (such as clad flattening) that could lead to unacceptable fuel performance was observed on the 8 fuel assemblies examined.

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FUEL INSPECTION EQUIPMENT DESCRIPTION

The fuel inspection system consists of two major modules: (1) an underwater three-dimensional traversing camera module, and (2) a control, monitoring, and data reduction module (see Figure 1).

The underwater three-dimensional traversing camera module is attached to, and fits within, the common spent fuel examination stand. The stand, along with the camera module, is placed on the bottom of the spent fuel pool floor. A fuel assembly is lowered into the support basket. The basket can be rotated by the operator so as to expose all sides of the fuel assembly to the television cameras. Two television cameras (one as backup) are mounted on the module and traverse the entire length and width dimensions of the fuel assembly allowing for examination of all peripheral rods. The third dimension (optical) movement capability of the module allows reduction of field of view from a full face to a detailed individual rod scan. As the fuel assembly is being scanned, precise position measurements are superimposed on the visual display at the control, monitoring, and data reduction module.

Selected position measurements from this display are utilized in the dimensional characterization of the individual peripheral fuel rods or of the assembly. These measurements for specific dimensional analysis may be automatically reduced and

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converted to a finished format by utilization of a mini-computer system.

The mini-computer system consists of a mini-computer, plotter, and computer program software. The mini-computer is electronically interfaced with the position measuring devices which are a part of the underwater three-dimensional traversing mechanism.

The position information is stored in the computer memory for processing by the software programs. These are data reduction programs for system calibration and fuel assembly dimensional measurement. The mini-computer is equipped with an auxiliary plotter for rapid display of engineering data immediately after a particular dimensional measurement has been completed.

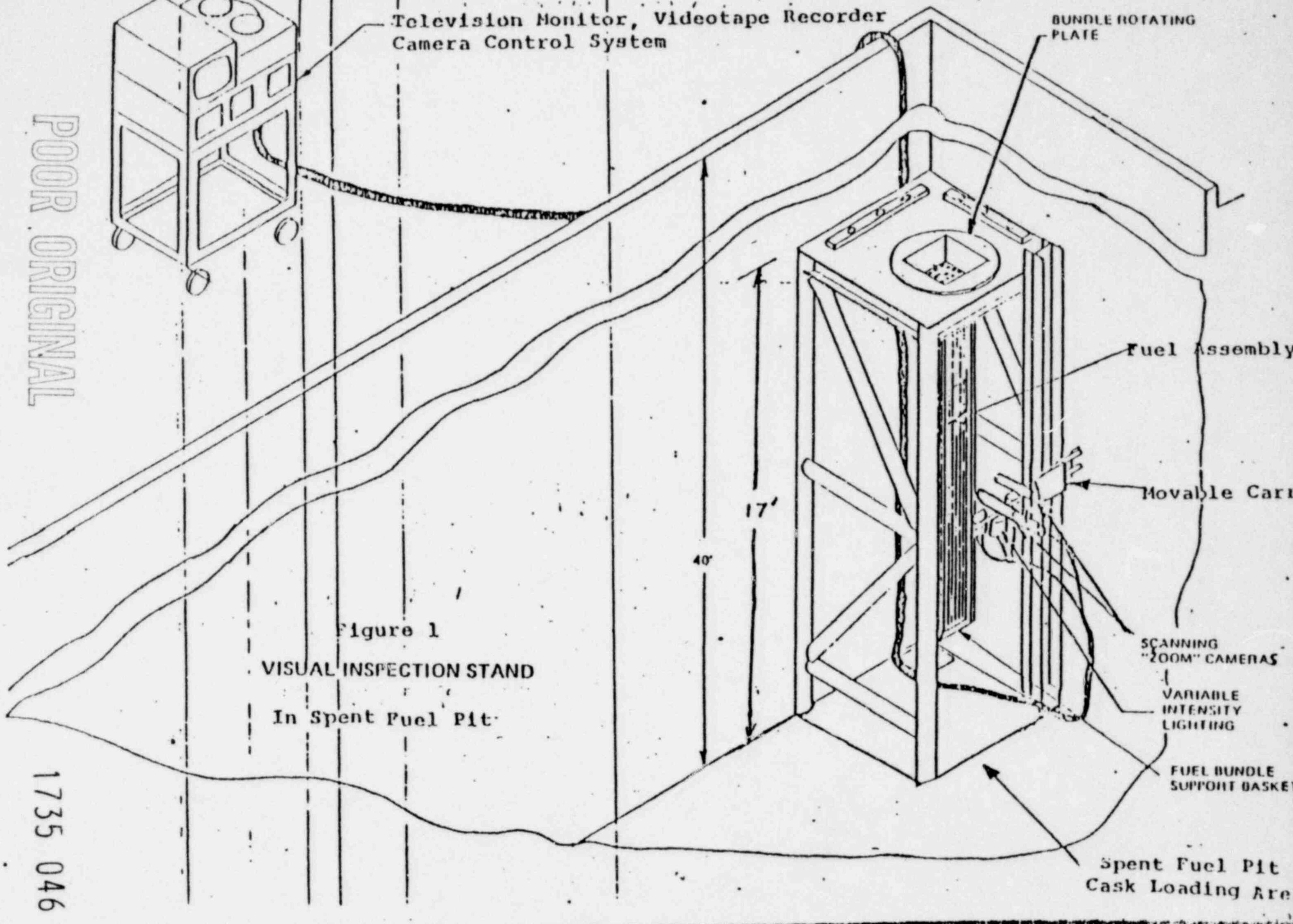

Figure 1

VISUAL INSPECTION STAND

In Spent Fuel Pit

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Qualification

The visual inspection system was qualified at Indian Point during the first week of July 1979 for width, length, and bow system runout. Table 1 is a summary of the system's bias and precision results.

TABLE 1

SYSTEM QUALIFICATION SUMMARY

	Bias (Inches)	Precision (Inches) One Sigma	Precision (Inches) Two Sigma
Length	<±0.0001	±0.0067	±0.0134
Width	<±0.0001	±0.0027	±0.0054
System Runout	<±0.0001	±0.0067	±0.0134

The precision of system runout is limited by the degree of polynomial fit. The precision could be improved by increasing (1) the number of data points taken and (2) the degree of polynomial regression analysis available. The system runout precision should approach that of the width precision. However, because of the way the system runout is calculated, the magnitude of system runout precision will be greater than the width precision.

The fuel inspection stand was set up in a vertical position and legs leveled by adjusting the (stand) feet. Using a bubble

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level, the television carriage (vertical) tracks were made vertical by adjusting the stand's feet. After the stand was properly aligned, the fuel assembly support basket was then leveled. At this time, the calibration standard was installed into the basket and also made vertical by adjusting its feet.

The first step to qualify the system was to determine the relationship of the vertical encoder to the standard's vertical scale. Encoder readings were taken at various positions over the entire length of the scale and then reduced using a calculation program to determine the bias and precision of the system. A linear least squares fit of the data was first performed to determine the relationship between the scale and encoder readings. This fit (Figure 2) indicated the vertical encoder readings had to be multiplied by 1.0009 to correct the reading of the vertical position in inches. The data in Table 2 were reduced to determine the reading bias, if any, and precision. The difference between the predicted value and the corrected encoder reading was used to determine the measurement error of the system. Figure 3 is a frequency histogram of the measurement errors incurred during the length qualification. The data reduction showed $<\pm 0.0001$ inches system bias and a precision of ± 0.0067 inches at the one sigma level.

Using the same calculator program as for length qualification, encoder width measurements were qualified. Multiple measurements shown in Table 3 were made to determine to the encoder correction factor, bias, and precision of the system.

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The first stage of the data reduction, Figure 4, showed a correlation between the encoder reading and scale position. This indicates that a 0.9985 correction factor was required for the width encoder readings to convert the width reading to inches. Further data reduction, Figure 5, showed $<\pm 0.0001$ inches bias and a precision factor of ± 0.0027 inches at the one sigma level.

After both encoders were calibrated for length and width measurements, the system for bow measurement was qualified. Qualification of the system for bow measurement was done in two steps; one to determine the runout of the mechanical system, and the other to determine the reading bias and precision. Incorporated within the standard is a 0.012 inch thick multiple strand wire stretched over the length to be measured for bow. Axial and vertical positions were taken at various points along this stretched wire to determine the system runout. These measurements (shown in Table 4) were taken by aligning the right side of the vertical crosshair imposed on the vertical television screen with the left side of the stretched wire and then recording the x and y positions. A polynomial regression analysis was used to best fit the data points. A 5th degree polynomial equation (shown in Figure 6) best represented the data points for system runout. Since it was highly improbable that the wire was vertical, a linear least squares fit was performed on the data to determine the vertical tilt of the wire. For a given vertical position, the difference between the 5th degree polynomial and lineal equations was determined to be

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the system runout as shown in Figure 7. The equation for the system runout x_s is shown below:

$$x_s = a_o + a_1 y + a_2 y^2 + a_3 y^3 + a_4 y^4 + a_5 y^5$$

where $a_o = -7.39612E^{-2}$

$a_1 = 2.27507E^{-3}$

$a_2 = -1.35111E^{-4}$

$a_3 = 4.19978E^{-6}$

$a_4 = -4.15464E^{-8}$

$a_5 = 1.25163E^{-10}$

To determine the bias and the precision of the system runout, the X values tabulated in Table 4 were compared with the X values calculated from the 5th degree polynomial equation. Figure 8 is a frequency histogram of the difference between the actual data points and calculated data points. The data reduction of error readings for bow runout correction showed $<\pm.0001$ inch bias and a precision of ± 0.0067 inches at the one sigma level. This bias and precision included the width and system runout error.

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TABLE 2

QUALIFICATION DATA - LENGTH MEASUREMENTS

Scale Reading (Inches)	Encoder Reading (Inches)
6.0000	5.9920
8.0000	7.9935
14.0000	13.9880
22.0000	21.9810
30.0000	29.9625
37.0000	36.9580
49.0000	48.9465
59.0000	58.9470
68.0000	67.9420
73.0000	72.9360
80.0000	79.9270
94.0000	93.9180
101.0000	100.9065
107.0000	106.8945
111.0000	110.8888
115.0000	114.8930
119.0000	118.8825
125.0000	124.8925
130.0000	129.8890
136.0000	135.8840
140.0000	139.8670
143.0000	142.8740
95.0000	94.9060
82.0000	81.9190
72.0000	71.9450
59.0000	58.9425
48.0000	47.9520
36.0000	35.9465
26.0000	25.9795
22.0000	21.9860
17.0000	16.9915
10.0000	9.9985
6.0000	5.9980
1.0000	1.0035
7.0000	7.0000
12.0000	12.0065
17.0000	16.9945
22.0000	21.9825
31.0000	30.9700
39.0000	38.9645
50.0000	49.9475
59.0000	58.9460
68.0000	67.9440
79.0000	78.9325
84.0000	83.9190

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Table 2 (continued)

Qualification Data - Length Measurements

92.0000	91.9125
107.0000	106.9100
118.0000	117.8940
125.0000	124.8930
139.0000	138.8860
123.0000	122.8865
103.0000	102.9080
82.0000	81.9220
61.0000	60.9455
34.0000	33.9650
8.0000	7.9950
1.0000	1.0140

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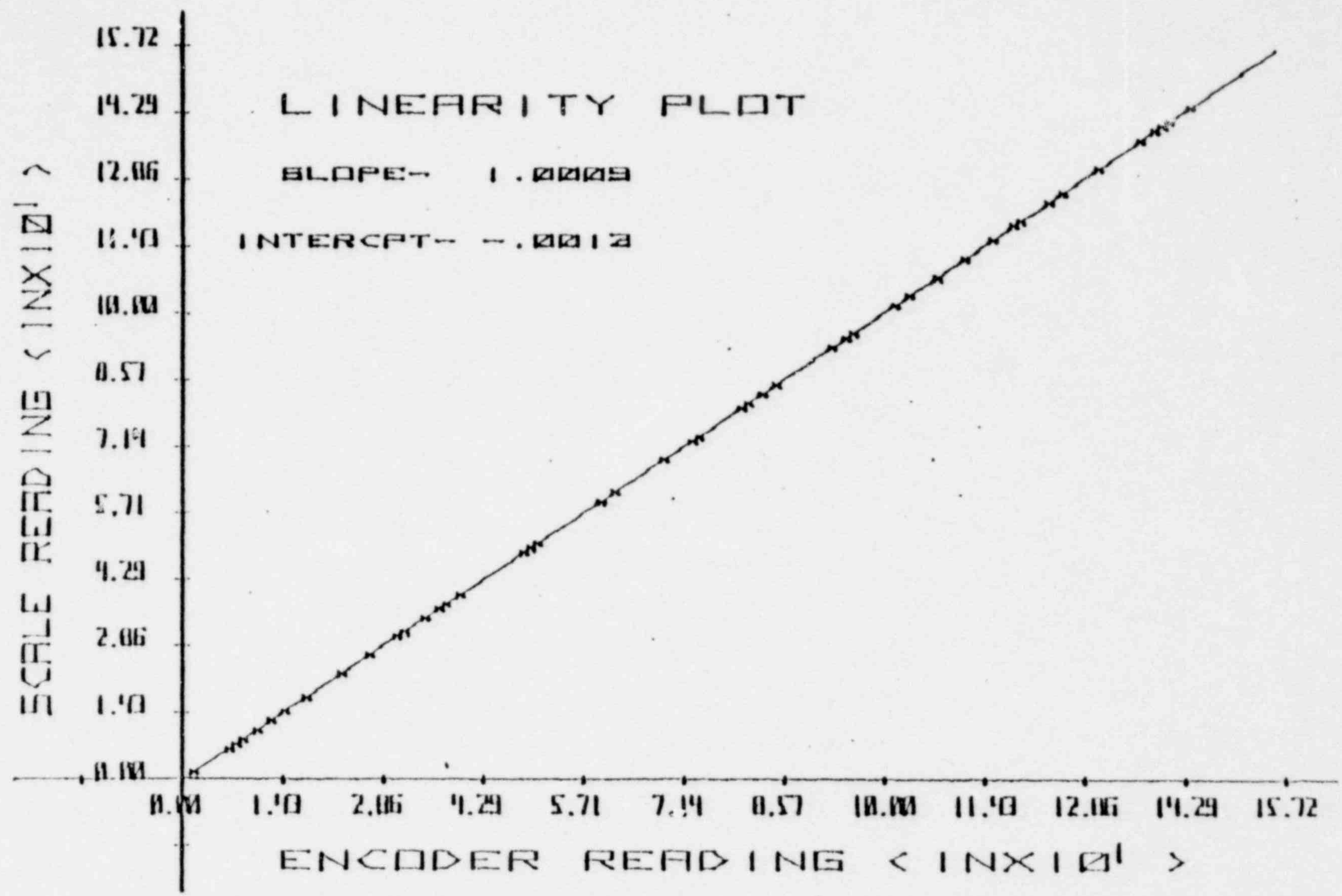

Figure 2 - Length Measurement Linearity

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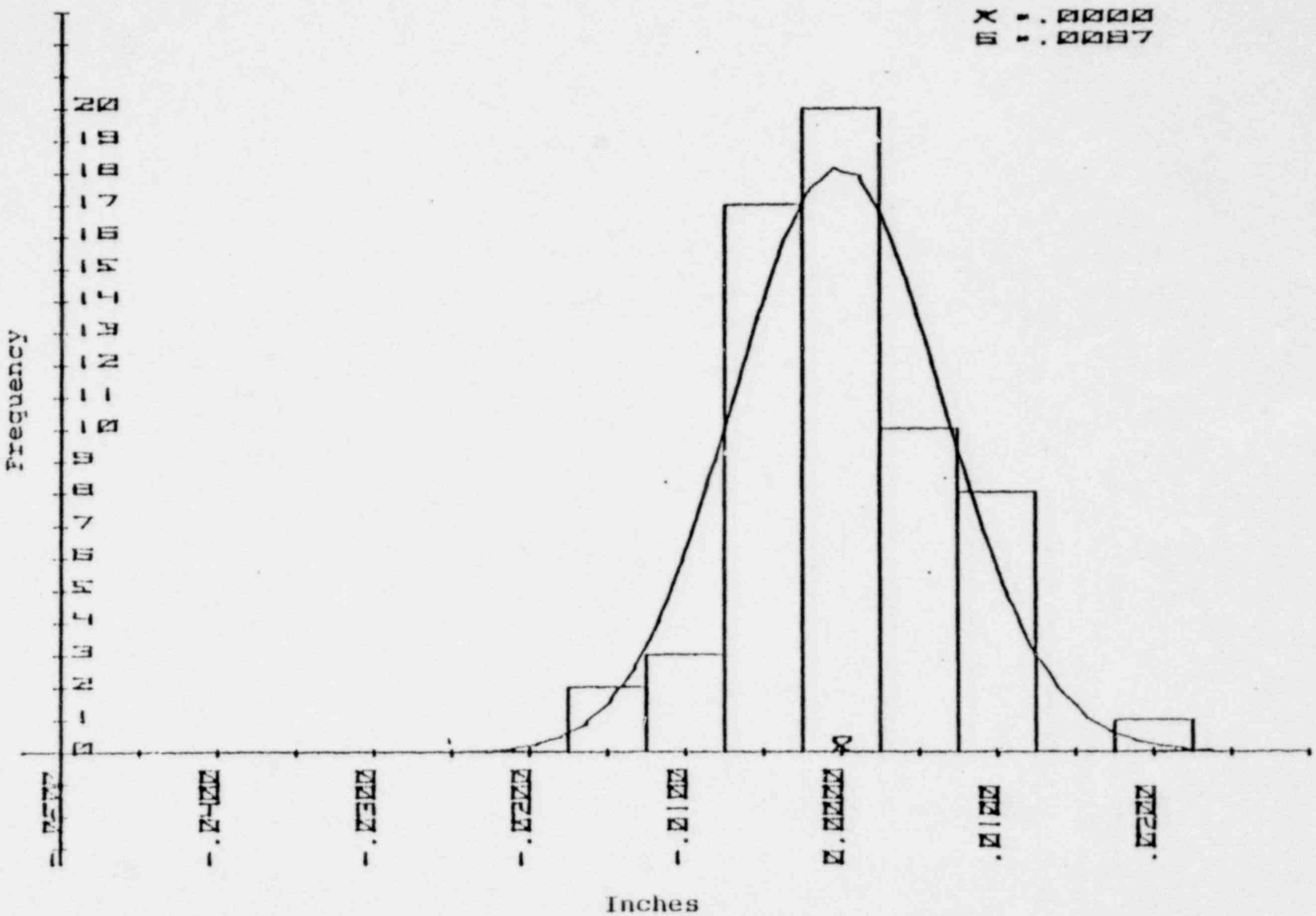

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Figure 3 - Length Qualification Bias and Standard Deviation

TABLE 3

QUALIFICATION DATA - WIDTH MEASUREMENT

Scale Reading (Inches)	Encoder (Inches)
2.0000	2.0082
3.0000	2.9997
4.0000	4.0084
5.0000	5.0051
6.0000	6.0071
7.0000	7.0089
8.0000	8.0041
9.0000	9.0123
10.0000	10.0158
9.0000	9.0130
8.0000	8.0113
7.0000	7.0105
6.0000	6.0095
5.0000	5.0085
4.0000	4.0079
3.0000	3.0009
2.0000	1.9994
1.0000	1.0023
2.0000	1.9982
3.0000	3.0013
4.0000	4.0019
5.0000	5.0087
6.0000	6.0098
7.0000	7.0088
8.0000	8.0103
9.0000	9.0141
10.0000	10.0136

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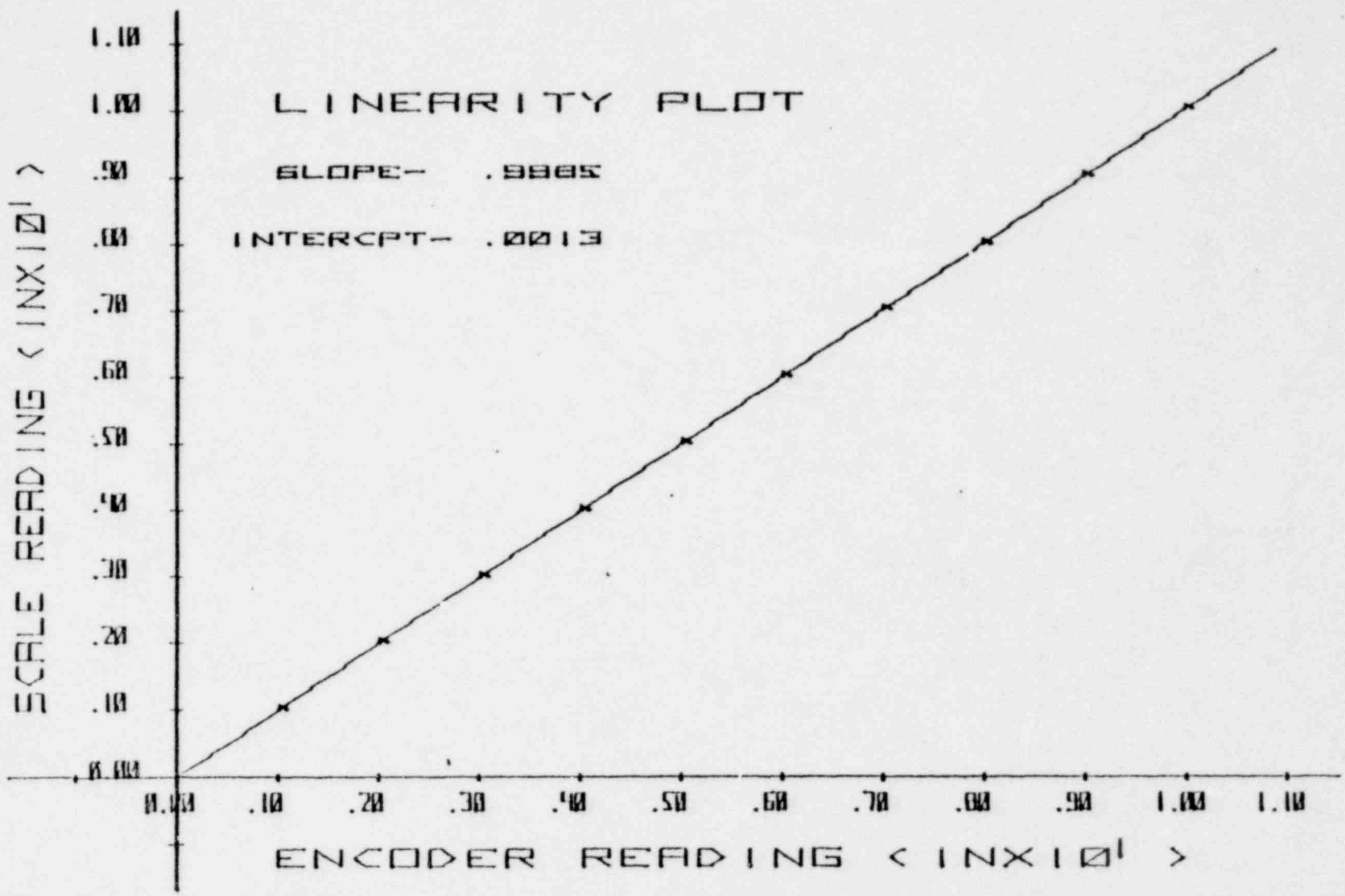

Figure 4 - Width Measurement Linearity

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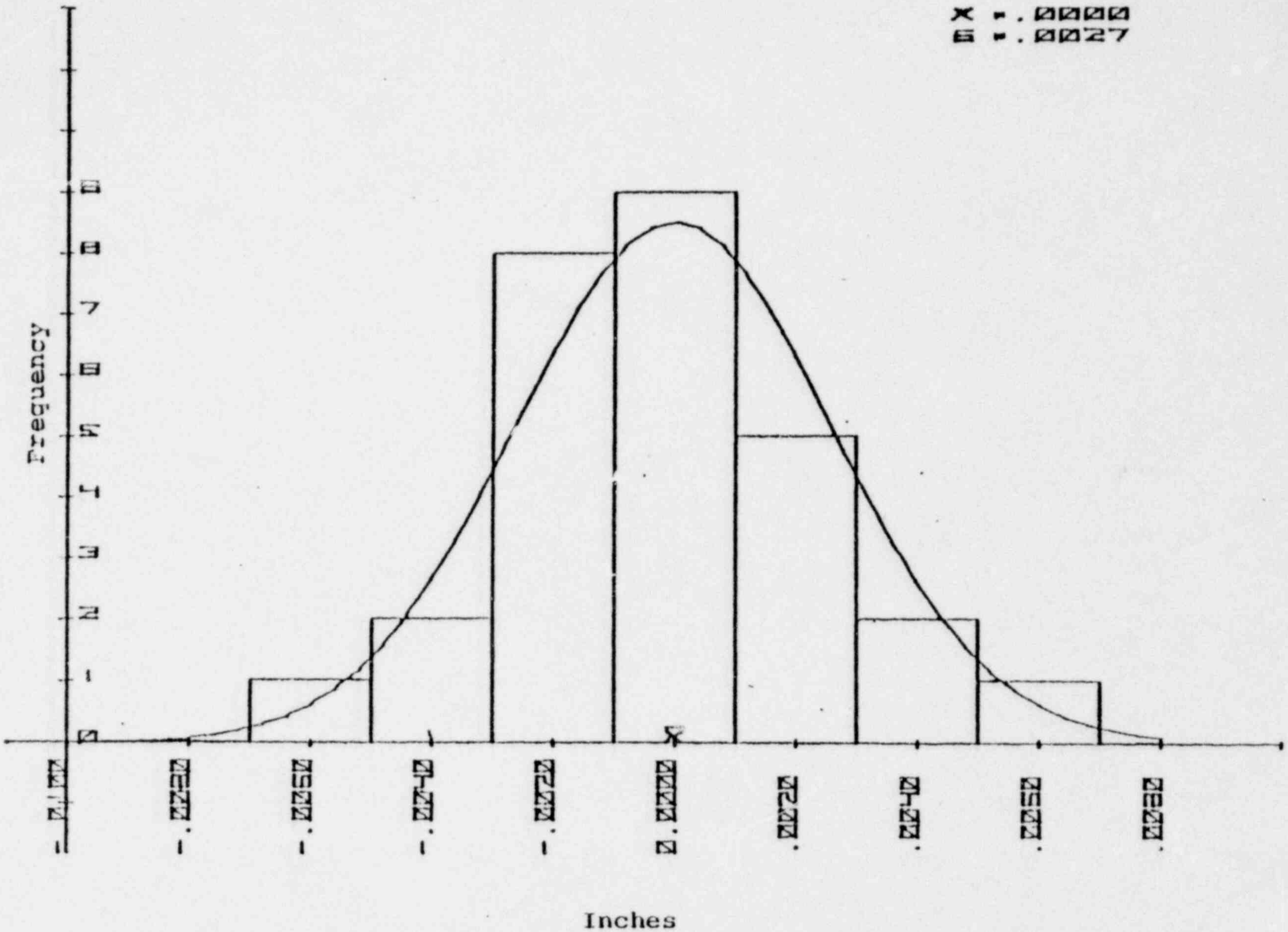

Figure 5 - Width Qualification Bias and Standard Deviation

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TABLE 4

BOW QUALIFICATION

X (Inches)	Y (Inches)	X (Inches)	Y (Inches)
-.0630	5.9610	-.1220	149.5350
-.0590	10.1440	-.1020	140.2150
-.0580	15.4210	-.0510	130.2290
-.0570	20.1700	-.0010	120.8560
-.0510	25.2480	.0440	110.8330
-.0340	31.3260	.0990	100.2540
-.0230	38.2940	.1230	91.0190
.0020	45.2270	.1070	80.7130
.0170	52.2840	.0720	70.6200
.0260	59.3220	.0260	60.6140
.0570	65.8570	.0220	56.8160
.0770	71.6280	.0180	50.5550
.1050	77.4090	-.0220	39.8550
.1180	84.3560	-.0450	30.4770
.1260	90.4920	-.0640	20.6670
.1180	96.8270	-.0620	10.7020
.0900	101.5510	-.0640	5.8900
.0640	107.8400		
.0340	113.4120		
.0200	118.8390		
-.0120	123.5210		
-.0400	128.5860		
-.0700	133.6460		
-.0960	138.6040		
-.1270	143.5570		
-.1380	148.8140		

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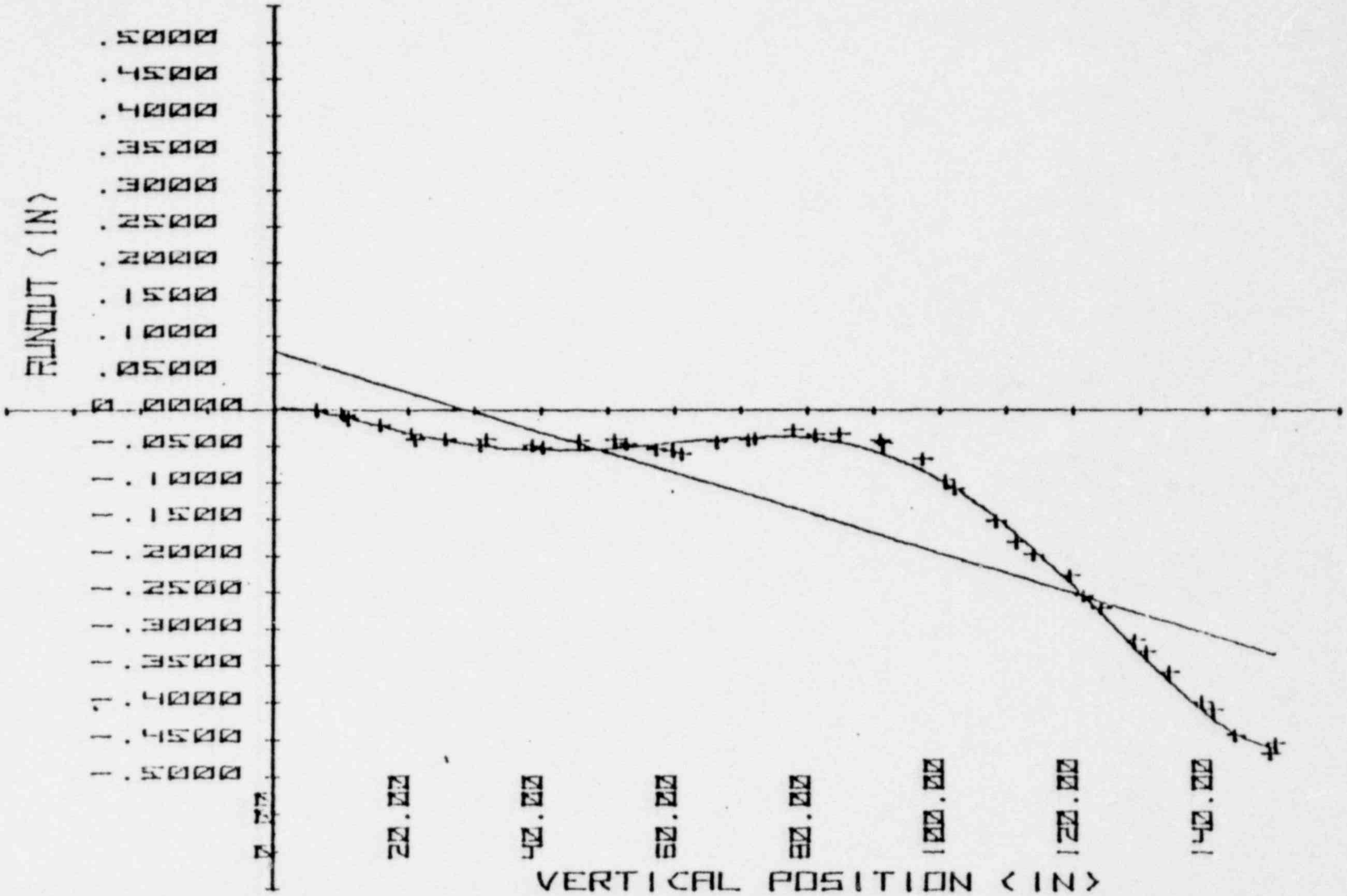

Figure 6 - Bow Qualification for System Runout

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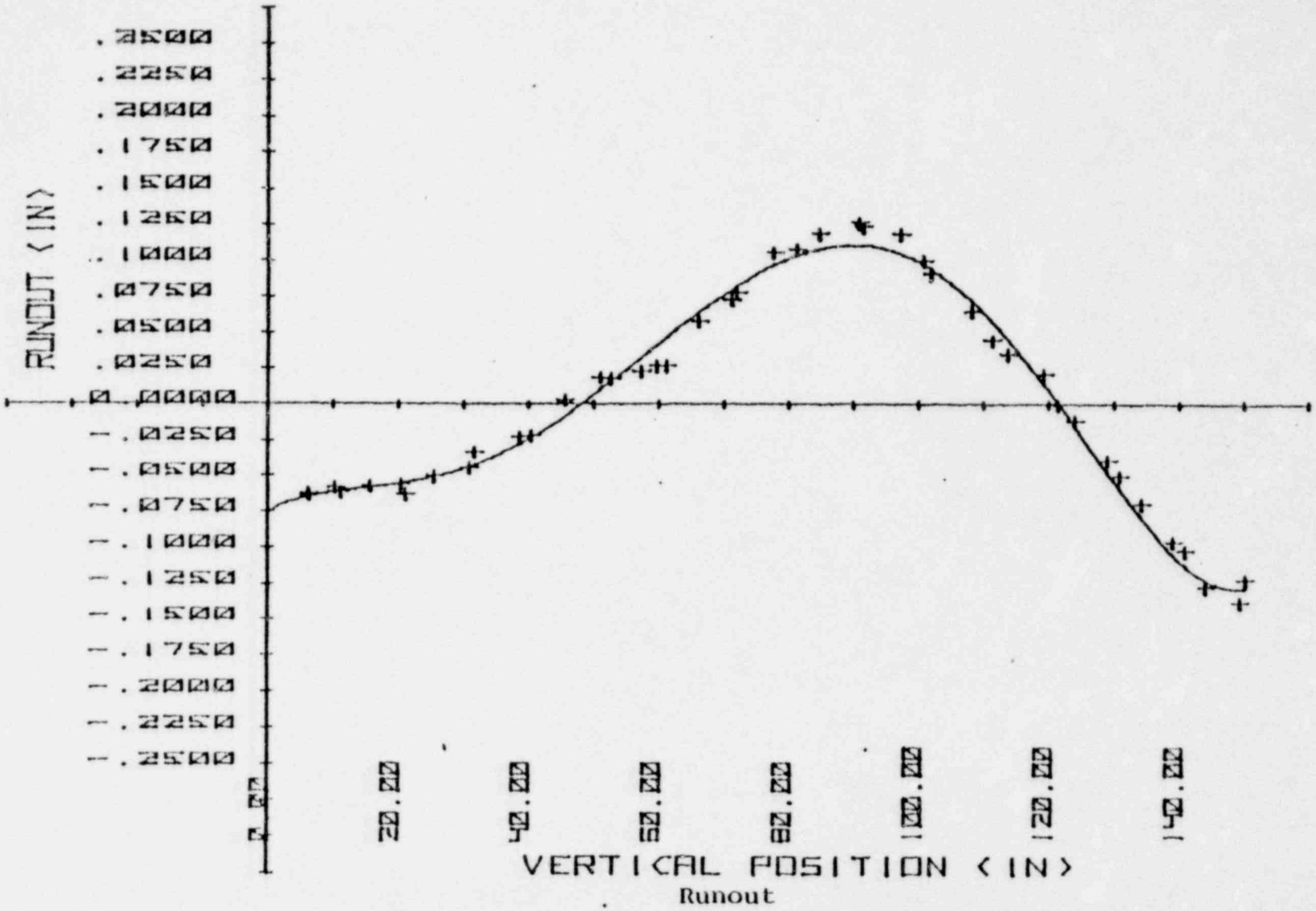

FIGURE 7 BOW QUALIFICATION FOR SYSTEM RUNOUT CORRECTED FOR TILT

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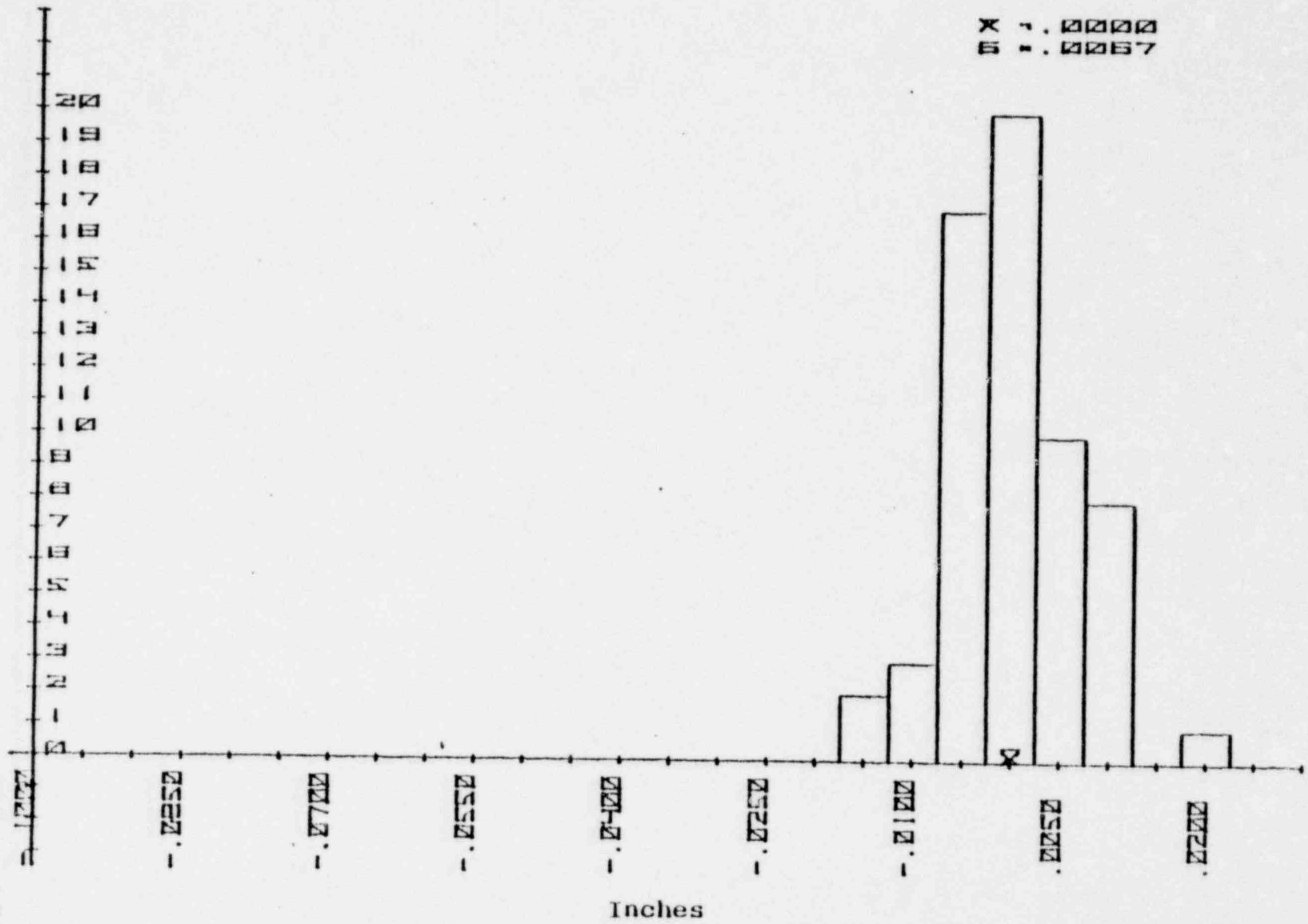

FIGURE 8 RUNOUT QUALIFICATION FOR LENGTH QUALIFICATION

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System Requalification

Periodically, during the fuel inspection operation, the system encoders were checked to see if they were within calibration. If the encoders were out of calibration, the equipment would have to be removed from the spent fuel pool and the encoders changed. Two scribe marks were made on the stainless steel mirror assembly portion of the fuel inspection basket, both in the horizontal and vertical directions. These four scribe marks were measured in air at 75°F after the fuel inspection system was qualified. The readings obtained 6.0115 inches and 12.0020 inches for the vertical direction and 5.9826 inches and 12.0189 inches for the horizontal direction were used as a reference to compare with the readings taken during the fuel inspection operation. The results of the readings taken during the inspection are shown in Table 5. The average difference between the actual reading taken under water and the known distances were -0.005 inches with a one sigma value of 0.0023 for the vertical encoder and +0.0005 inches with a one sigma value of 0.0013 for the horizontal encoder. These measurements were well within the expected error band determined during the initial system qualification.

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TABLE 5

MEASUREMENTS TAKEN OF KNOWN DISTANCES

DURING THE FUEL INSPECTION

Measurement No.	Reading (inches)	Difference (inches)
1	6.0100	-0.0015
	12.0040	+0.0020
	5.9838	+0.0012
	12.0204	+0.0015
2	6.0110	-0.0005
	12.0000	-0.0020
	5.9834	+0.0008
	12.0174	-0.0015
3	6.0100	-0.0015
	12.0050	+0.0030
	5.9814	-0.0012
	12.0168	-0.0021
4	6.0080	-0.0035
	12.0045	+0.0025
	5.9844	+0.0018
	12.0204	+0.0015
5	6.0080	-0.0035
	11.9995	-0.0025
	5.9834	+0.0008
	12.0201	+0.0012
6	6.0130	+0.0015
	12.0015	-0.0005
	5.9838	+0.0012
	12.0195	+0.0006

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Comparison of Rod Closure Measurements

Six of the predetermined rod closure measurements were repeated during the course of the fuel inspection at Indian Point #2 in order to determine the operator precision for these types of measurements underwater. Figure 9 shows the frequency histogram of the variation between these rod closure measurements. Figures 10 through 15 show the actual comparison of the rod closure measurements. The comparison of the data showed a standard deviation at the one sigma level of ± 0.0057 inches, which is within the system runout qualification precision of ± 0.0067 inches at the one sigma level.

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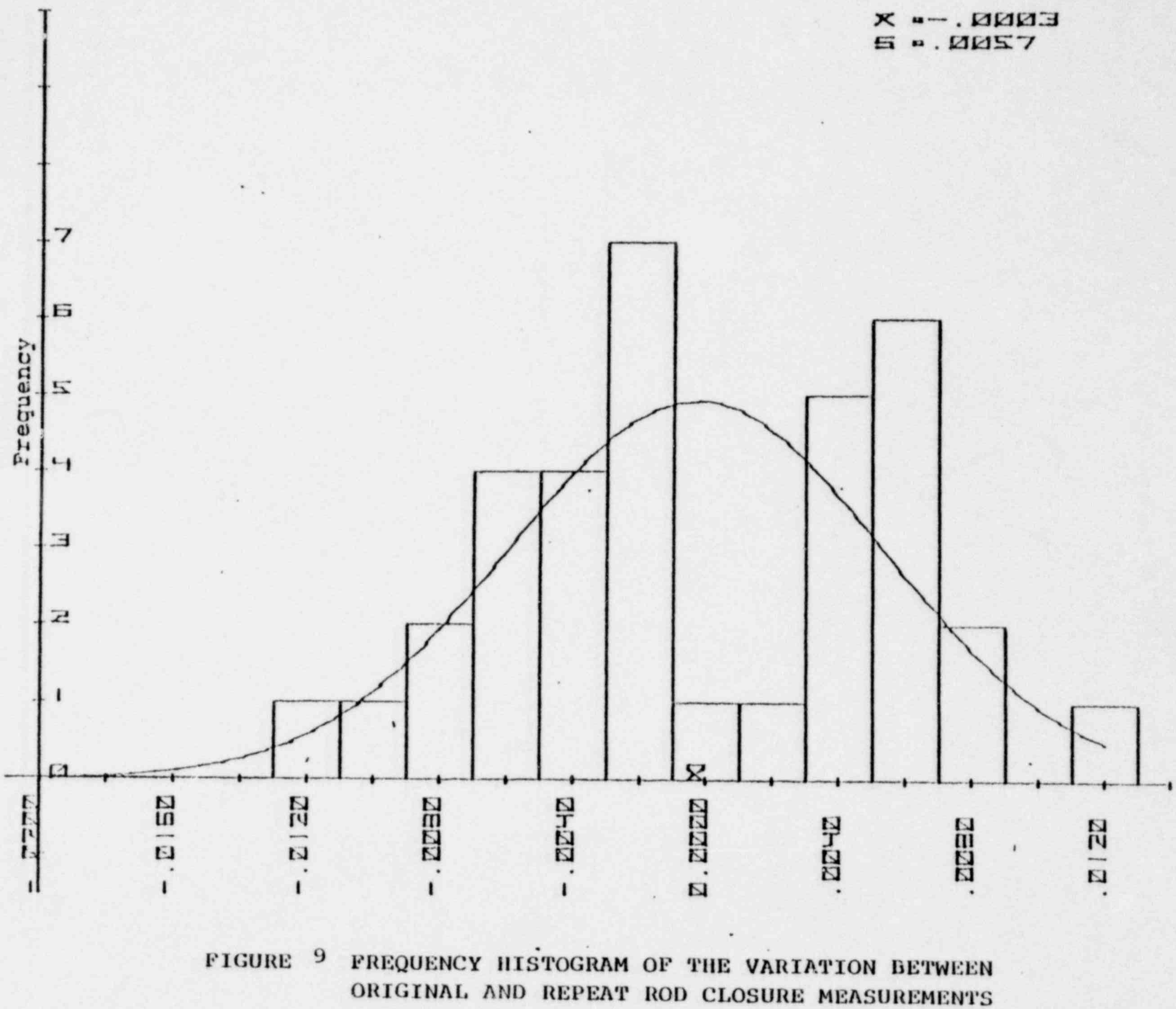

FIGURE 9 FREQUENCY HISTOGRAM OF THE VARIATION BETWEEN ORIGINAL AND REPEAT ROD CLOSURE MEASUREMENTS

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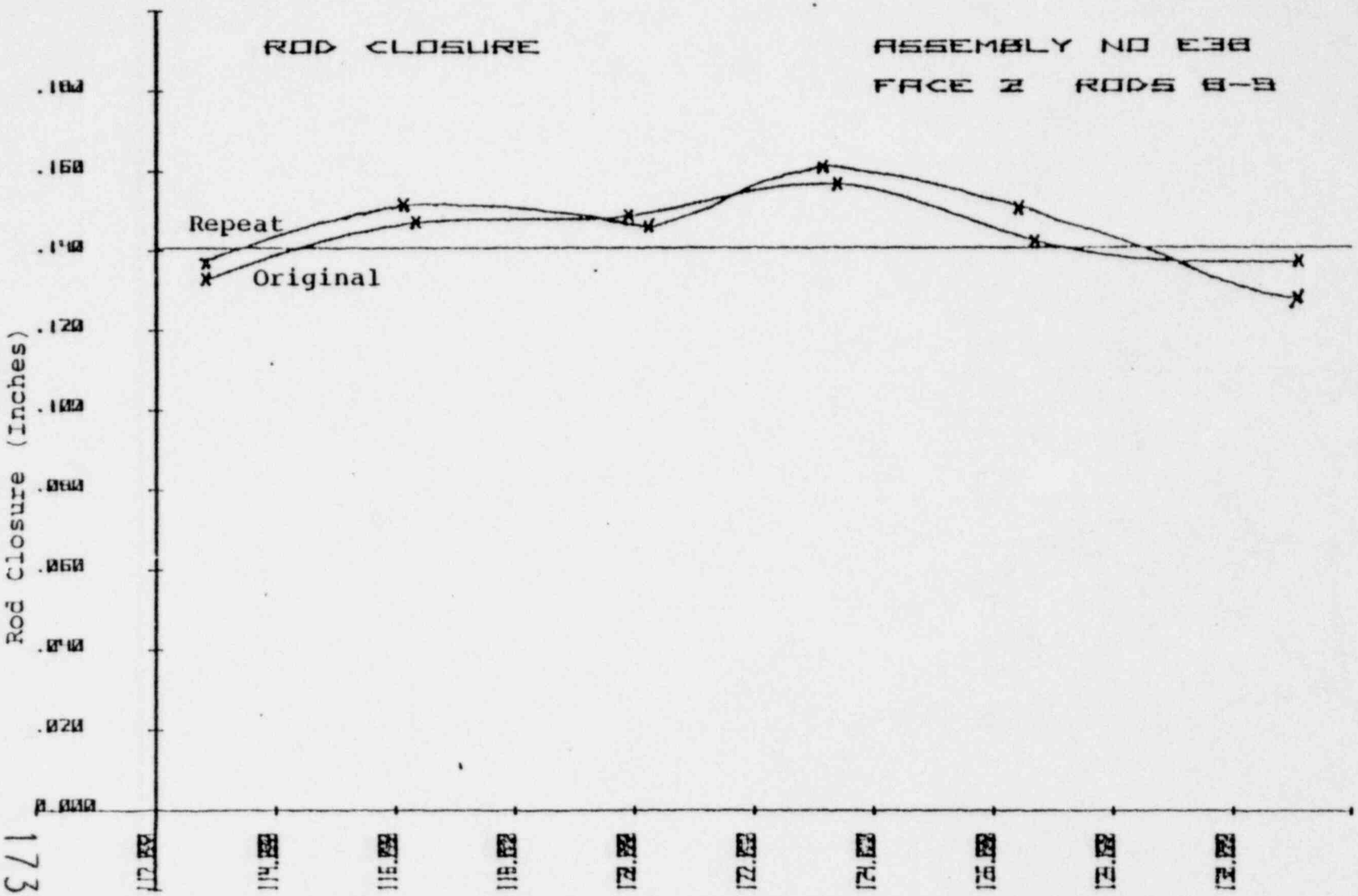

FIGURE 10 Rod Closure of Rods 8 and 9, Between Grids 7 and 8, Face 2, Assembly E-38

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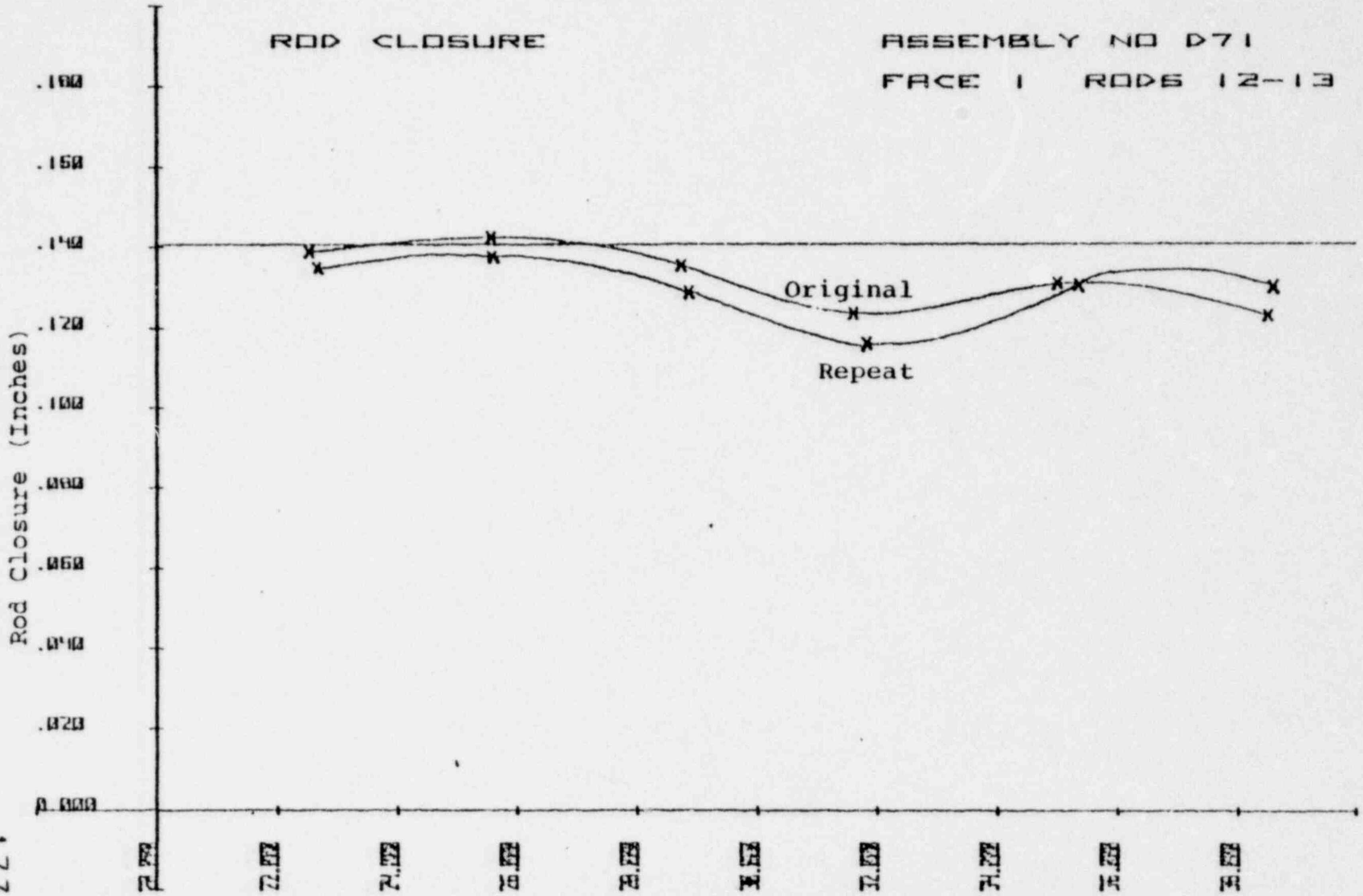

FIGURE 11 Rod Closure of Rods 12 and 13, Between Grids 2 and 3, Face 1, Assembly D-71

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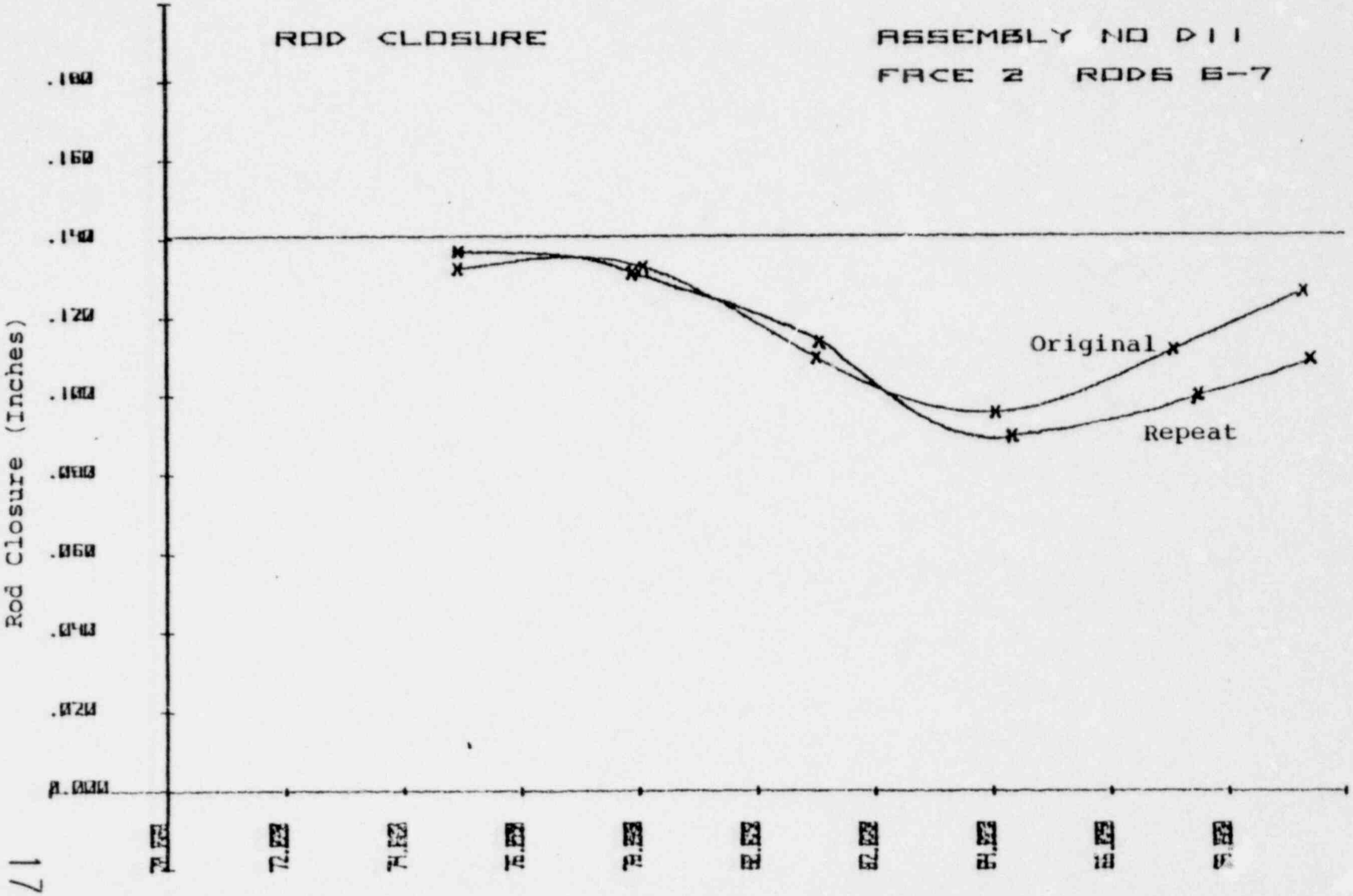

FIGURE 12 Rod Closure of Rods 6 and 7, Between Grids 5 and 6, Face 2, Assembly D-11

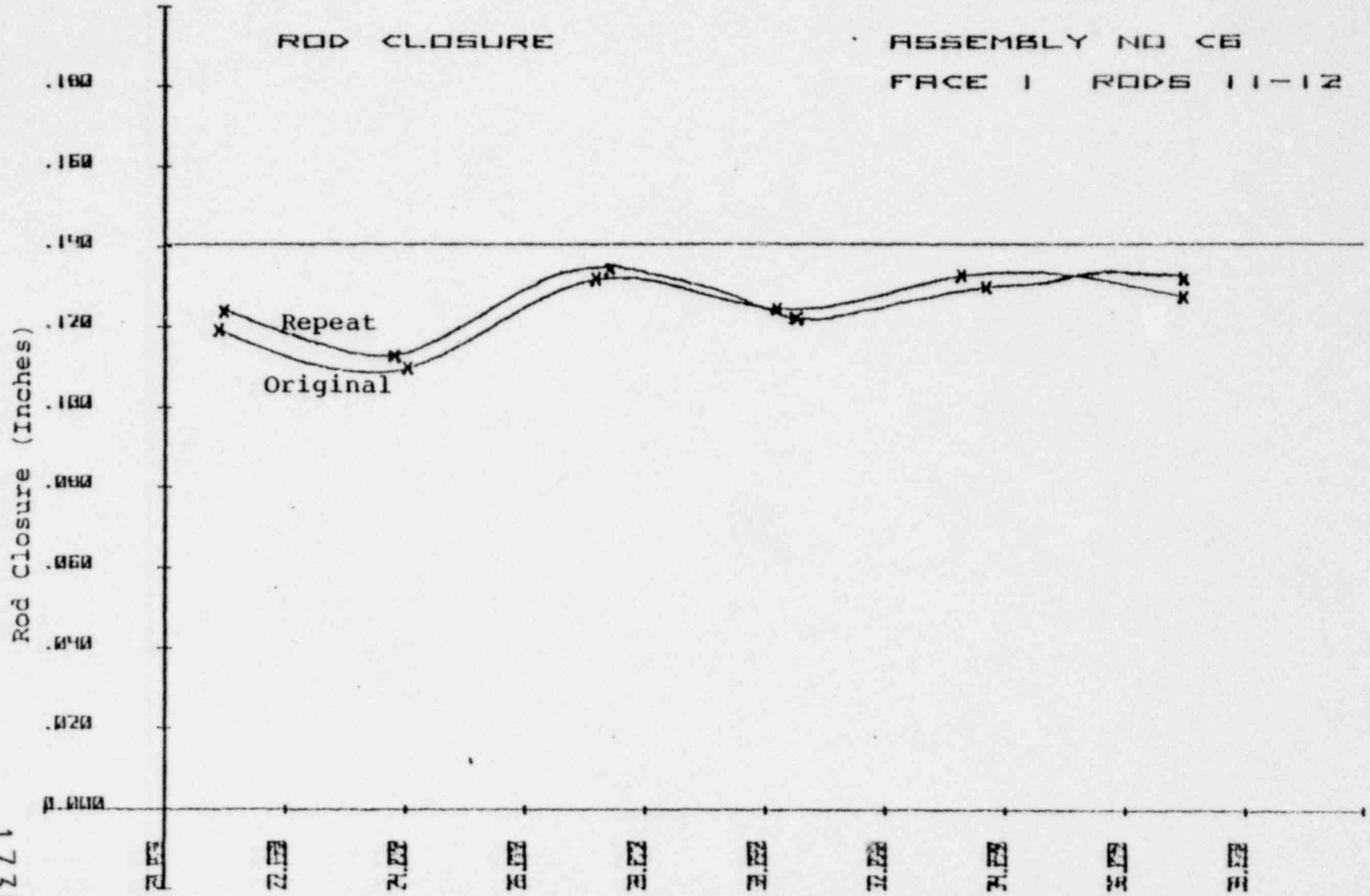

FIGURE 13 Rod Closure of Rods 11 and 12, Between Grids 2 and 3, Face 1, Assembly C-06

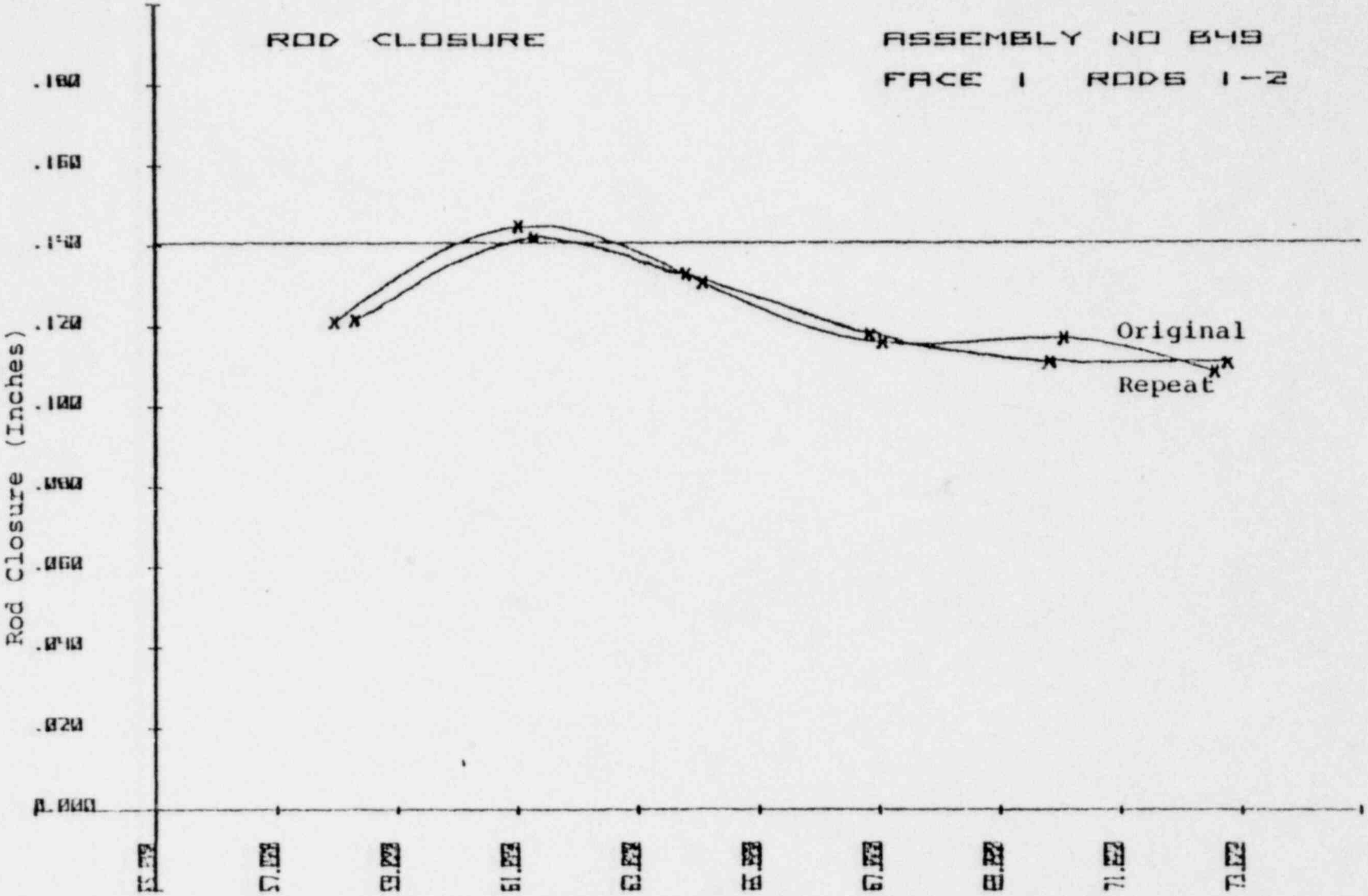

FIGURE 14 Rod Closure of Rods 1 and 2, Between Grids 4 and 5, Face 1, Assembly B-49

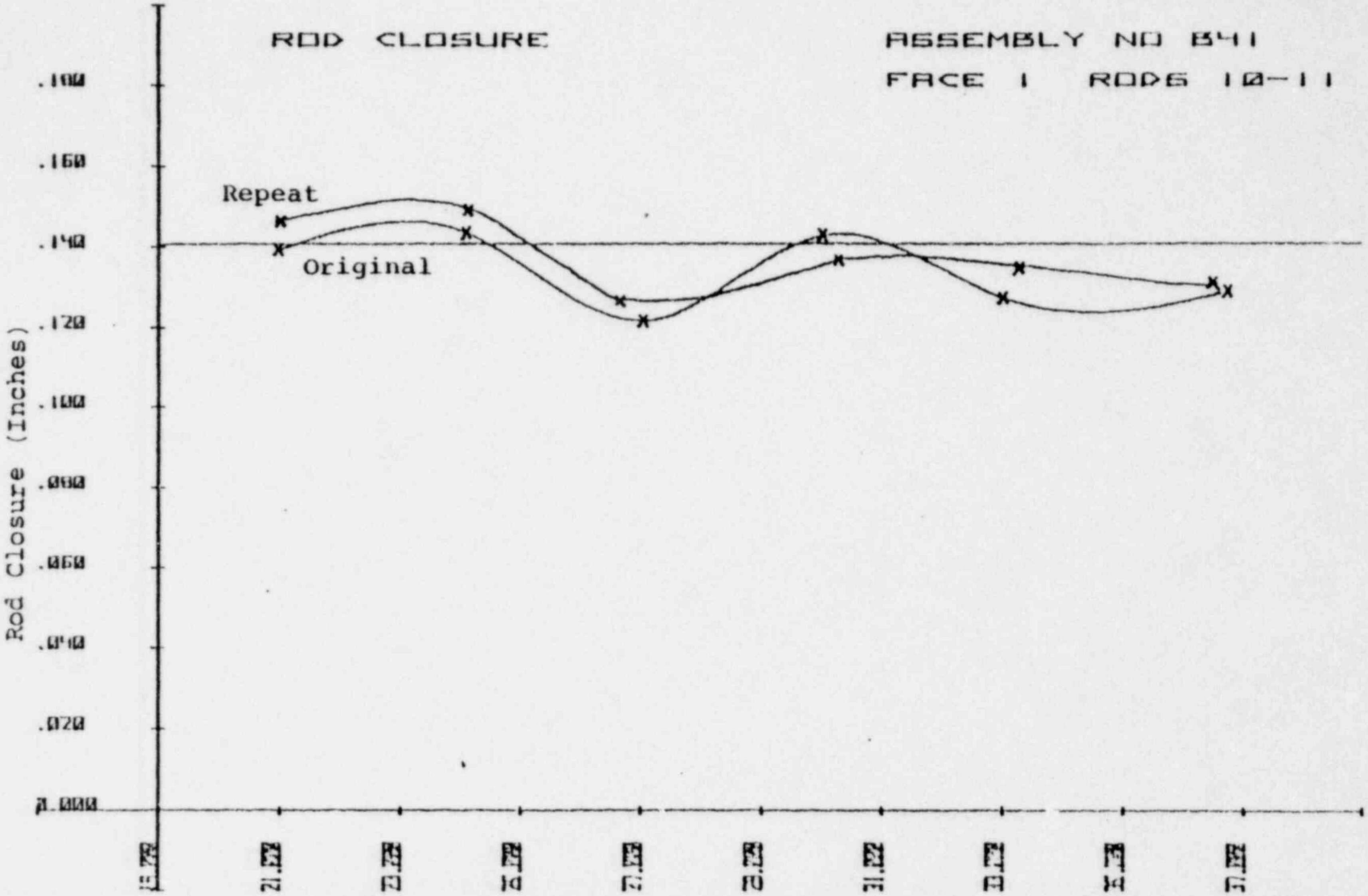

FIGURE 16 Rod Closure of Rods 10 and 11, Between Grids 2 and 3, Face 1, Assembly B-41

FUEL INSPECTION METHODS

Visual Examination

The visual examination of an individual face was carried out in two stages. The first half of the peripheral rods were examined by starting at the lower left side of the assembly and scanning upward at approximately 2-1/2 to 3 feet/min. The second half of the rods were examined by starting from the upper right side of the assembly and scanning downward at the same rate. The elapsed time to scan a complete face for visual examination was approximately 15 to 20 minutes. Complete video tapes were made of the visual examination. Figure 16 shows the face orientation for the Indian Point Unit No. 2 fuel assemblies.

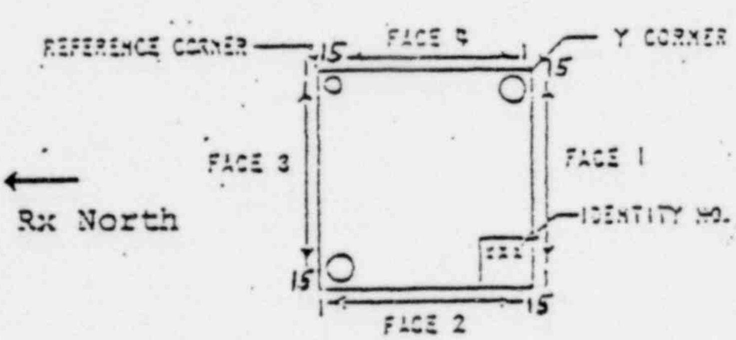

Figure 16

Fuel Assembly Face Orientation

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Dimensional Measurements

Individual rod closure measurements were made by first aligning the right hand edge of the left rod with the left edge of the cross hair on the television monitor and recording the axial and vertical position. After the reading is taken, the camera is then moved until the left hand edge of the right rod is aligned with the left edge of the cross hair on the television monitor. The axial and vertical position of the right rod is then recorded. This procedure at intermediate locations in the grid span was repeated. A minimum of six rod closure measurements were taken per grid slot. These encoder readings, using a calculator program, were then converted to inches and the axial delta between the two readings was determined. These axial delta values were then plotted versus their vertical location and compared to a design value of 0.141 inches.

Rod length measurements were made by aligning the bottom and top of the selected rods with the horizontal cross hair on the monitor and recording the encoder readings. The encoder readings were converted to inches and the difference between the two corrected values was the actual rod length.

In order to look at assembly length, guide thimble length measurements were made by recording the encoder position of the upper edge of the lower nozzle at the mid-point of Rod 8 and then the position of the lower edge of

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the upper nozzle above the mid-point of Rod 8. The corrected difference of the two readings was determined to be the guide thimble length.

Assembly bow measurements were performed on one face of the specified assemblies. Bow measurements were made at the edge of the selected face. These readings actually describe the bow of the face at 90° to the face being observed. The measurements involved first aligning the right hand side of the monitor crosshair with the left hand center edge of the individual grids and then recording the position location. The locations were then converted to inches and the appropriate system runout for the particular vertical position added to the horizontal reading. The displacement of each grid or bow was then determined by correcting for tilt. This was done by assuming grids 1 and 9 were fixed points of the assembly, and determining the slope between them.

Twist measurements were made by rotating the assembly at 45° to orientate the plane of the corner of the upper and lower nozzles to be perpendicular with respect to the camera axis. The location of the nozzle corners was then determined. These encoders readings, using a calculator program, were corrected for runout. By assuming the distance between the corners of the upper and lower nozzles in the axial direction is a chord of a circle with a radius of 5.9581 inches (the radius of the fuel assembly), one can compute the angle of the arc formed by the chord.

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RESULTS

Visual Examination

The peripheral rods examined in the eight 15 X 15 Indian Point No. 2 HIPAR fuel assemblies, appeared to be in excellent condition with light to medium patchy oxide covering the active fuel cladding surfaces. The crud level on the peripheral rods' surfaces appeared to be low; however, slight crud spalling was noticed on some of the rods. As a result of the rubbing action between adjacent assemblies during shuffle, many grid straps were shining, and some had shallow scratches. Also observed were a few slightly dented grid corners with insignificant amount of protrusion.

Two assemblies showed a few rods that were either touching or almost touching both the upper and the lower nozzles. In particular, the rod 9 on face 1 of assembly B-41 was touching both the upper and the lower nozzles, and was bowed in both directions, alternately touching or almost touching rods 8 and 10 between every grid. Also in this assembly, rod 7 on face 3 was interference bowed in the same manner. It should be noted that Regions B and C fuel rods with relatively longer as built rod length had lesser free room to grow than Regions D and E fuel rods (see Rod Length section for dimensions).

In another observation, a partial fret was seen at the lower end plug region of rod 1 on face 3 in assembly D-11. This anamoly not considered significant. Complete video tapes were made of the visual examination of these 8 fuel assemblies. Table 6 is an index of the video tapes used at Indian Point No. 2 during the examination of the irradiated fuel assemblies.

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TABLE 6

TAPE CATALOG OF THE EIGHT FUEL ASSEMBLIES VISUALLY INSPECTED

AT INDIAN POINT NO. 2 AT THE END OF CYCLE 3

Tape Catalog of B-41

Description	Start	Finish
Scan Face 1L	000	141
Scan Face 1R	141	242
Scan Face 2L	242	348
Scan Face 2R	348	411
Scan Face 3L	411	502
Scan Face 3R	502	557
Lower Nozzle	557	560
Scan Face 4L	560	635
Scan Face 4R	635	683

Tape Catalog of B-49

Description	Start	Finish
Scan Face 1L	000	148
Scan Face 1R	148	230
Scan Face 2L	230	341
Scan Face 2R	341	414
Scan Face 3L	414	507
Scan Face 3R	507	564
Lower Nozzle	564	568
Scan Face 4L	568	643
Scan Face 4R	643	704

Tape Catalog of C-06

Description	Start	Finish
Scan Face 1L	000	100
Scan Face 1R	100	231
Scan Face 2L	231	341
Scan Face 2R	341	406
Scan Face 3L	406	480
Scan Face 3R	480	565
Bottom Grid - Rods 3-4	565	576
Scan Face 4L	576	656
Scan Face 4R	656	704
Rod 1, Top of 1st grid	704	708
Lower Nozzle	708	715

TABLE 6 (Continued)

Tape of Catalog of D-11

Description	Start	Finish
Scan Face 1L	000	157
Scan Face 1R	157	234
Scan Face 2R	234	342
Scan Face 2L	342	405
Scan Face 3R	405	497
Scan Face 3L	497	551
Scan Face 3, Rod 1	551	555
Scan Face 4L	555	634
Scan Face 4R	634	682

Tape Catalog of D-71

Description	Start	Finish
Scan For Face 1L Missing	000	158
Scan Face 1R	158	243
Scan Face 2L	243	352
Scan Face 2R	352	419
Scan Face 3L	419	510
Scan Face 3R	510	565
Lower Nozzle	565	570
Scan Face 4L	570	649
Scan Face 4R	649	695

Tape of Catalog of E-38

Description	Start	Finish
Scan of Face 1L	000	196
Scan of Face 1R	196	298
Scan of Face 2L	298	430
Scan of Face 2R	430	508
Lower Nozzle	509	516
Scan of Face 3L	516	603
Scan of Face 3R	603	681
Scan of Face 4L	681	763
Scan of Face 4R	763	809

1735 077

TABLE 6 (Continued)

Tape Catalog of E-49

Description	Start	Finish
Scan of Face 1L (incomplete)	000	018
Scan of Face 2L	018	160
Scan of Face 2R	160	236
Scan of Face 1L	236	340
Scan of Face 1R	340	406
Scan of Face 4L	406	500
Scan of Face 4 - Upper Nozzle	500	506
Scan of Face 4R	506	561
Scan of Face 3L	561	644
Scan of Face 3R	644	694

Tape Catalog of C-23

Description	Start	Finish
Scan Face 1L	000	159
Scan Face 1R	159	237
Scan Face 2L	237	347
Scan Face 2R	347	416
Scan Face 3L	416	506
Scan Face 3R	506	571
Lower Nozzle	571	581
Scan Face 4L	581	659
Scan Face 4R	659	708

1735 078

[redacted]

Rod Closure

Fuel rod closure measurements were performed on the seven fuel assemblies at 172 randomly chosen locations. The location of individual rod closure measurements was predetermined using a random number generator program.

Rod closure data are contained in Table 10. Based on burnup, the measurements can be grouped into three populations (burn-up of approximately 13,000, 25,000, and 36,500 MWD/MTU)* and the average rod closures are 0.1211, 0.1208, and 0.1160 inches, respectively, with standard deviations at the one sigma level of 0.0077, 0.0128, and 0.0143 inches. As previously noted, rod closure is defined as the minimum projected spacing or gap between two adjacent fuel rods and two successive grids (corresponding in the unbowed case to 0.141 inches).

TABLE 7a

ROD CLOSURE MEASUREMENT OCCURRENCE

(Burnup ≃ 36,500 MWD/MTU)

Rod Closure	No. of Occurrences	% of Total
> One Sigma	12	12.4
> Two Sigma	4	4.1
> Three Sigma	3	3.1

* 36,500 for "B" and "C", 25,000 for "D" and 13,000 for "E" assemblies.

1735 079

TABLE 7b

ROD CLOSURE MEASUREMENT OCCURRENCE

(Burnup ≃ 25,000 MWD/MTU)

Rod Closure	No. of Occurrences	% of Total
> One Sigma	7	14.6
> Two Sigma	1	2.1
> Three Sigma	0	0

TABLE 7c

ROD CLOSURE MEASUREMENT OCCURRENCE

(Burnup ≃ 13,000 MWD/MTU)

Rod Closure	No. of Occurrences	% of Total
> One Sigma	3	11.1
> Two Sigma	1	3.7
> Three Sigma	1	3.7

The maximum rod closure measured (Assembly B-41 between grids 2 and 3) was 0.0668 inches (versus nominal of 0.141), which corresponds to a 52% rod to rod closure.

The individual rod closure data was compared to axial location. The histograms for the individual grid locations (spans) are shown in Figure 17 through 25c and summarized in Tables 8 and 9. Figures 26 through 29 show rod closure vs. burnup comparison in histogram form.

1735 080

TABLE 8

ROD CLOSURE VERSUS GRID LOCATION (ALL)

Grid Location	Average Rod Closure	No. of Measurements
1-2	0.1201	21
2-3	0.1212	21
3-4	0.1187	16
4-5	0.1181	24
5-6	0.1146	16
6-7	0.1206	29
7-8	0.1180	21
8-9	0.1152	24

TABLE 9a

ROD CLOSURE VERSUS GRID LOCATION

(Burnup ≥ 36,500 MWD/MTU)

Grid Location	No.	Span Length (in)	Rod Closure (in.) Average	Maximum	1 Sigma	Sample Size
1-2	1	15.54	0.1189	0.0935	0.0134	11
2-3	2	18.50	0.1215	0.0668	0.0184	15
3-4	3	18.50	0.1150	0.0829	0.0135	9
4-5	4	16.88	0.1163	0.0993	0.0110	13
5-6	5	16.87	0.1103	0.1004	0.0107	8
6-7	6	19.50	0.1141	0.0958	0.0127	14
7-8	7	20.75	0.1141	0.0693	0.0161	14
8-9	8	16.82	0.1149	0.0699	0.0158	13
All			0.1160	0.0668	0.0143	97

1735 081

TABLE 9b

ROD CLOSURE VERSUS GRID LOCATION

(Burnup ≃ 25,000 MWD/MTU)

Grid Location	No.	Span Length (in.)	Rod Closure (in.) Average	Maximum	1 Sigma	Sample Size
1-2	1	15.54	0.1269	0.1171	0.0083	6
2-3	2	18.50	0.1235	0.1232	0.0004	2
2-3	3	18.50	0.1233	0.1075	0.0091	6
3-4	4	16.88	0.1151	0.0978	0.0099	8
4-5	5	16.87	0.1174	0.0959	0.0169	9
5-6	6	19.50	0.1288	0.1100	0.0104	7
6-7	7	20.75	0.1245	0.1117	0.0145	4
7-8	8	16.82	0.1120	0.0932	0.0142	6
All			0.1208	0.0932	0.0128	48

TABLE 9c

ROD CLOSURE VERSUS GRID LOCATION

(Burnup ≃ 13,000 MWD/MTU)

Grid Location	No.	Span Length (in.)	Rod Closure (in.) Average	Maximum	1 Sigma	Sample Size
1-2	1	15.54	0.1133	0.0976	0.0111	4
2-3	2	18.50	0.1192	0.1109	0.0081	4
3-4	3	18.50	0.1247	--	--	1
4-5	4	16.88	0.1221	0.1177	0.0066	3
5-6	5	16.87	--	--	--	0
6-7	6	19.50	0.1230	0.1184	0.0040	8
7-8	7	20.75	0.1276	0.1203	0.0066	3
8-9	8	16.82	0.1206	0.1081	0.0094	4
All			0.1211	0.0976	0.0077	27

TABLE 10

INDIAN POINT #2 FUEL INSPECTION
ROD CLOSURE SUMMARY

ASSEMBLY	FACE	RODS	GRIDS	MAX. CLOSURE
B-41	1	10-11	2-3	.1218
B-41	1	3-4	3-4	.1192
B-41	1	14-15	3-4	.0829
B-41	1	9-10	6-7	.0958
B-41	1	4-5	8-9	.1089
B-41	2	2-3	1-2	.1217
B-41	2	4-5	1-2	.1189
B-41	2	11-12	1-2	.1203
B-41	2	10-11	4-5	.1129
B-41	2	10-11	6-7	.1058
B-41	3	6-7	6-7	.1223
B-41	3	7-8	6-7	.1238
B-41	3	13-14	6-7	.1178
B-41	3	3-4	7-8	.1276
B-41	3	9-10	7-8	.0693
B-41	3	2-3	8-9	.1245
B-41	3	9-10	2-3	.0668
B-41	3	8-9	4-5	.1019
B-41	3	9-10	5-6	.1273
B-41	3	11-12	8-9	.1231
B-41	3	14-15	8-9	.0699
B-41	4	5-6	1-2	.1213
B-41	4	9-10	1-2	.1023
B-41	4	7-8	2-3	.1373
B-41	4	6-7	3-4	.1262
B-41	4	4-5	4-5	.0993
B-41	4	7-8	4-5	.1308
B-41	4	13-14	6-7	.0979
B-41	4	11-12	7-8	.1118
B-49	1	7-8	2-3	.1440
B-49	1	6-7	3-4	.1157
B-49	1	9-10	3-4	.1079
B-49	1	1-2	4-5	.1087
B-49	1	2-3	4-5	.1229
B-49	1	4-5	4-5	.1229
B-49	1	14-15	6-7	.0974
B-49	1	10-11	7-8	.1111
B-49	2	6-7	4-5	.1024
B-49	2	7-8	7-8	.1204
B-49	2	13-14	7-8	.1162
B-49	3	3-4	2-3	.1249
B-49	3	11-12	2-3	.1195
B-49	3	3-4	6-7	.1025
B-49	3	7-8	7-8	.1378
B-49	4	5-6	4-5	.1272
B-49	4	6-7	5-6	.1004
B-49	4	5-6	6-7	.1245
B-49	4	3-4	8-9	.1284
B-49	4	9-10	7-8	.1195

1735 083

TABLE 10 (Continued)

INDIAN POINT #2 FUEL INSPECTION
ROD CLOSURE SUMMARY

ASSEMBLY	FACE	RODS	GRIDS	MAX. CLOSURE
C-06	1	11-12	1-2	.1245
C-06	1	11-12	2-3	.1099
C-06	1	9-10	4-5	.1150
C-06	1	14-15	5-6	.1010
C-06	1	12-13	6-7	.1142
C-06	1	3-4	7-8	.1029
C-06	1	13-14	8-9	.1061
C-06	2	3-4	1-2	.1355
C-06	2	8-9	1-2	.1070
C-06	2	9-10	2-3	.1315
C-06	2	8-9	3-4	.1222
C-06	2	9-10	6-7	.1226
C-06	2	1-2	8-9	.1099
C-06	2	4-5	8-9	.1202
C-06	2	5-6	8-9	.1172
C-06	3	13-14	5-6	.1221
C-06	3	14-15	7-8	.1124
C-06	3	3-4	8-9	.1245
C-06	4	5-6	2-3	.1045
C-06	4	11-12	2-3	.1271
C-06	4	5-6	3-4	.1208
C-06	4	8-9	3-4	.1127
C-06	4	10-11	5-6	.1051
C-06	4	11-12	5-6	.1005
C-06	4	9-10	8-9	.1069
C-23	1	9-10	2-3	.1282
C-23	1	14-15	4-5	.1276
C-23	1	11-12	6-7	.1304
C-23	1	10-11	7-8	.1165
C-23	2	12-13	1-2	.1242
C-23	2	9-10	2-3	.1294
C-23	2	11-12	2-3	.1120
C-23	2	6-7	6-7	.1090
C-23	2	4-5	7-8	.1313
C-23	2	3-4	8-9	.1284
C-23	2	9-10	8-9	.1262
C-23	3	2-3	1-2	.0935
C-23	3	6-7	1-2	.1388
C-23	3	12-13	4-5	.1275
C-23	3	13-14	7-8	.1168
C-23	3	1-2	7-8	.1039
C-23	4	1-2	2-3	.1328
C-23	4	3-4	2-3	.1323
C-23	4	12-13	3-4	.1270
C-23	4	14-15	4-5	.1132
C-23	4	6-7	5-6	.1076
C-23	4	10-11	5-6	.1183
C-23	4	14-15	6-7	.1331

1735 084

TABLE 10 (Continued)

INDIAN POINT #2 FUEL INSPECTION
ROD CLOSURE SUMMARY

ASSEMBLY	FACE	RODS	GRIDS	MAX. CLOSURE
D-11	1	3-4	6-7	.1218
D-11	1	2-3	7-8	.1254
D-11	2	13-14	1-2	.1314
D-11	2	6-7	5-6	.0959
D-11	2	10-11	6-7	.1394
D-11	2	4-5	8-9	.1138
D-11	3	3-4	3-4	.1270
D-11	3	8-9	3-4	.1282
D-11	3	9-10	4-5	.1198
D-11	3	7-8	5-6	.1302
D-11	3	12-13	6-7	.1370
D-11	3	7-8	7-8	.1446
D-11	4	9-10	2-3	.1238
D-11	4	7-8	3-4	.1334
D-11	4	9-10	4-5	.1154
D-11	4	1-2	5-6	.1358
D-11	4	2-3	5-6	.1286
D-11	4	9-10	5-6	.1386
D-11	4	3-4	6-7	.1326
D-11	4	14-15	6-7	.1350
D-11	4	9-10	8-9	.1346
D-71	1	4-5	1-2	.1363
D-71	1	9-10	1-2	.1340
D-71	1	12-13	2-3	.1232
D-71	1	10-11	4-5	.1216
D-71	1	13-14	4-5	.1029
D-71	1	1-2	5-6	.1091
D-71	1	7-8	5-6	.0963
D-71	1	10-11	5-6	.1202
D-71	1	7-8	6-7	.1257
D-71	1	8-9	8-9	.1089
D-71	2	5-6	1-2	.1248
D-71	2	12-13	1-2	.1175
D-71	2	1-2	3-4	.1075
D-71	2	4-5	4-5	.1175
D-71	2	13-14	5-6	.1021
D-71	2	12-13	8-9	.1027
D-71	3	1-2	3-4	.1252
D-71	3	12-13	3-4	.1185
D-71	3	1-2	7-8	.1164
D-71	3	14-15	8-9	.1186
D-71	4	3-4	1-2	.1171
D-71	4	4-5	4-5	.1177
D-71	4	5-6	4-5	.1280
D-71	4	6-7	4-5	.0978
D-71	4	8-9	6-7	.1100
D-71	4	14-15	7-8	.1117
D-71	4	7-8	8-9	.0932

1735 085

TABLE 10 (Continued)

INDIAN POINT #2 FUEL INSPECTION
ROD CLOSURE SUMMARY

ASSEMBLY	FACE	RODS	GRIDS	MAX. CLOSURE
E-38	1	11-12	6-7	.1309
E-38	1	12-13	7-8	.1292
E-38	1	9-10	8-9	.1265
E-38	2	8-9	1-2	.1168
E-38	2	11-12	1-2	.0976
E-38	2	7-8	2-3	.1135
E-38	2	4-5	6-7	.1184
E-38	2	5-6	6-7	.1207
E-38	2	10-11	6-7	.1248
E-36	2	8-9	7-8	.1332
E-38	2	1-2	1-2	.1151
E-38	2	2-3	2-3	.1265
E-38	3	5-6	2-3	.1257
E-38	3	12-13	2-3	.1109
E-38	3	9-10	3-4	.1247
E-38	3	13-14	4-5	.1188
E-38	3	4-5	4-5	.1297
E-38	3	4-5	6-7	.1247
E-38	3	1-2	6-7	.1230
E-38	3	12-13	6-7	.1226
E-38	3	11-12	7-8	.1203
E-38	3	13-14	8-9	.1290
E-38	4	12-13	8-9	.1188
E-38	4	2-3	8-9	.1081
E-38	4	10-11	6-7	.1190
E-38	4	10-11	4-5	.1177
E-38	4	7-8	1-2	.1236

1735 086

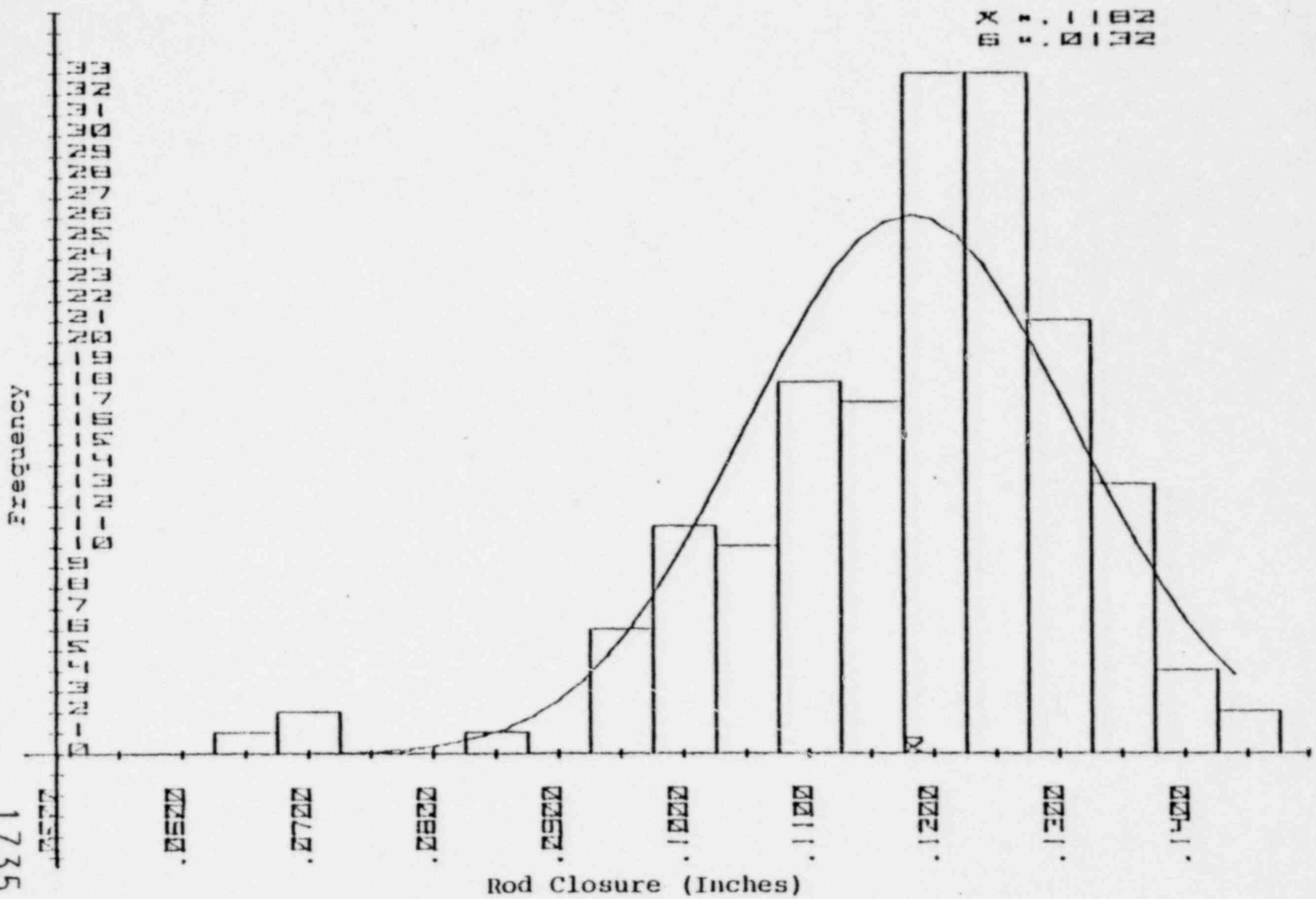


FIGURE 17 HISTOGRAM OF THE ROD CLOSURE MEASURED AT INDIAN POINT #2 AT THE END OF CYCLE 3

1735 087

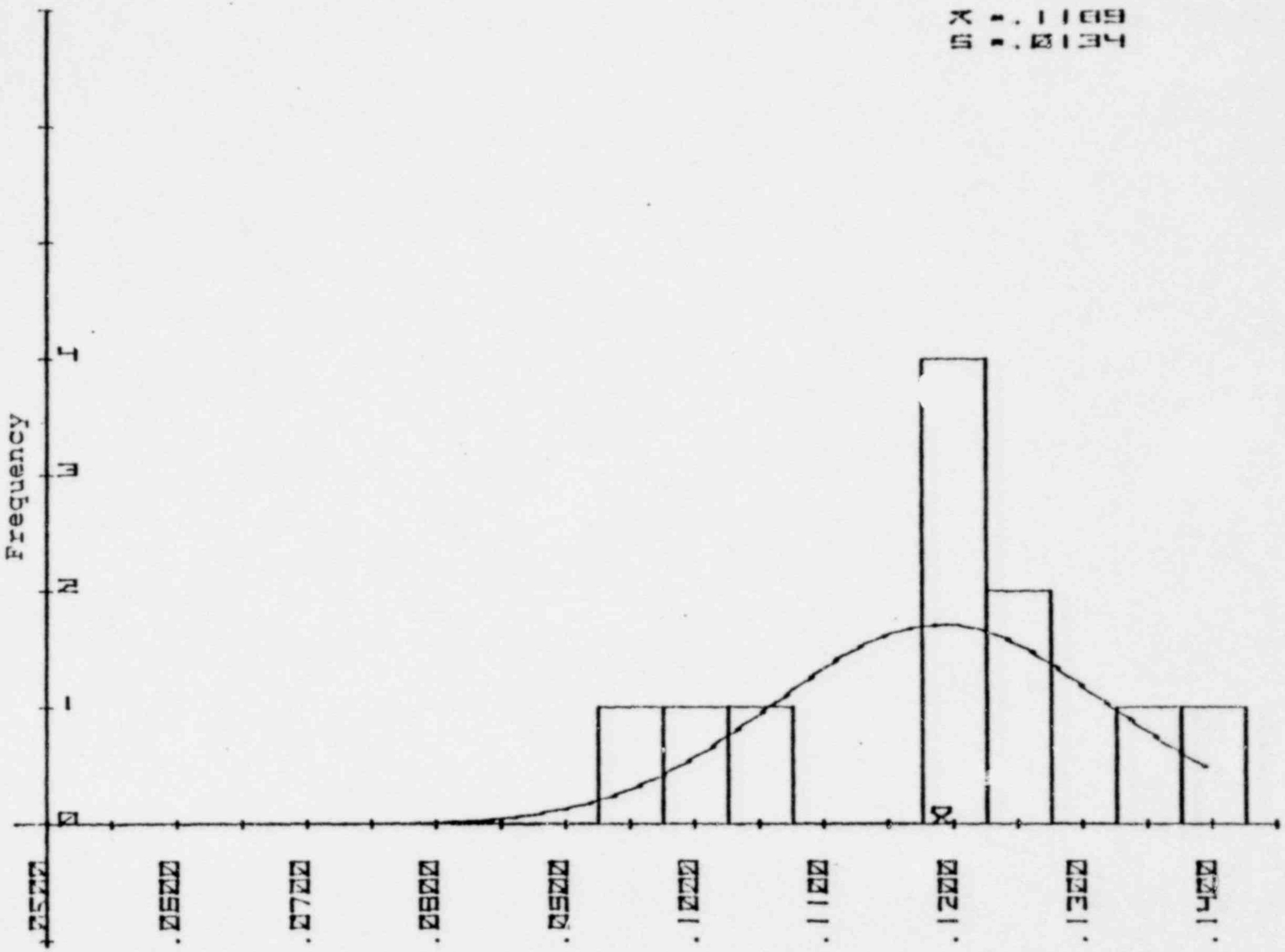


FIGURE 18a HISTOGRAM OF THE ROD CLOSURE MEASURED WITHIN GRID SPAN 1 (36,500 MWD/MTU)

1735 088

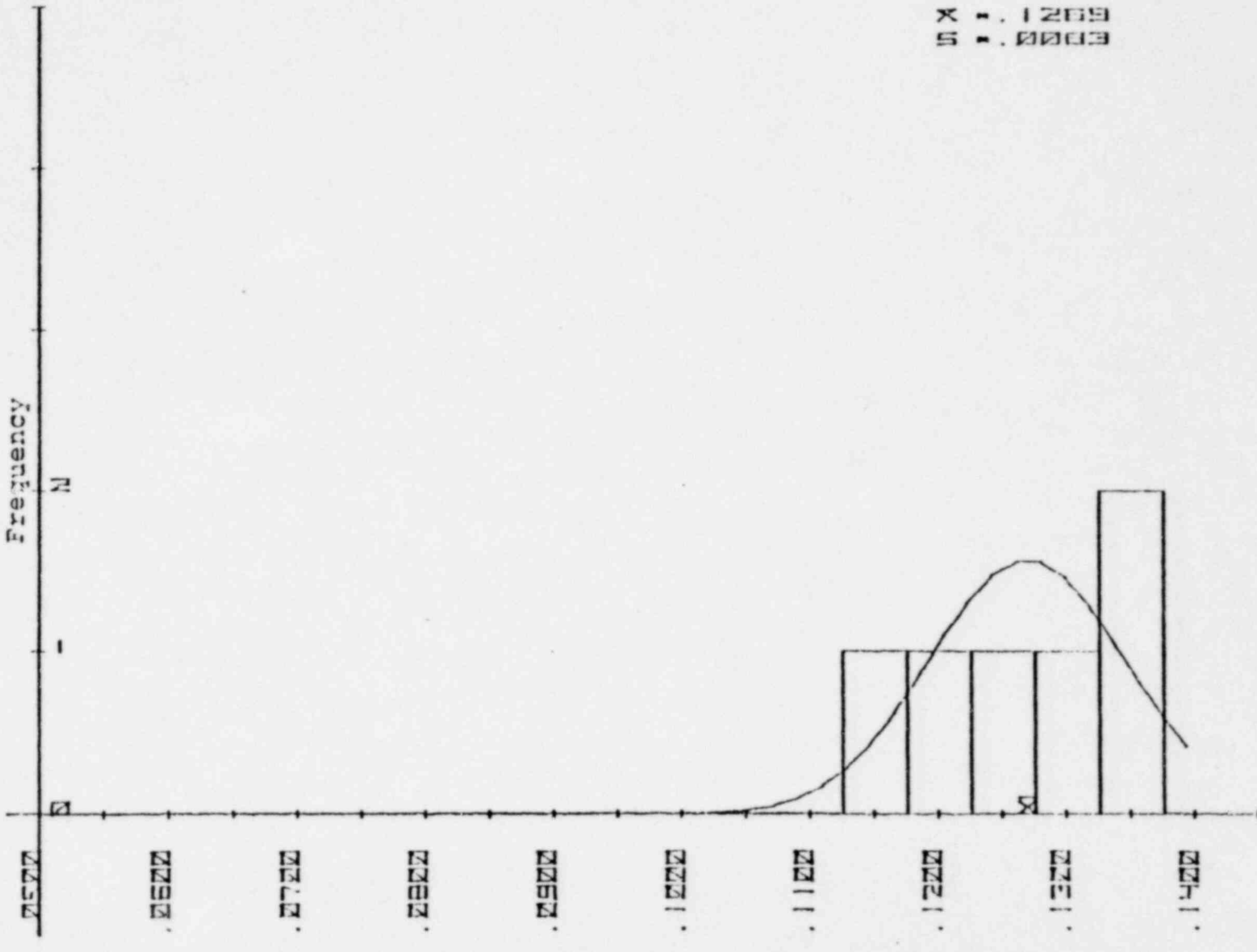


FIGURE 18b HISTOGRAM OF THE ROD CLOSURE MEASURED WITHIN GRID SPAN 1 (25,000 MWD/MTU)

1735 089

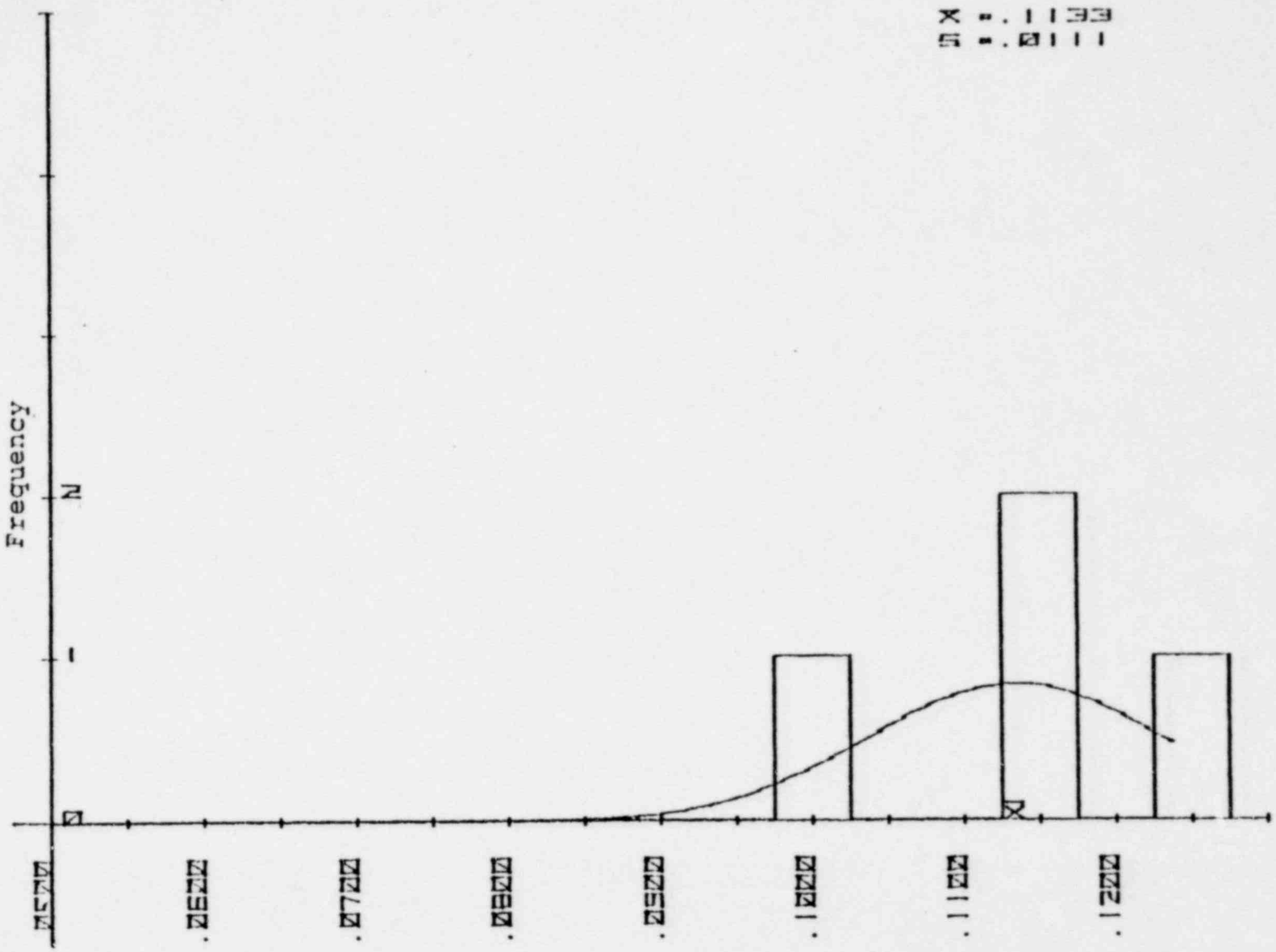


FIGURE 18c HISTOGRAM OF THE ROD CLOSURE MEASURED WITHIN GRID SPAN 1 (13,000 MWD/MTU)

1735 090

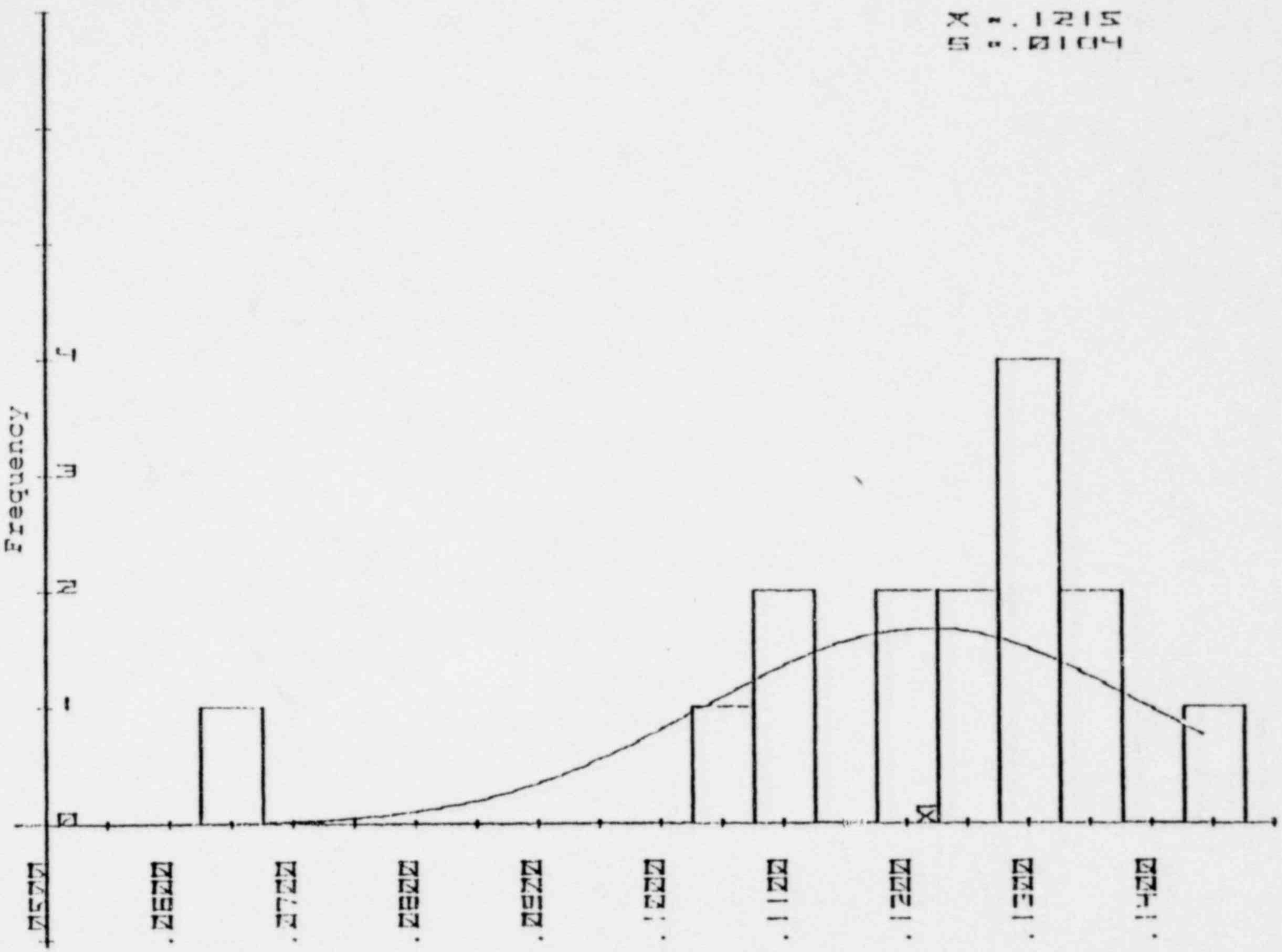


FIGURE 19a HISTOGRAM OF THE ROD CLOSURE MEASURED WITHIN GRID SPAN 2 (36,500 MWD/MTU)

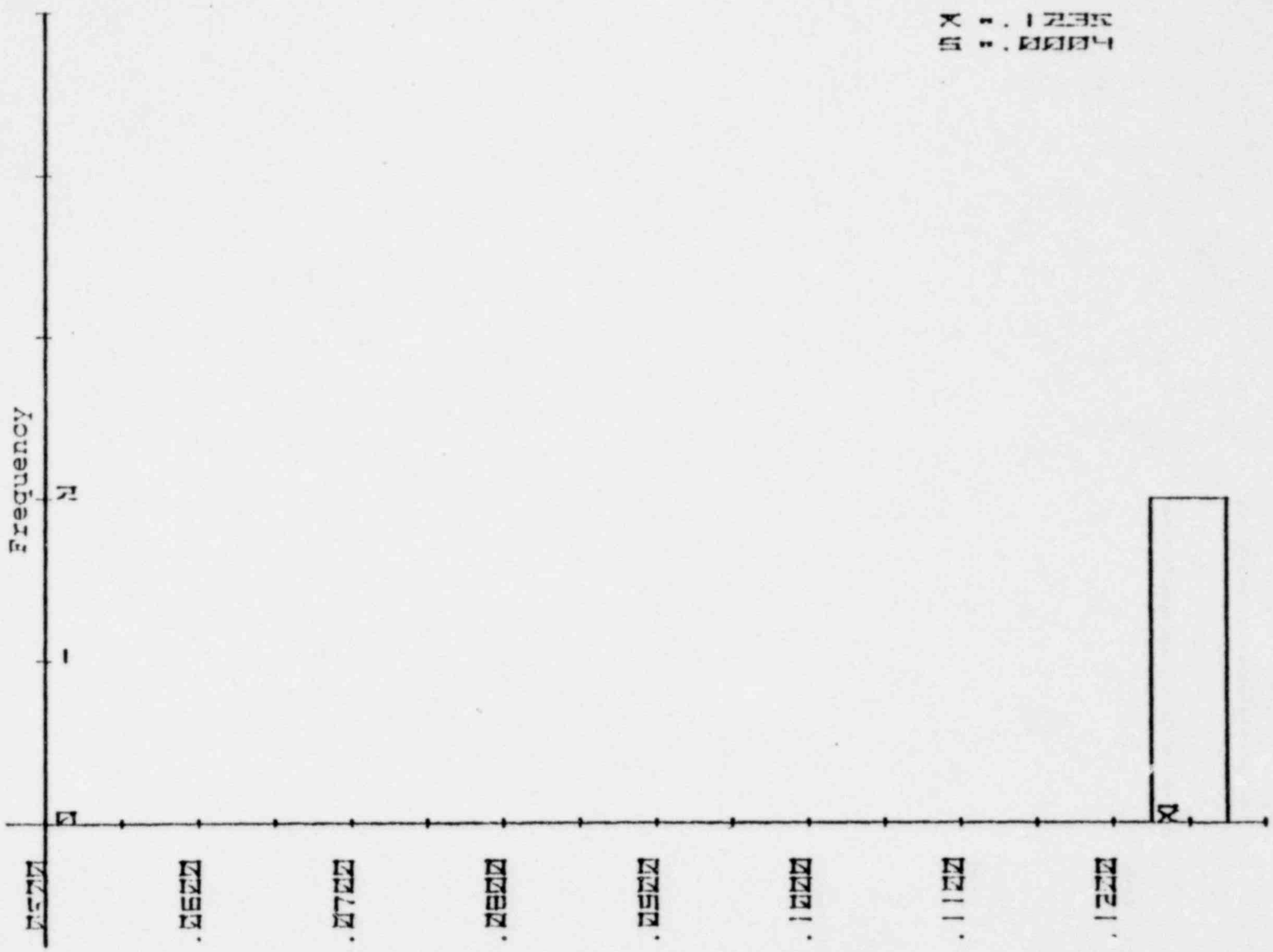


FIGURE 19b HISTOGRAM OF THE ROD CLOSURE MEASURED WITHIN GRID SPAN 2 (25,000 MWD/MTU)

1735 092

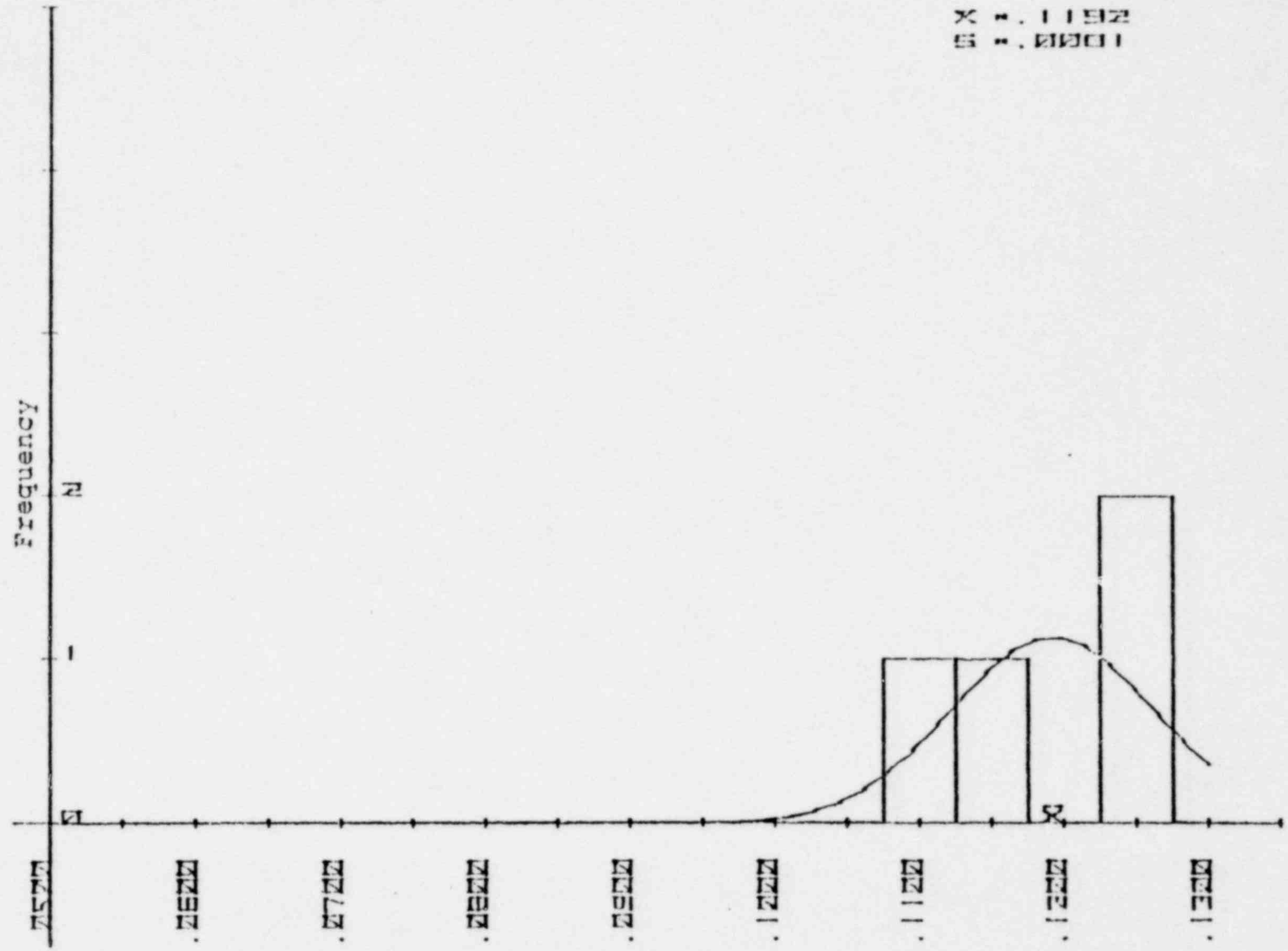


FIGURE 15c HISTOGRAM OF THE ROD CLOSURE MEASURED WITHIN GRID SPAN 2 (13,000 MWD/MTU)

1735 093

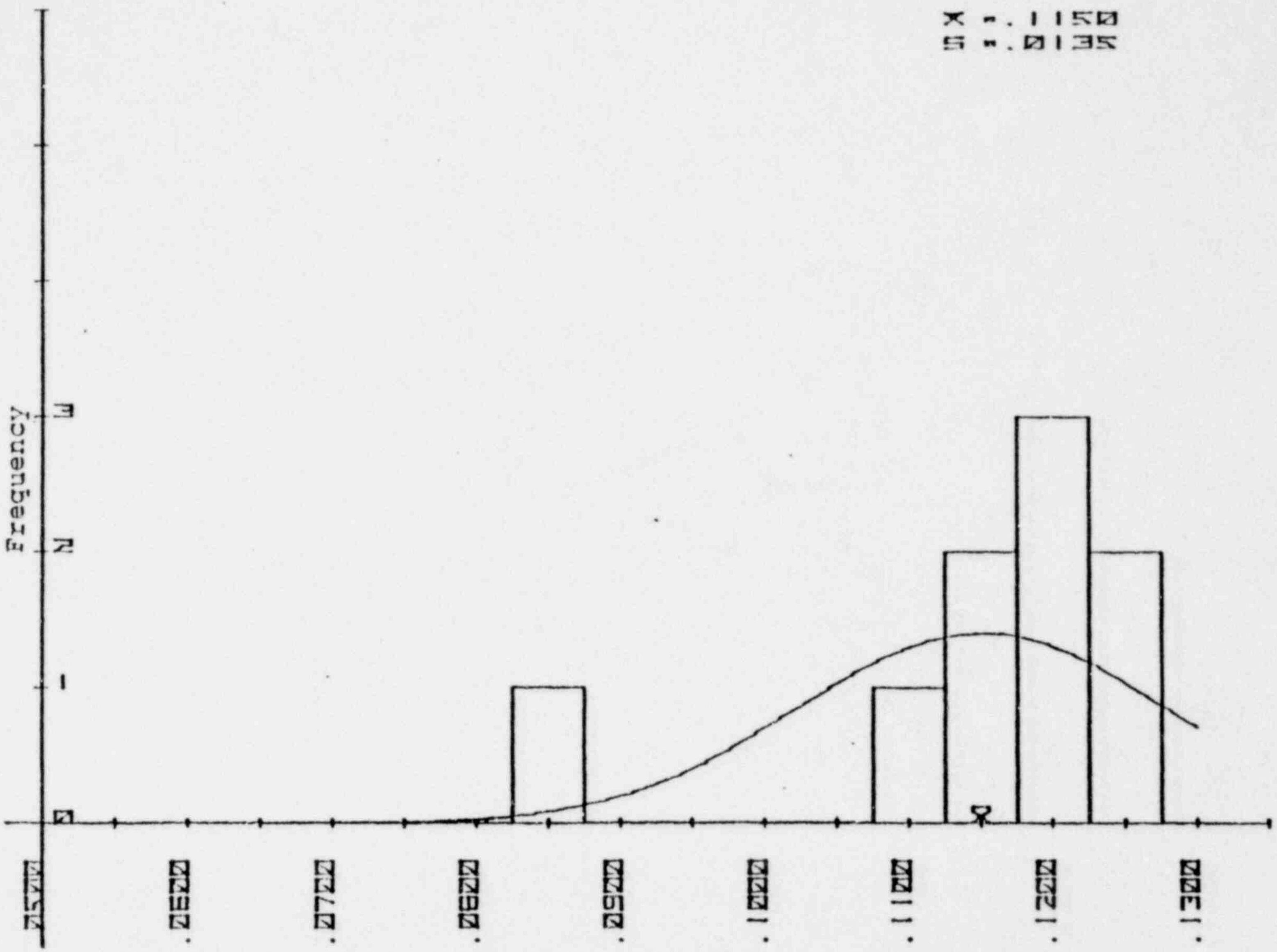


FIGURE 20a HISTOGRAM OF THE ROD CLOSURE MEASURED WITHIN GRID SPAN 3 (36,500 MWD/MTU)

1735 094

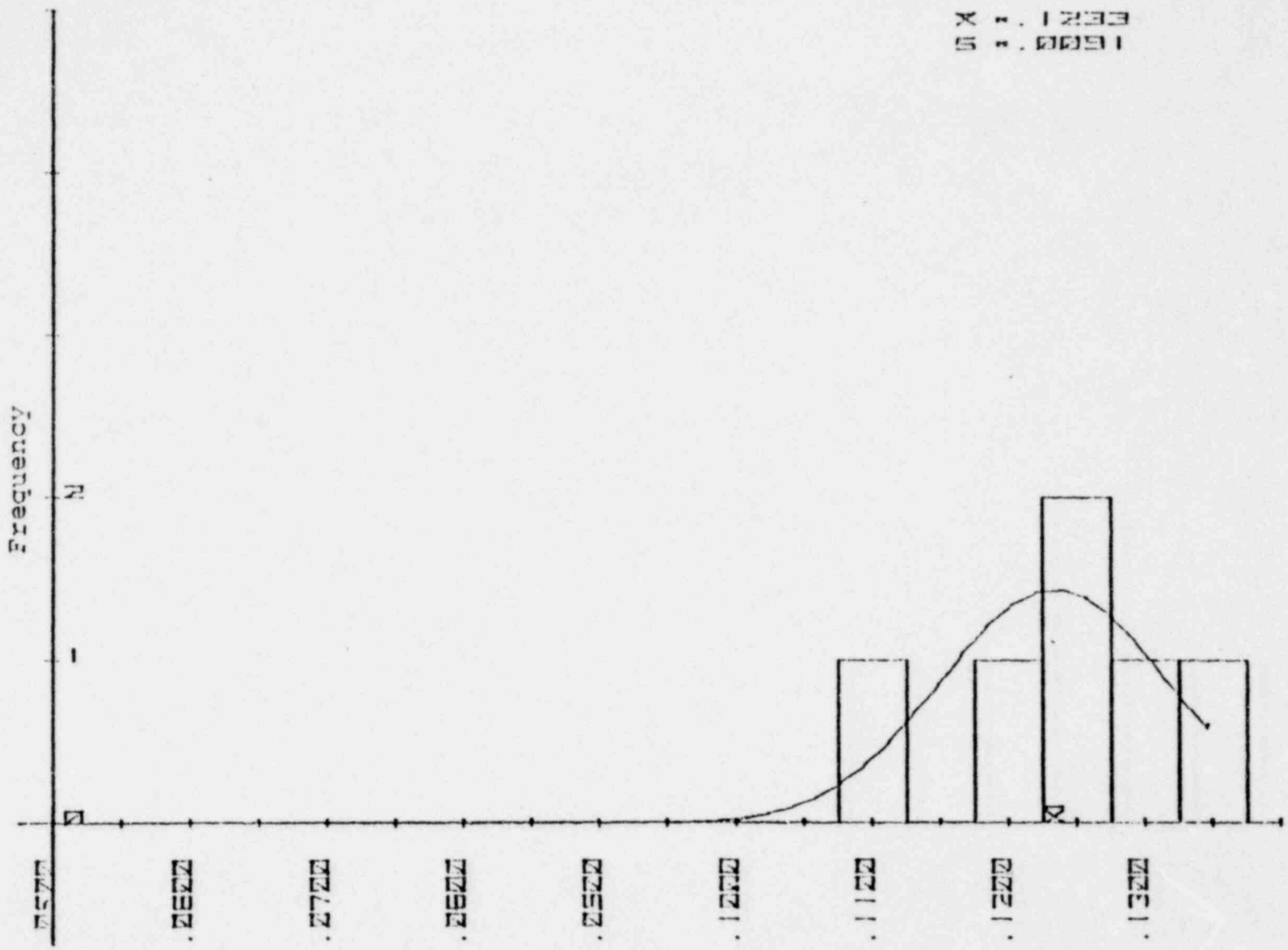


FIGURE 20b HISTOGRAM OF THE ROD CLOSURE MEASURED WITHIN GRID SPAN 3 (25,000 MWD/MTU)

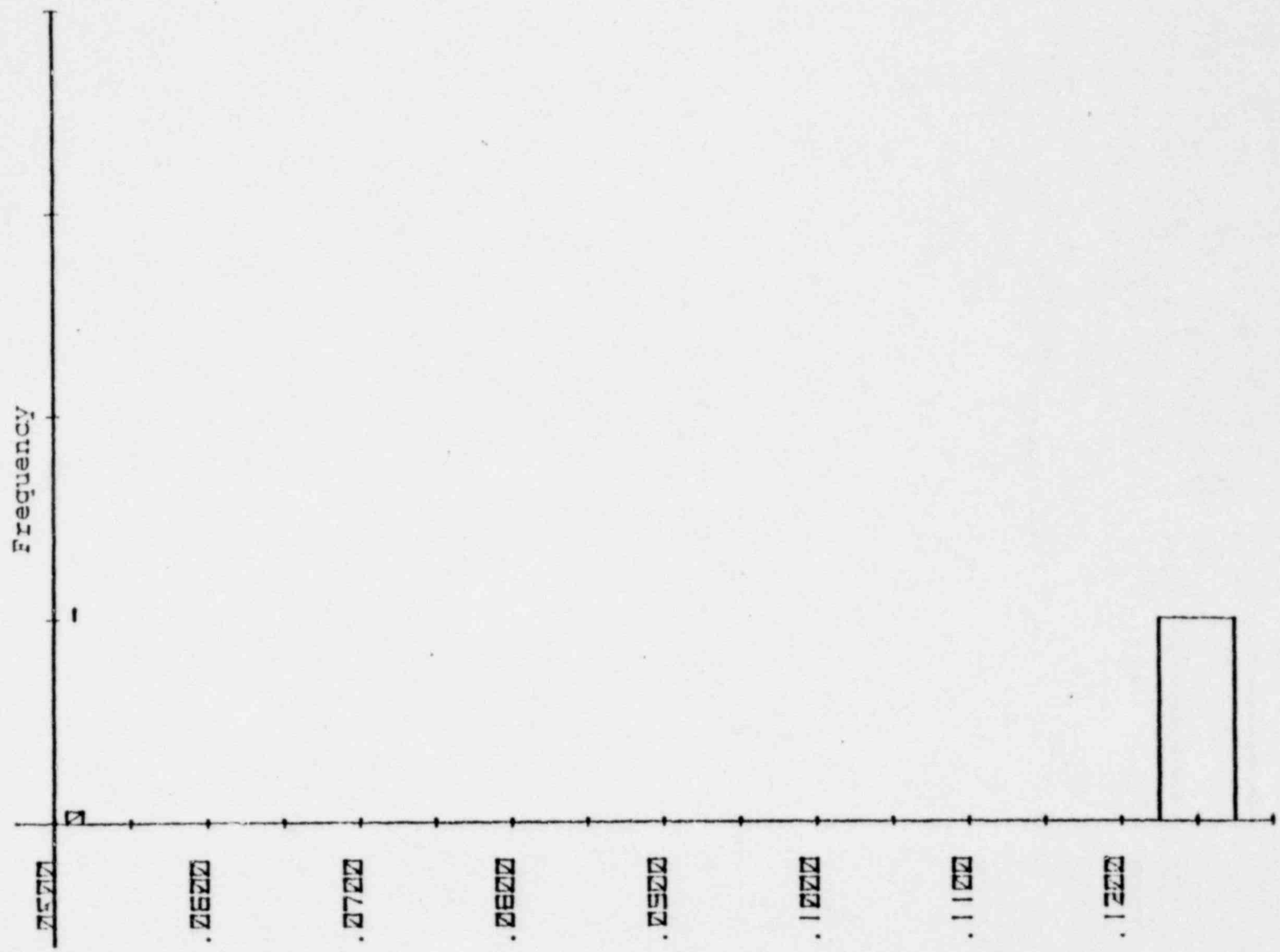


FIGURE 20c HISTOGRAM OF THE ROD CLOSURE MEASURED WITHIN GRID SPAN 3 (13,000 MWD/MTU)

1735 096

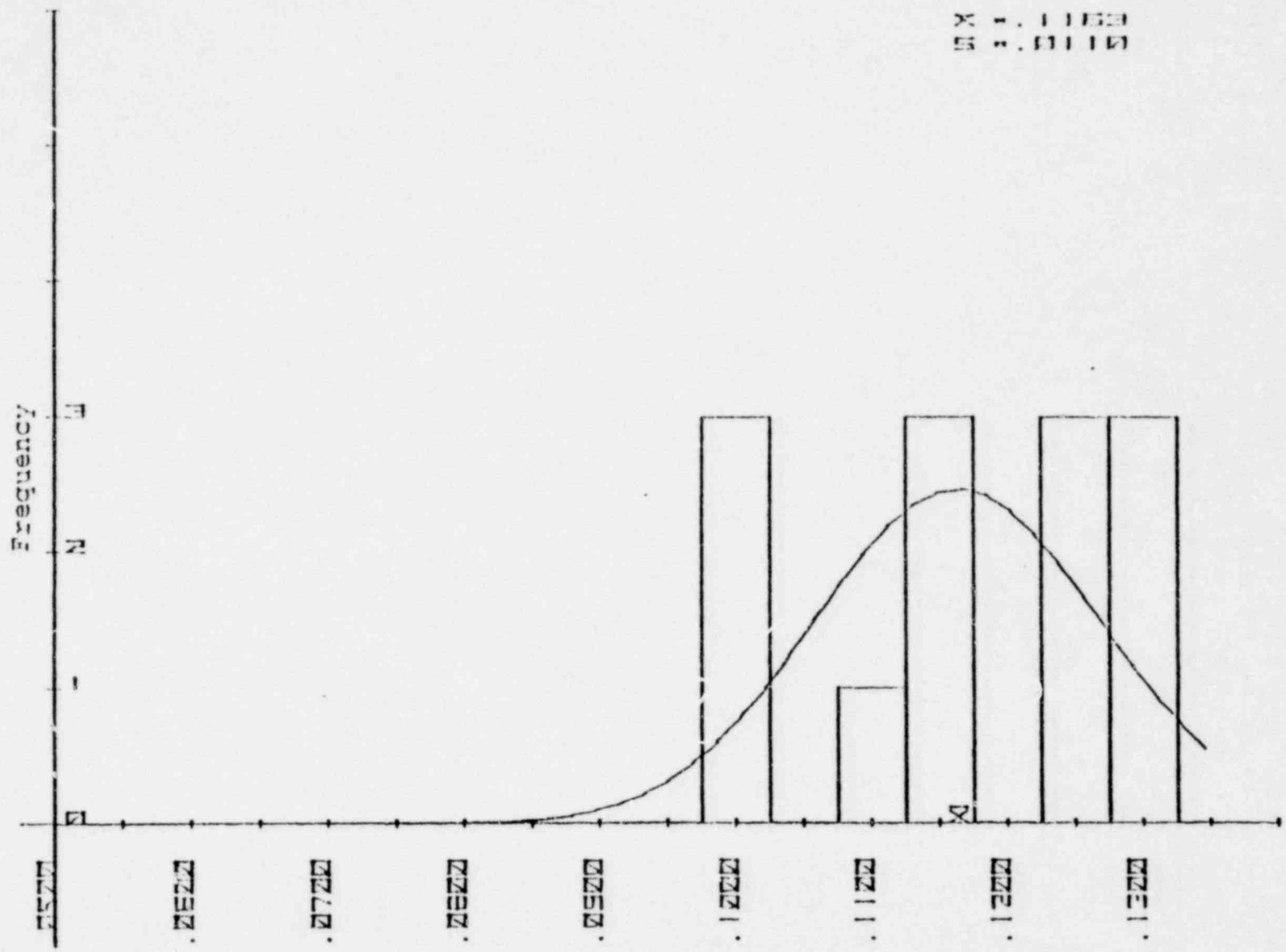


FIGURE 21a HISTOGRAM OF THE ROD CLOSURE MEASURED WITHIN GRID SPAN 4 (36,500 MWD/MTU)

1735 097

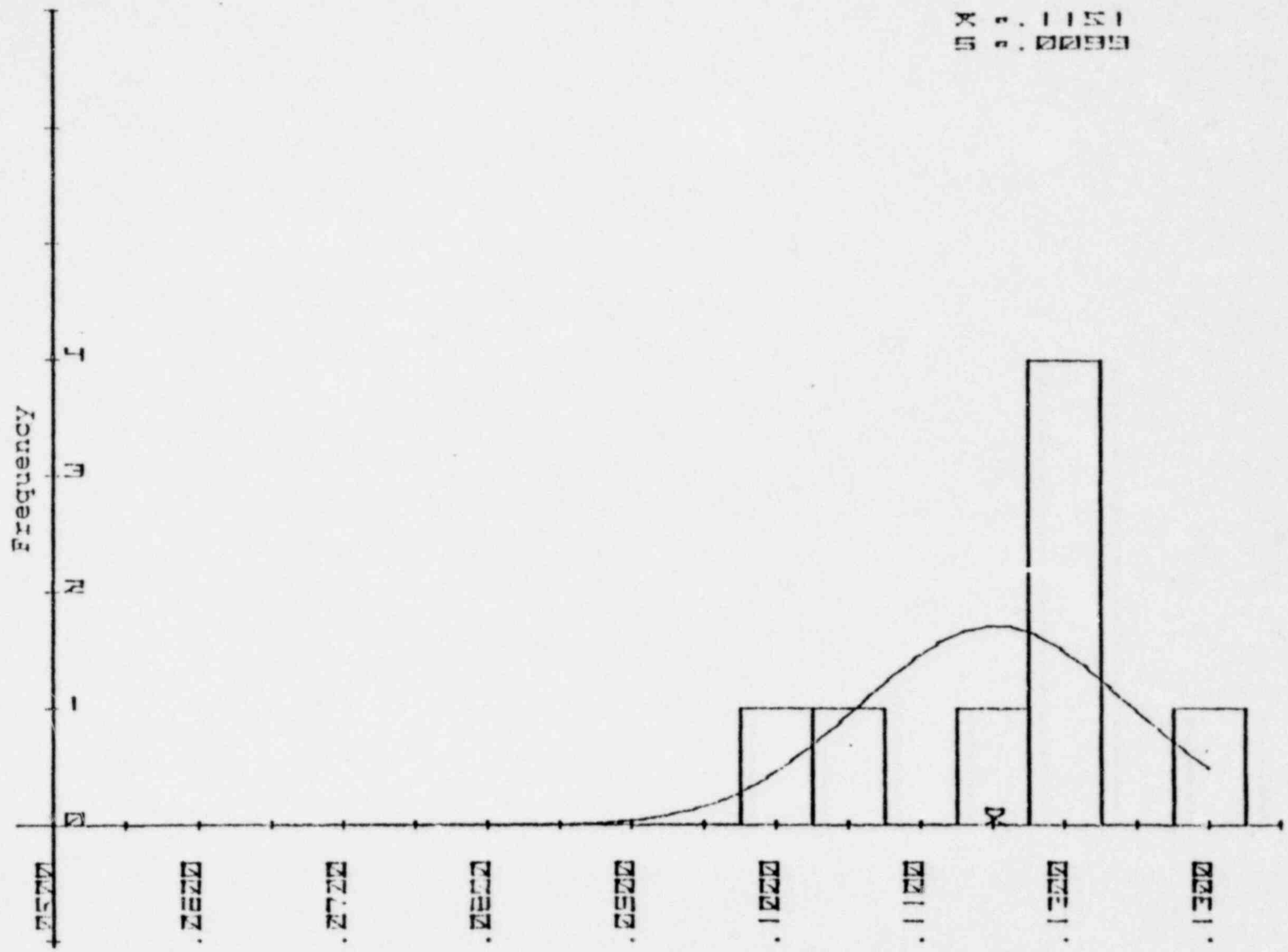
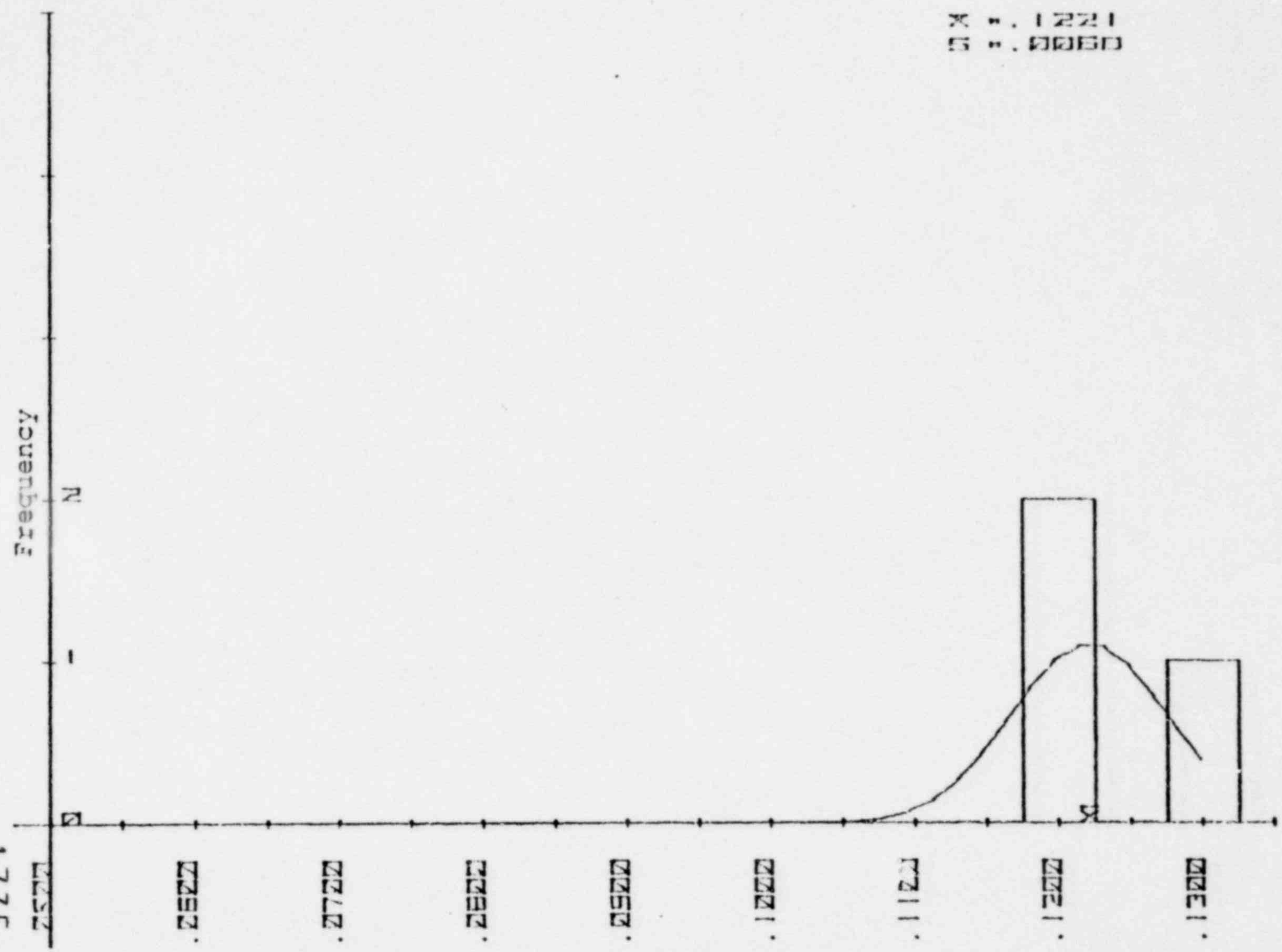


FIGURE 21b HISTOGRAM OF THE ROD CLOSURE MEASURED WITHIN GRID SPAN 4 (25,000 MWD/MTU)

1735 098



1735 099

FIGURE 21c HISTOGRAM OF THE ROD CLOSURE MEASURED WITHIN GRID SPAN 4 (13,000 MWD/MTU)

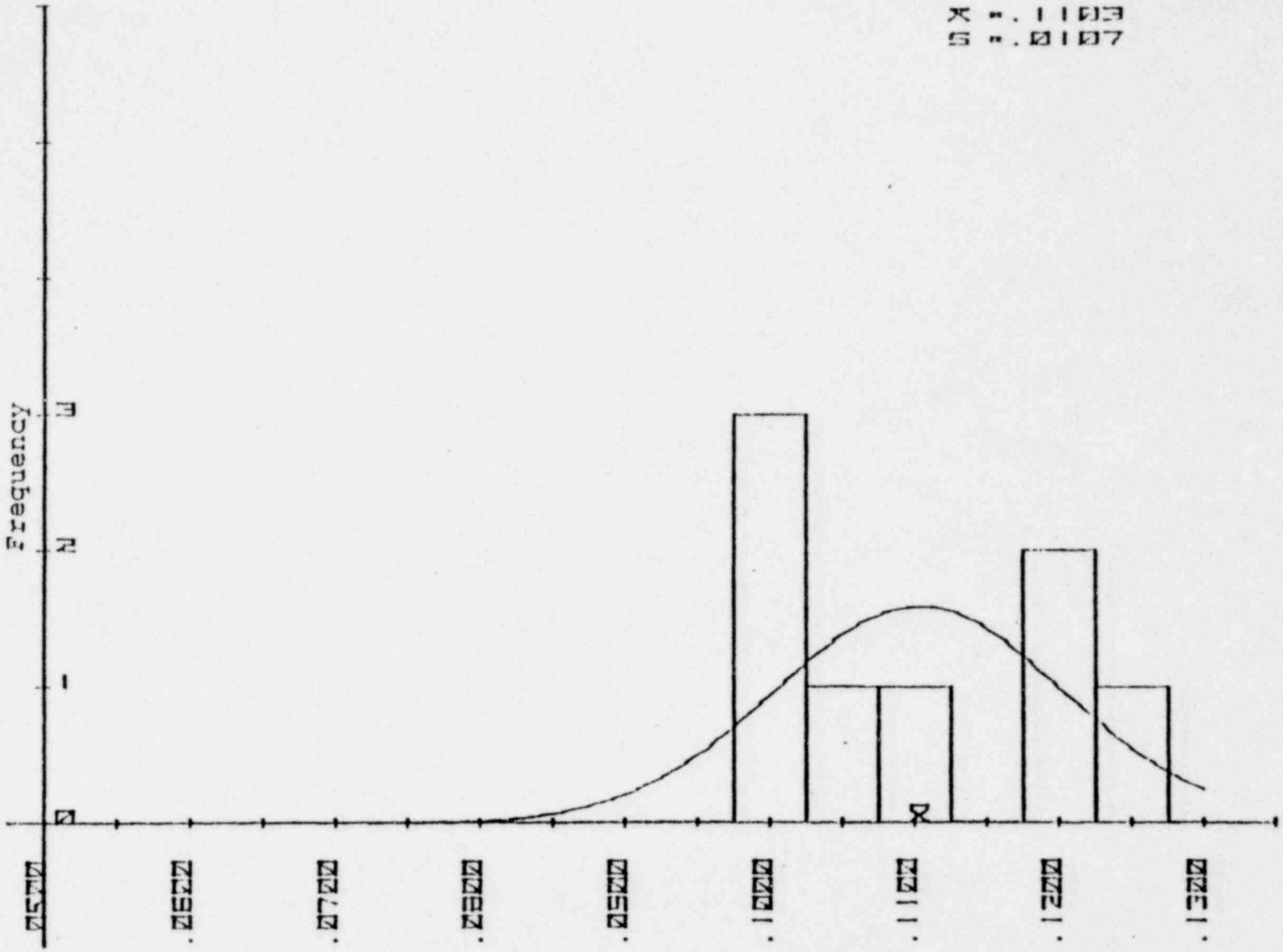


FIGURE 22a HISTOGRAM OF THE ROD CLOSURE MEASURED WITHIN GRID SPAN 5 (36,500 MWD/MTU)

1735 100

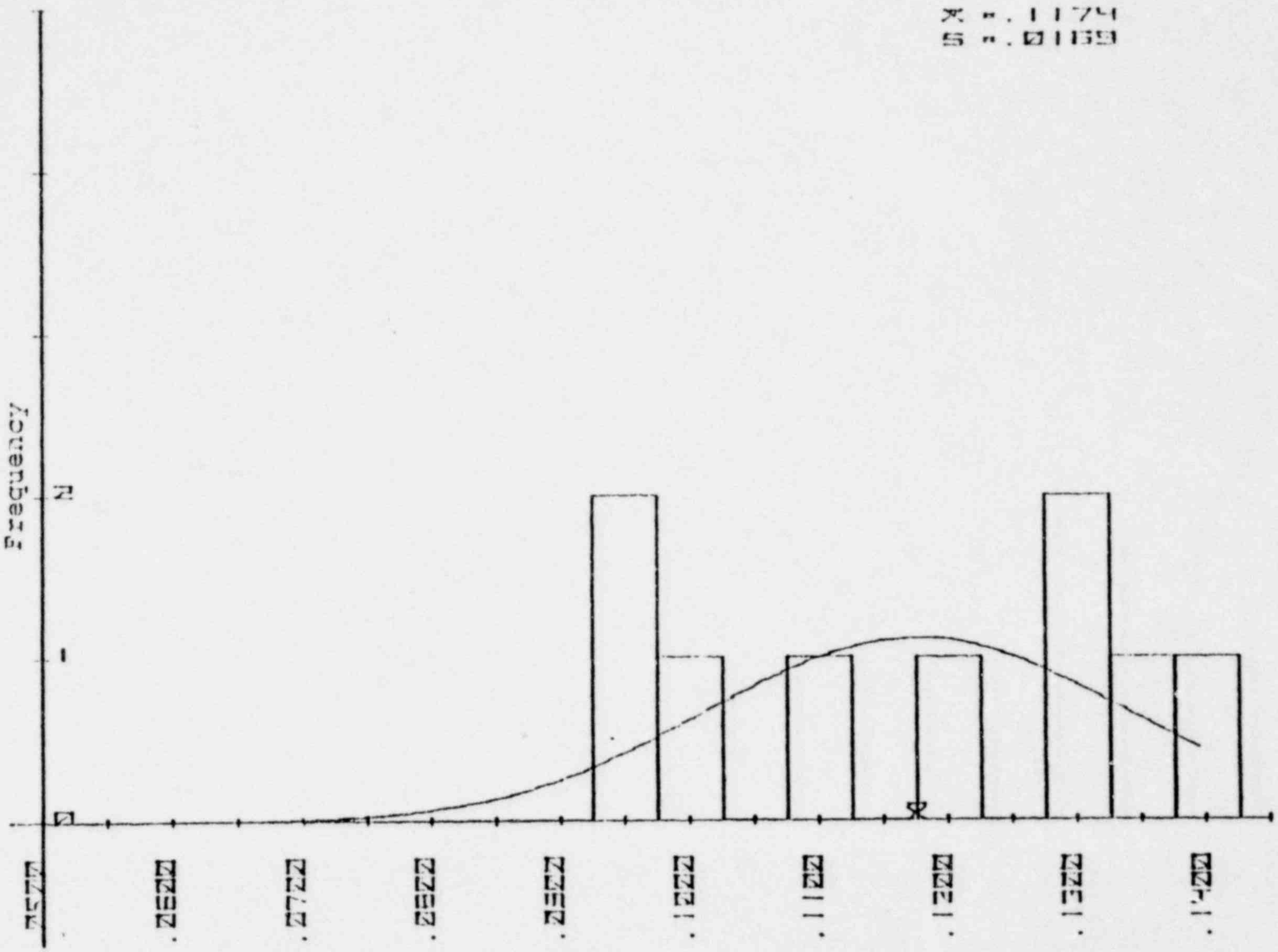


FIGURE 22b HISTOGRAM OF THE ROD CLOSURE MEASURED WITHIN GRID SPAN 5 (25,000 MWD/MTU)

1735 101

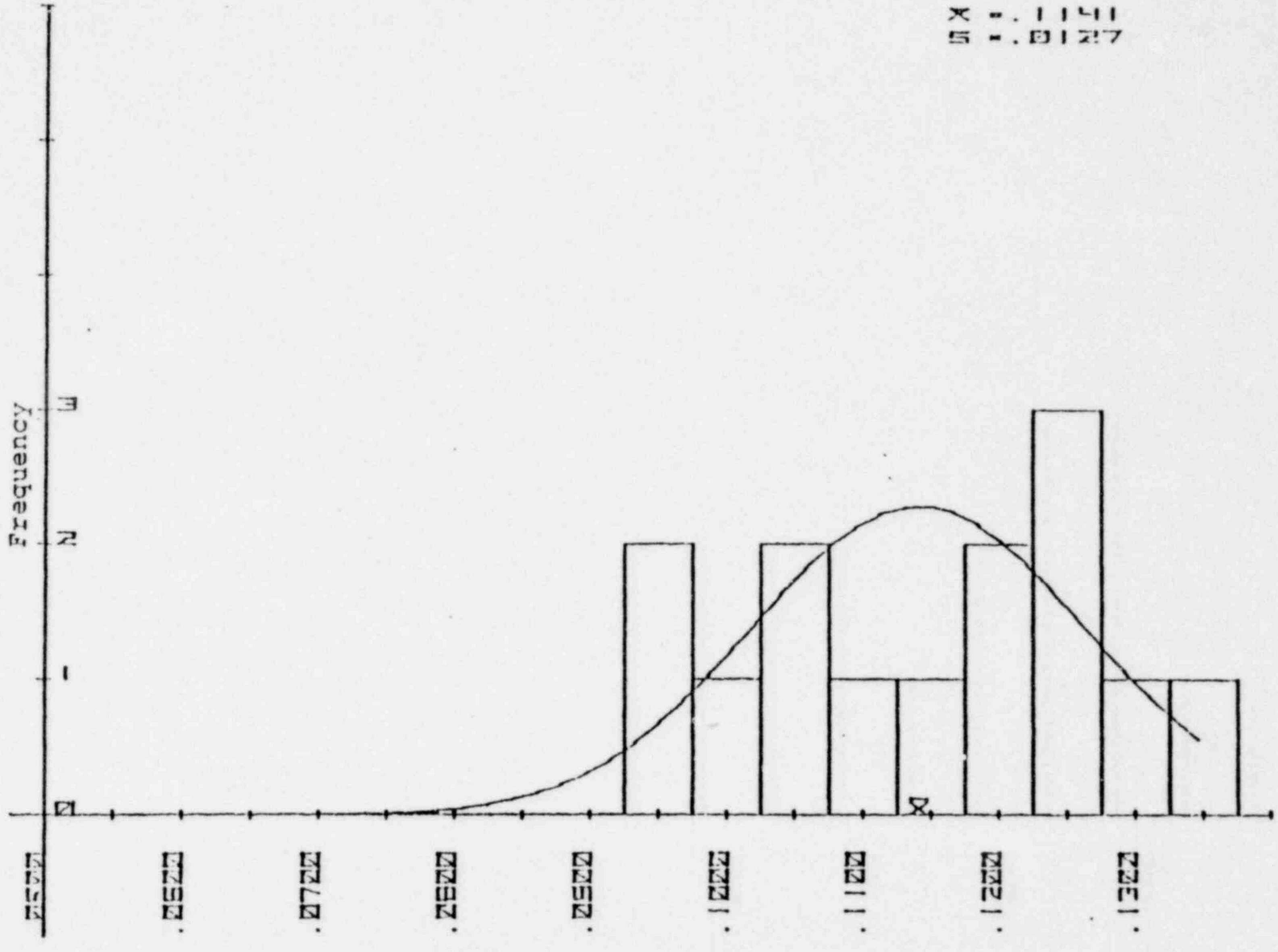


FIGURE 23a HISTOGRAM OF THE ROD CLOSURE MEASURED WITHIN GRID SPAN 6 (36,500 MWD/MTU)

1735 102

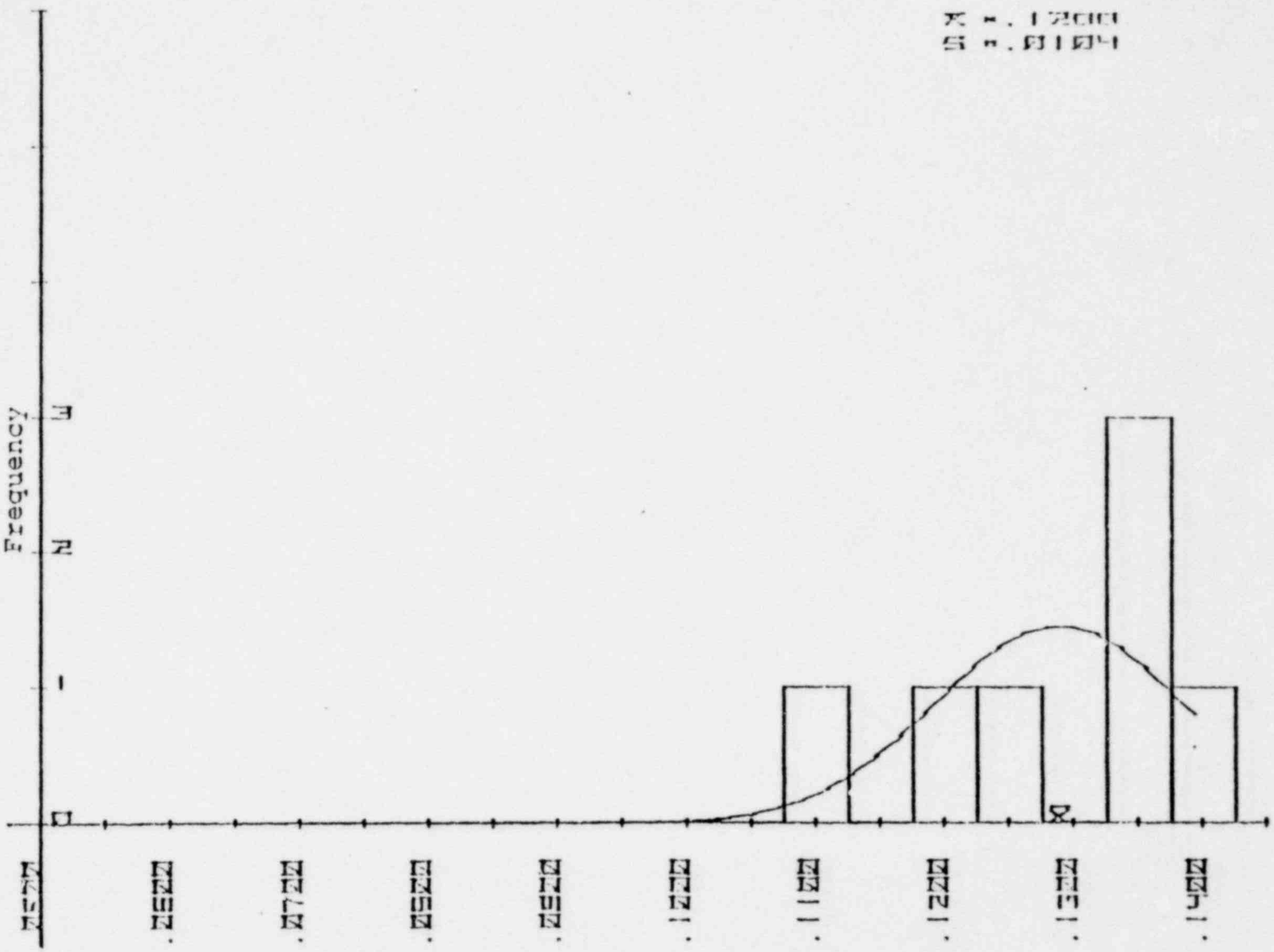


FIGURE 23b HISTOGRAM OF THE ROD CLOSURE MEASURED WITHIN GRID SPAN 6 (25,000 MWD/MTU)

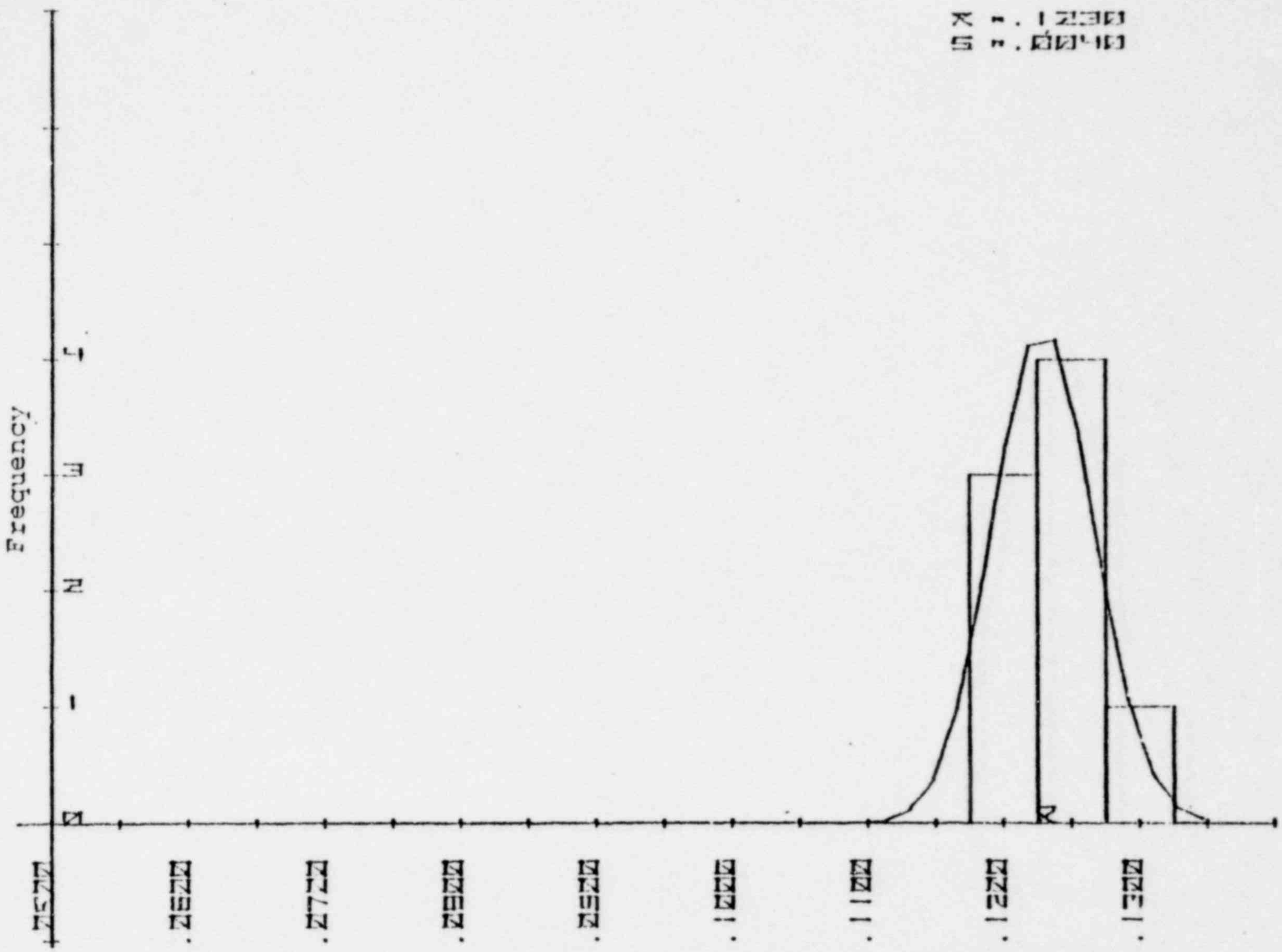


FIGURE 23c HISTOGRAM OF THE ROD CLOSURE MEASURED WITHIN GRID SPAN 6 (13,000 MWD/MTU)

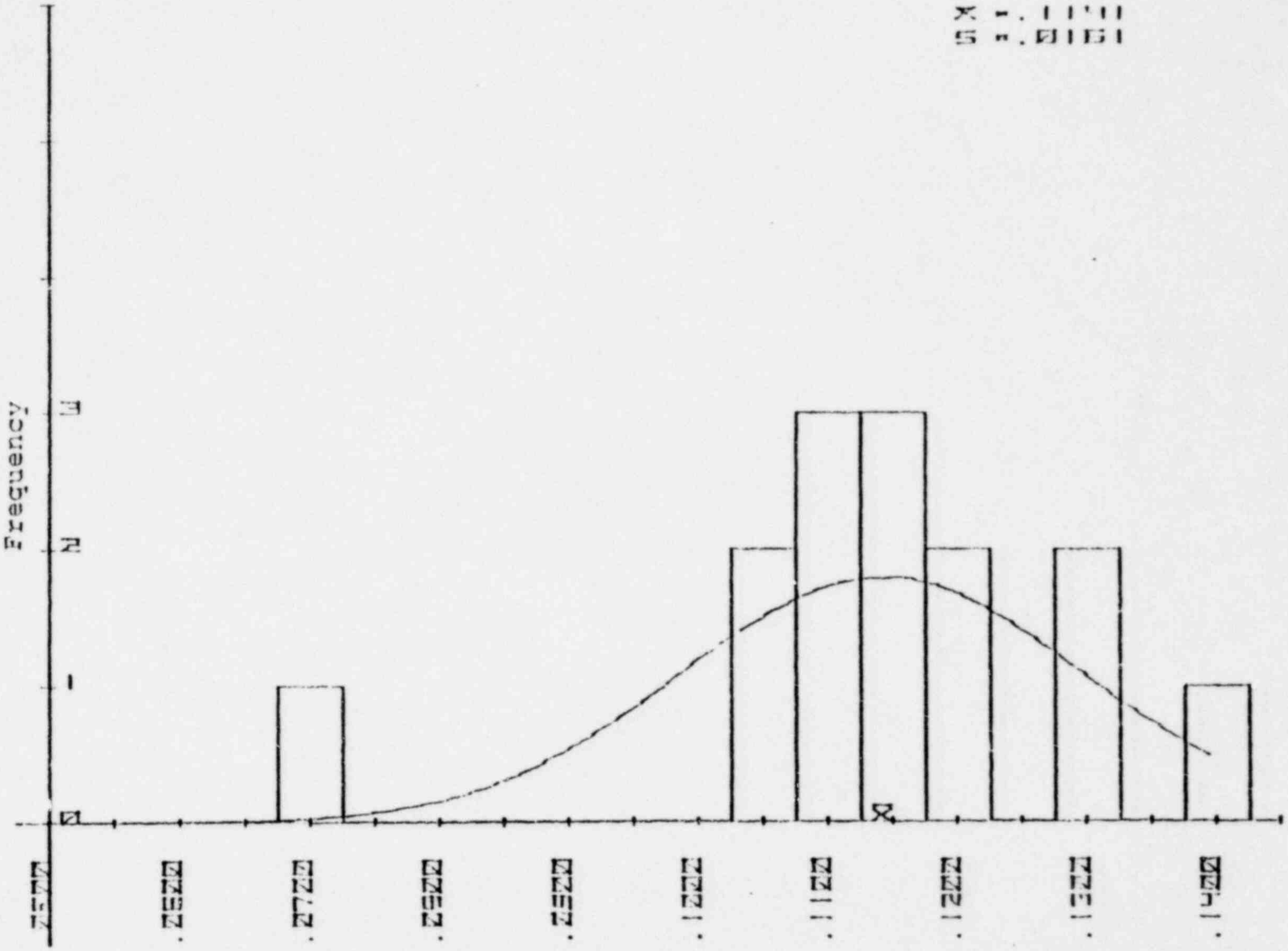


FIGURE 24a HISTOGRAM OF THE ROD CLOSURE MEASURED WITHIN GRID SPAN 7 (36,500 MWD/MTU)

1735 105

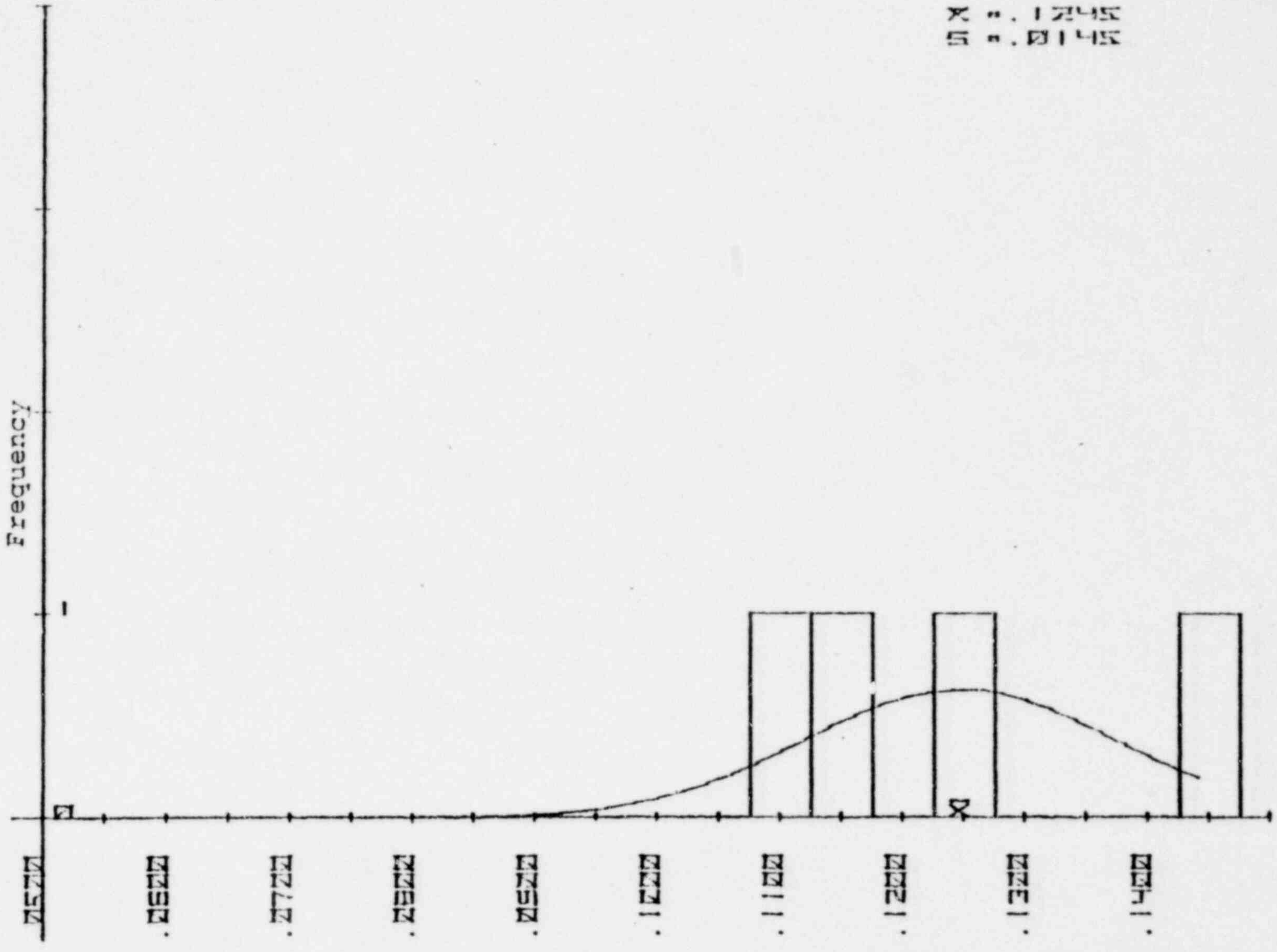


FIGURE 24b HISTOGRAM OF THE ROD CLOSURE MEASURED WITHIN GRID SPAN 7 (25,000 MWD/MTU)

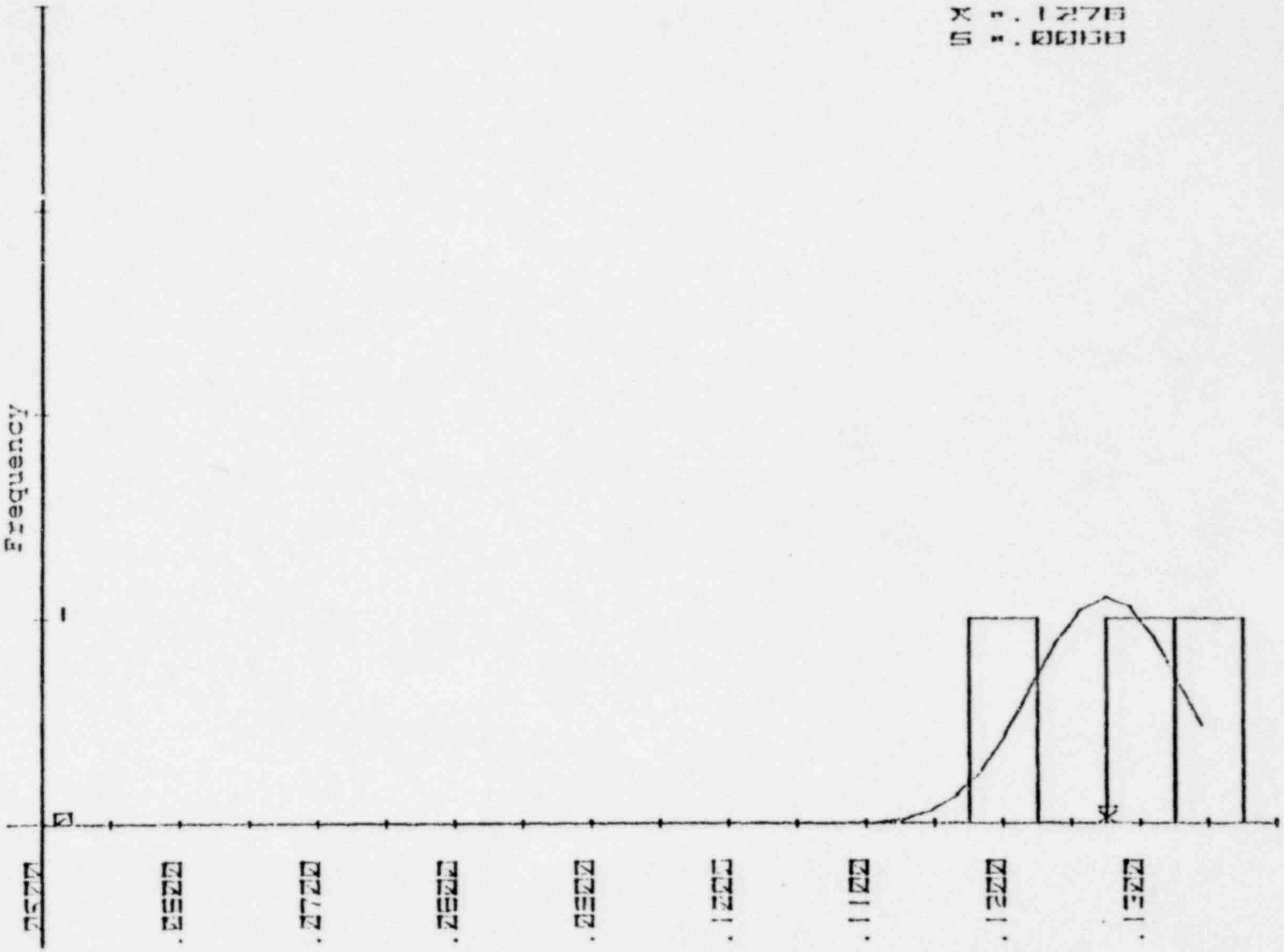


FIGURE 24c HISTOGRAM OF THE ROD CLOSURE MEASURED WITHIN GRID SPAN 7 (13,000 MWD/MTU)

1735 107

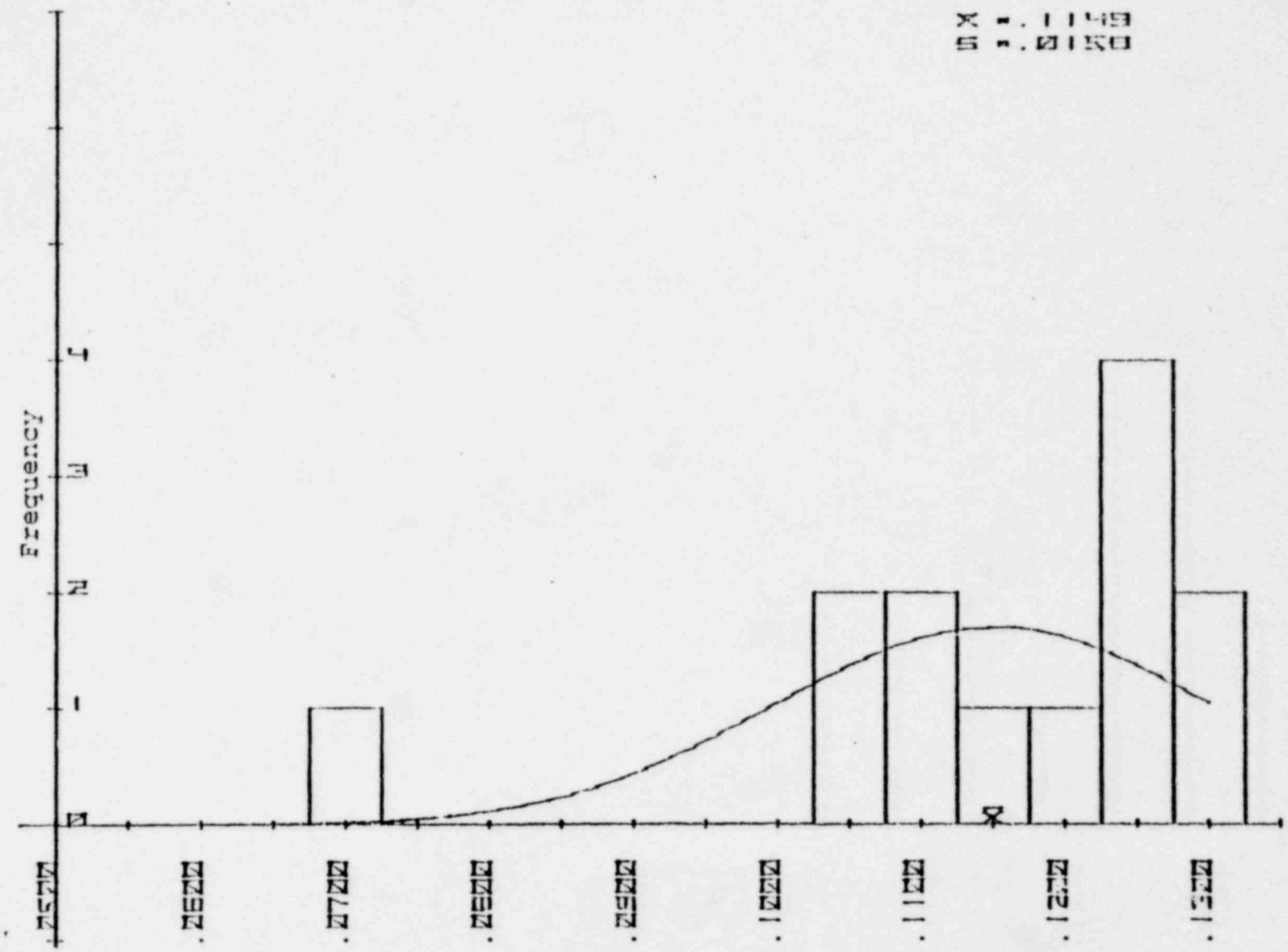


FIGURE 25a HISTOGRAM OF THE ROD CLOSURE MEASURED WITHIN GRID SPAN 8 (36,500 MWD/MTU)

1735 108

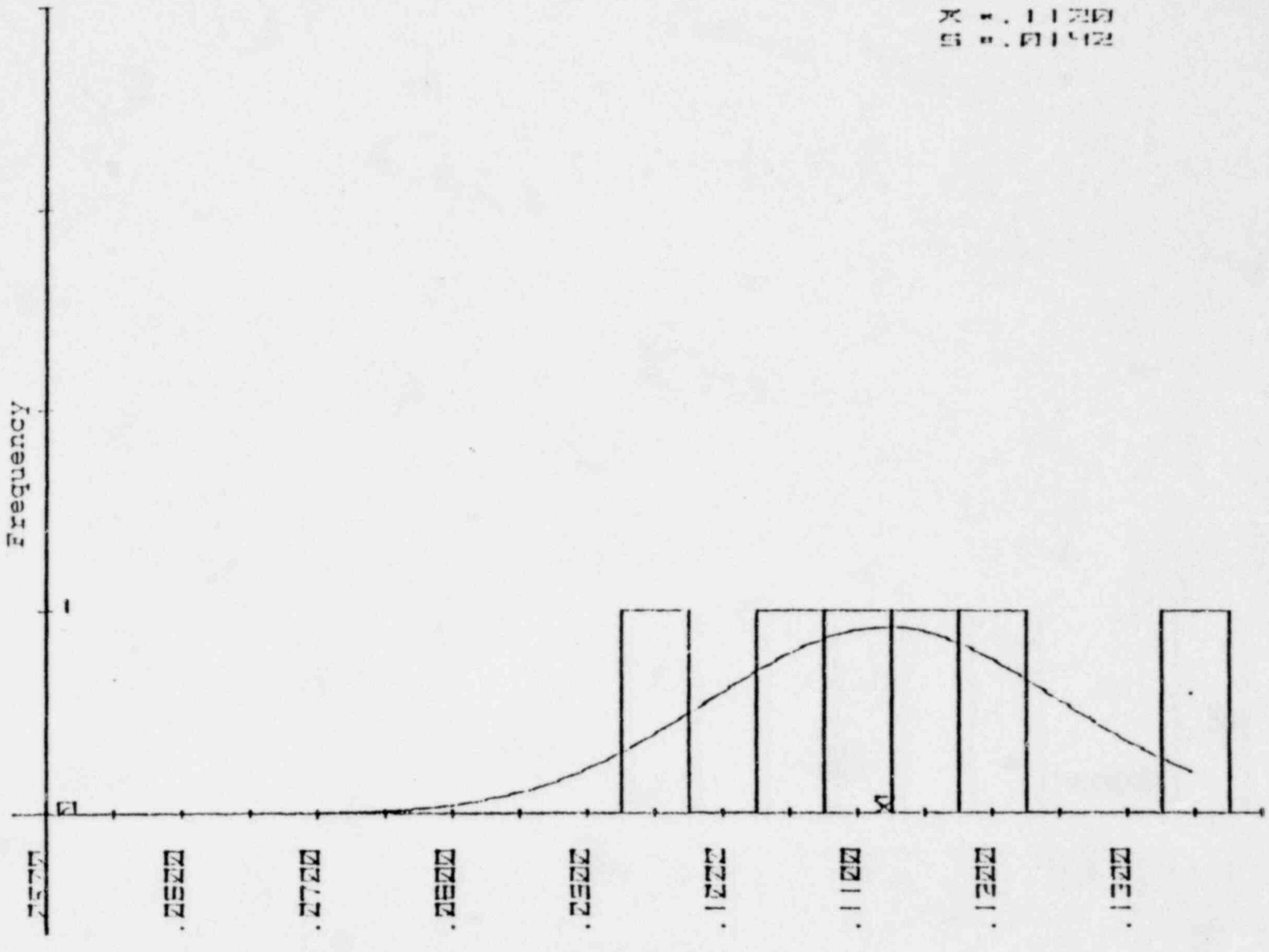


FIGURE 25b HISTOGRAM OF THE ROD CLOSURE MEASURED WITHIN GRID SPAN 8 (25,000 MWD/MTU)

1735 109

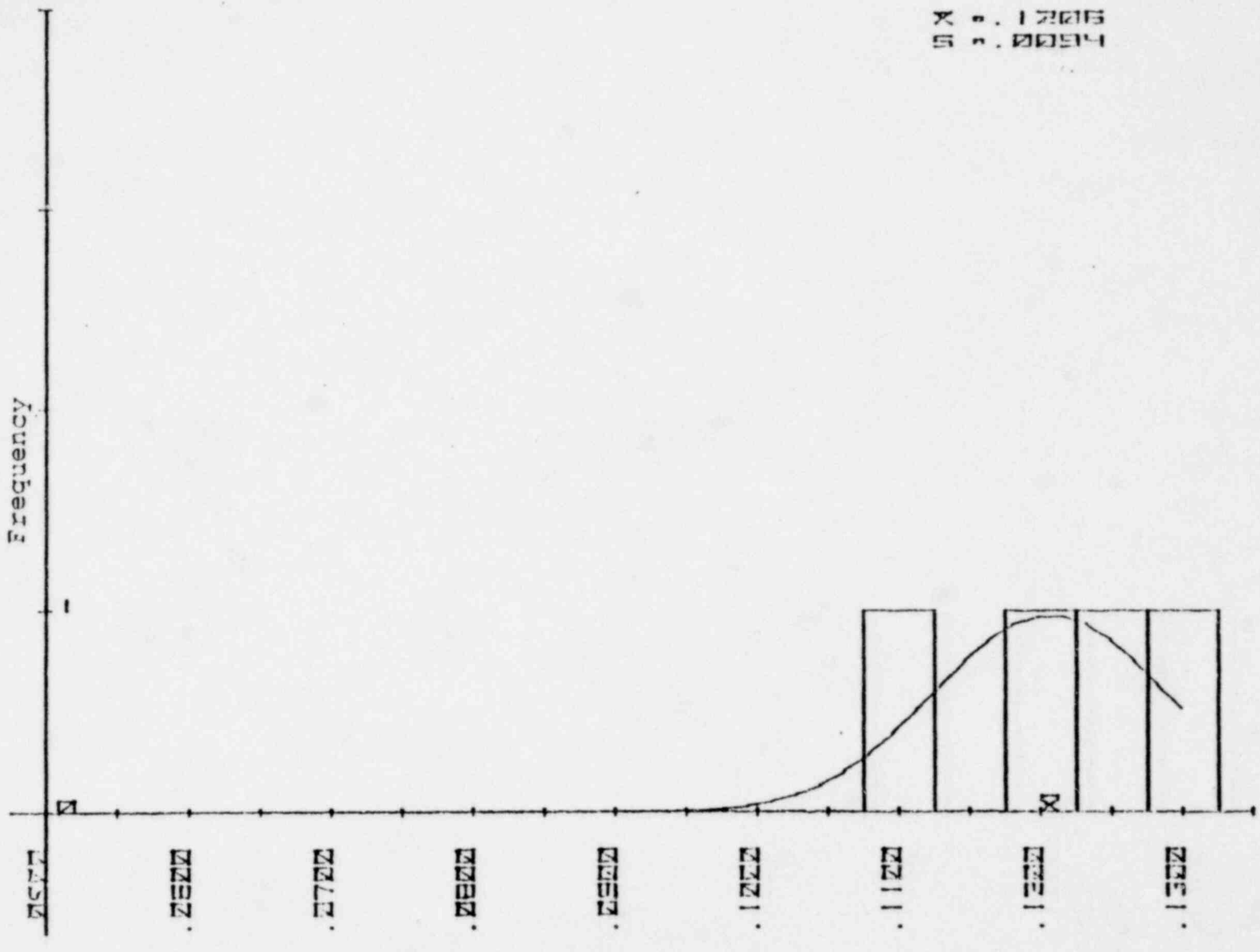


FIGURE 25c HISTOGRAM OF THE ROD CLOSURE MEASURED WITHIN GRID SPAN 8 (13,000 MWD/MTU)

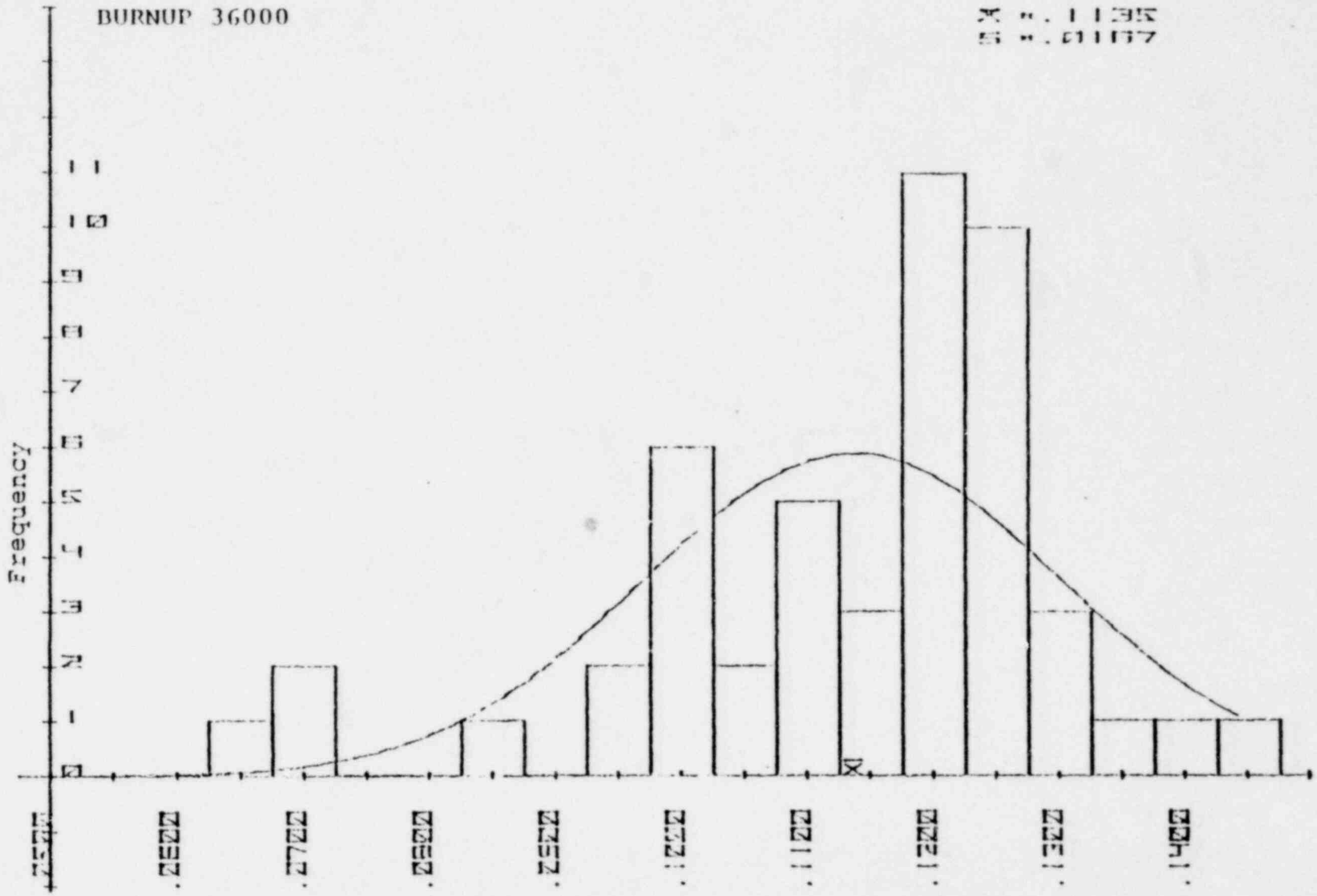


FIGURE 26 FREQUENCY HISTOGRAM OF ROD CLOSURE MEASUREMENTS FOR THE B ASSEMBLIES

1735 111

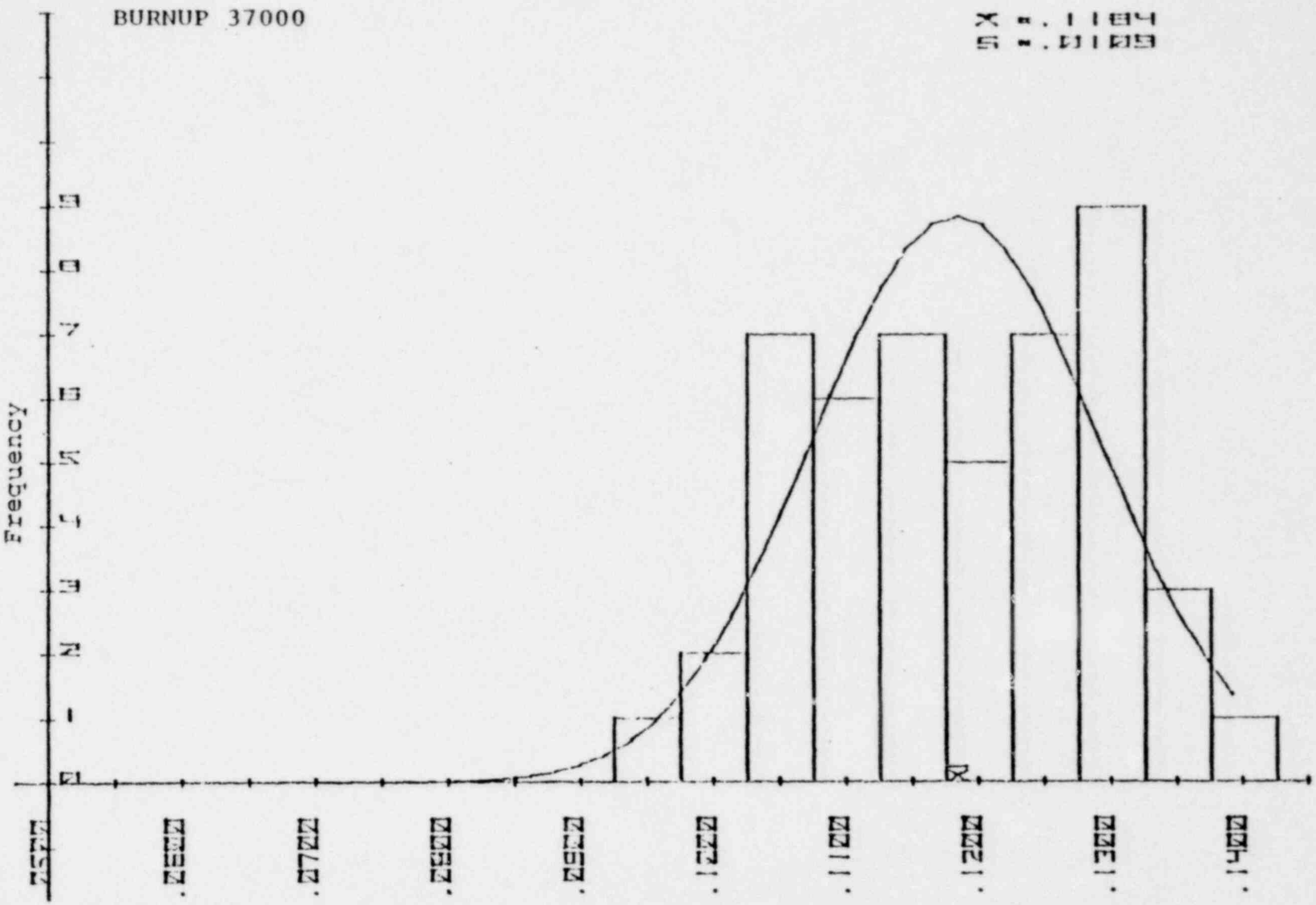


FIGURE 27 FREQUENCY HISTOGRAM OF ROD CLOSURE MEASUREMENTS FOR C ASSEMBLIES

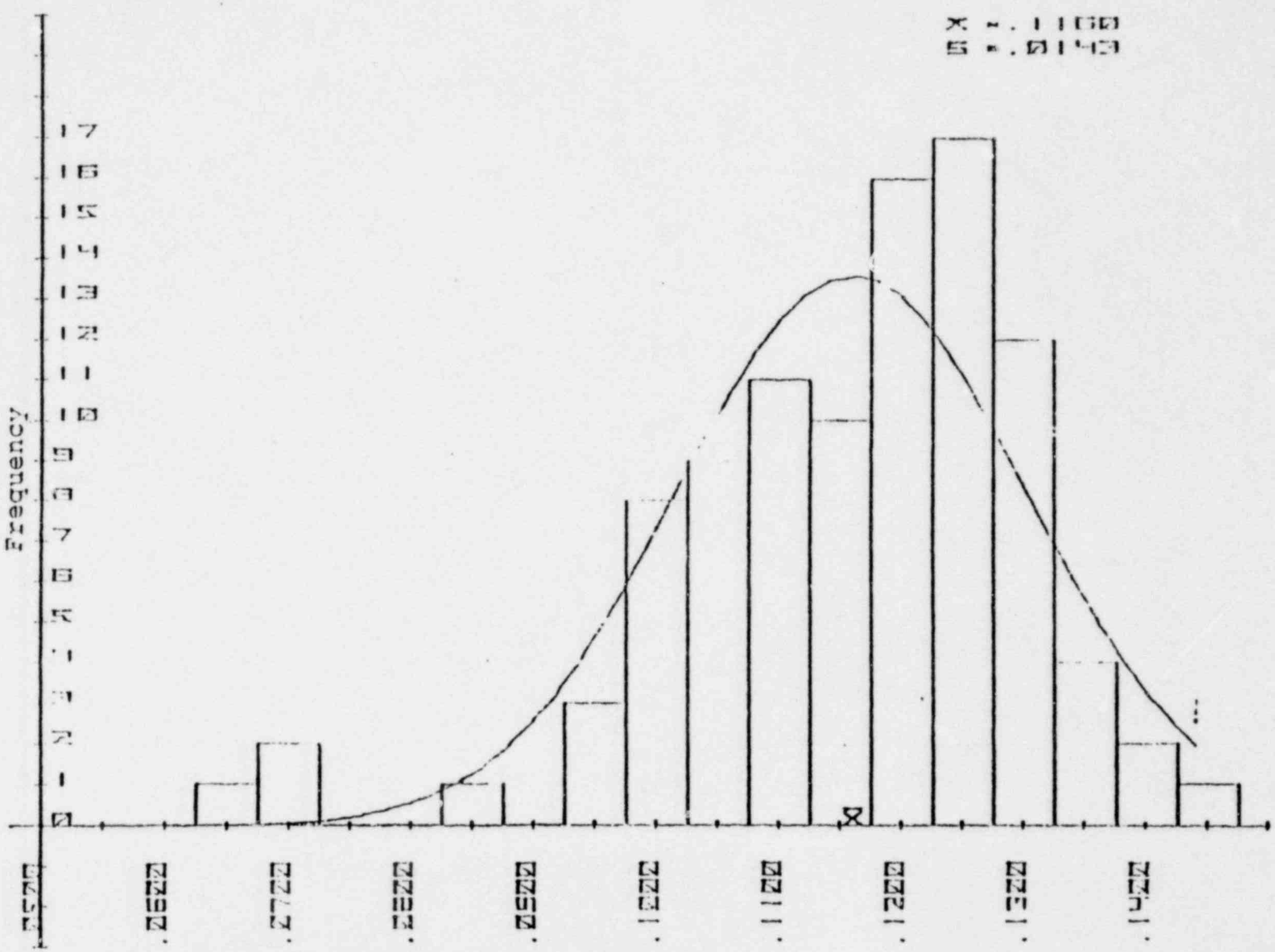


FIGURE 27a FREQUENCY HISTOGRAM OF ROD CLOSURE MEASUREMENTS FOR B & C ASSEMBLIES

1735 113

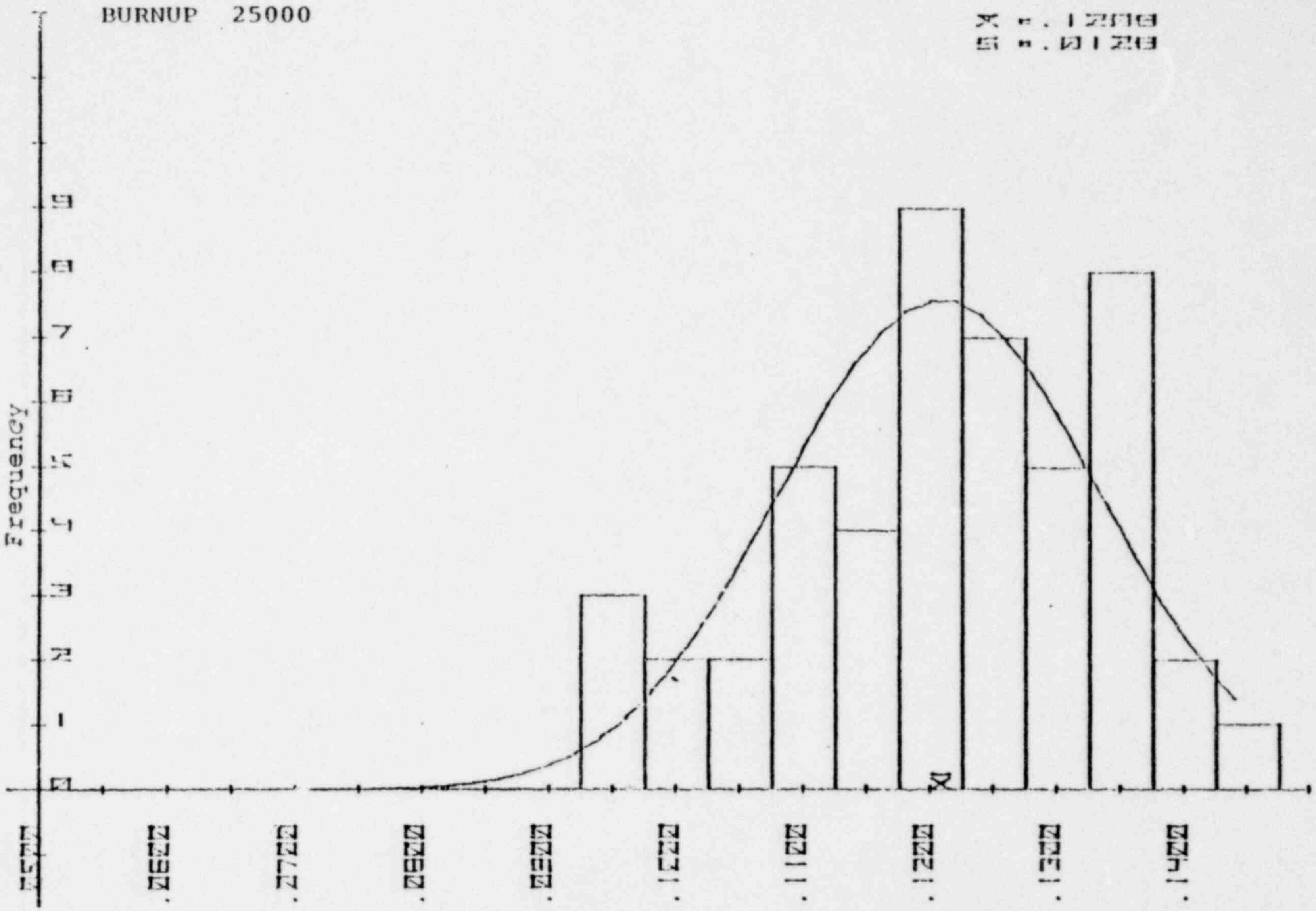


FIGURE 28 FREQUENCY HISTOGRAM OF ROD CLOSURE MEASUREMENTS FOR D ASSEMBLIES

1735 114

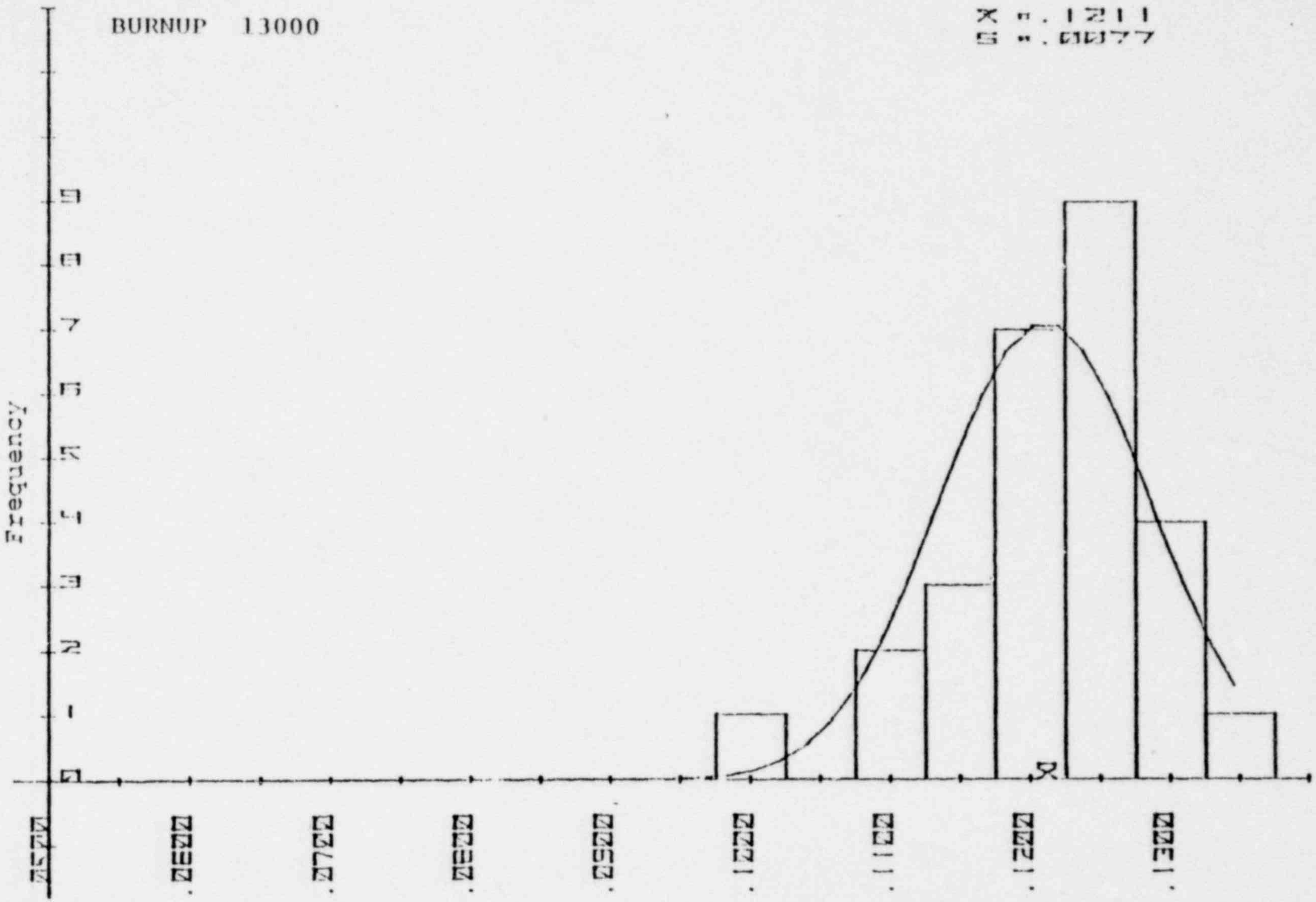


FIGURE 29 FREQUENCY HISTOGRAM OF ROD CLOSURE MEASUREMENTS FOR E ASSEMBLIES

1735 115

Rod Length (Uncorrected for Temperature)

Rod lengths were taken on each assembly face at specified locations. By predetermining which four rods were to be measured, the results should be interpreted as typical and not biased. The rod lengths measured for the seven assemblies are summarized in Table 11 and shown in Table 13.

TABLE 11

ROD LENGTH STATISTICAL RESULTS
(Uncorrected for Temperature)

Assembly
(inches)

Item	B	C	D	E	D* & E
X Max.	150.6078	150.4533	149.5699	149.5149	149.5149
X Min.	149.9967	149.5012	148.9369	148.9434	148.9021
Range	.6111	.9521	.6330	.5715	.6128
Mean	150.2978	150.1614	149.2556	149.1433	149.1206
Variance	.0128	.0568	.0253	.0363	.0264
Skewness	.2255	-1.5334	-0.3337	.7451	.8727
Kurtosis	141.5806	6.1971	62.3799	-2.7051	-81.1183
N	32	32	32	16	48

The mean rod length for the "B" assemblies was 150.2978 inches. This indicated an average rod growth for "B" assemblies during the first 3 Cycles of 0.928 inches (Cycles 1 and 2 growth, 0.682 inches and Cycle 3 growth of 0.246 inches) as compared

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* Results from 1978 examination after first cycle burnup. See discussion on page 77.

with an initial rod length of 149.370 ± 0.035 inches. Figure 30 is a frequency histogram of the measured rod lengths of the "B" assemblies and shows the standard deviation at the one sigma level to be 0.1146 inches. The mean rod length for the "C" assemblies was 150.1614 inches, which indicated an average rod growth during the first three cycles of 0.791 inches (Cycles 1 and 2 growth, 0.621 inches, Cycle 3 growth, 0.170 inches) as compared with the initial rod length of 149.370 ± 0.035 inches. Figure 31 is a frequency histrogram of the measured rod lengths of the "C" assemblies and shows the deviation at one sigma level to be 0.2383 inches. The mean rod length for the "D" assemblies (Figure 32) was 149.2556 inches, which indicated an average rod growth during its first two cycles of exposure of 0.665 inches (Cycle one growth, 0.518 inches) as compared with the initial fuel rod length of 148.591 inches. The mean rod length for the "E" assembly (Figure 33) is 149.1433, which indicated a growth during the first cycle of 0.497 inches as compared to an initial length of 148.646 inches.

Additionally, in order to increase the E assembly sample size, values measured on "D" assemblies during the 1978 inspection (at similar burnup 13000 MWD/MTU) were combined and analyzed with the measured values for the "E" assemblies. the mean rod length for this sample was 149.1206 inches with one sigma deviation of 0.1625 (Figure 34).

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The statistics and precision indices presented in Table 11 are general and apply to any type of frequency distribution. The third and fourth moments about the mean, skewness, and kurtosis, are presented mainly for completeness. Their values are very sensitive to the number of measurements (n) and unless n is large, the values are unreliable because of their high sensitivity to fluctuations in the tail regions of the distribution. With the exception of the measurements of the C assemblies, a chi square test (X_1^2) at the 95% confidence level indicated that the sets of measurements were normally distributed. However, if the 4 low measurements on Face 2 of C-06 are discounted, this set also appears to have a normal distribution.

To correct for temperature differential between the system qualification and the time of inspection, one has to consider both the temperature expansion of stainless steel and Zircaloy-4. The following formula can be used to correct for temperature:

$$\frac{\Delta L}{L_o} = (15.8 \times 10^{-6} \cdot \Delta T)^{*} - (-2.506 \times 10^{-5} \Delta T + 2.22 \times 10^{-6} (T_f^2 - T_o^2))^{**}$$

As shown in the above formula, to determine the rod length at 75°F, the correction factor for stainless steel encoder racks

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* Coefficient of thermal expansion for 304 Stainless Steel per °C.

** Coefficient of thermal expansion for Zircaloy -4 per °C, per p. 179, TREE-NUREG-1005, MATPRO-VERSION 09, A Handbook of Material Properties for Use in the Analysis of Light Water Reactor Rod Behavior.

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would be added and the correction factor for zircaloy rod expansion would be subtracted from the rod lengths taken at elevated temperatures.

Table 12 lists the temperature correction zircaloy that should be applied to the individual rod length measurements.

TABLE 12

TEMPERATURE CORRECTION FOR ROD LENGTH MEASUREMENTS

Assembly Number	Mesurement Temperature, °F	Correction Inches
B-41	93	-0.131
B-49	95	-0.150
C-23	95	-0.150
C-06	95	-0.150
D-11	95	-0.149
D-17	95	-0.149
E-38	97.5	-0.173

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TABLE 13

ROD LENGTH SUMMARY
(Uncorrected for Temperature)

Assembly Number	Rod No.	Face 1	Face 2	Face 3	Face 4
B-41	3	150.6078	150.2221	150.2151	150.3006
B-49		150.2496	150.2356	150.2856	150.3962
C-06		150.1840	149.6111	149.7546	150.1415
C-23		150.2971	150.2766	150.2941	150.2346
D-11		149.4129	149.5699	149.3368	149.4028
D-71		149.2442	148.9624	148.9815	149.2372
E-38		149.0816	148.9434	148.9579	149.3548
B-41	8	149.9967	150.2081	150.1996	150.2401
B-49		150.3222	150.4097	150.2471	150.4283
C-06		150.1916	149.7586	150.1435	150.1981
C-23		150.4002	150.3377	150.2696	150.2131
D-11		149.4023	149.1934	149.2957	149.3748
D-71		149.2507	149.1406	149.0565	149.3208
E-38		149.0725	149.3428	149.0605	149.3968
B-41	10	150.3292	150.2766	150.3722	150.2196
B-49		150.4453	150.4423	150.2376	150.1991
C-06		150.2436	149.6553	150.1445	150.1835
C-23		150.2771	150.3337	150.2396	150.2211
D-11		149.4103	148.9369	149.2937	149.3863
D-71		149.2412	149.3203	149.0130	149.1791
E-38		149.0986	148.9760	148.9880	149.4073
B-41	15	150.4268	150.3667	150.2466	150.1986
B-49		150.3087	150.1951	150.4193	150.2806
C-06		150.2891	149.5012	150.1325	150.1210
C-23		150.3667	150.4533	150.3312	150.3657
D-11		149.4199	149.5100	149.3518	149.3278
D-71		149.1576	149.0690	149.1731	149.2072
E-38		149.0165	149.0956	148.9859	149.5149

1735 120

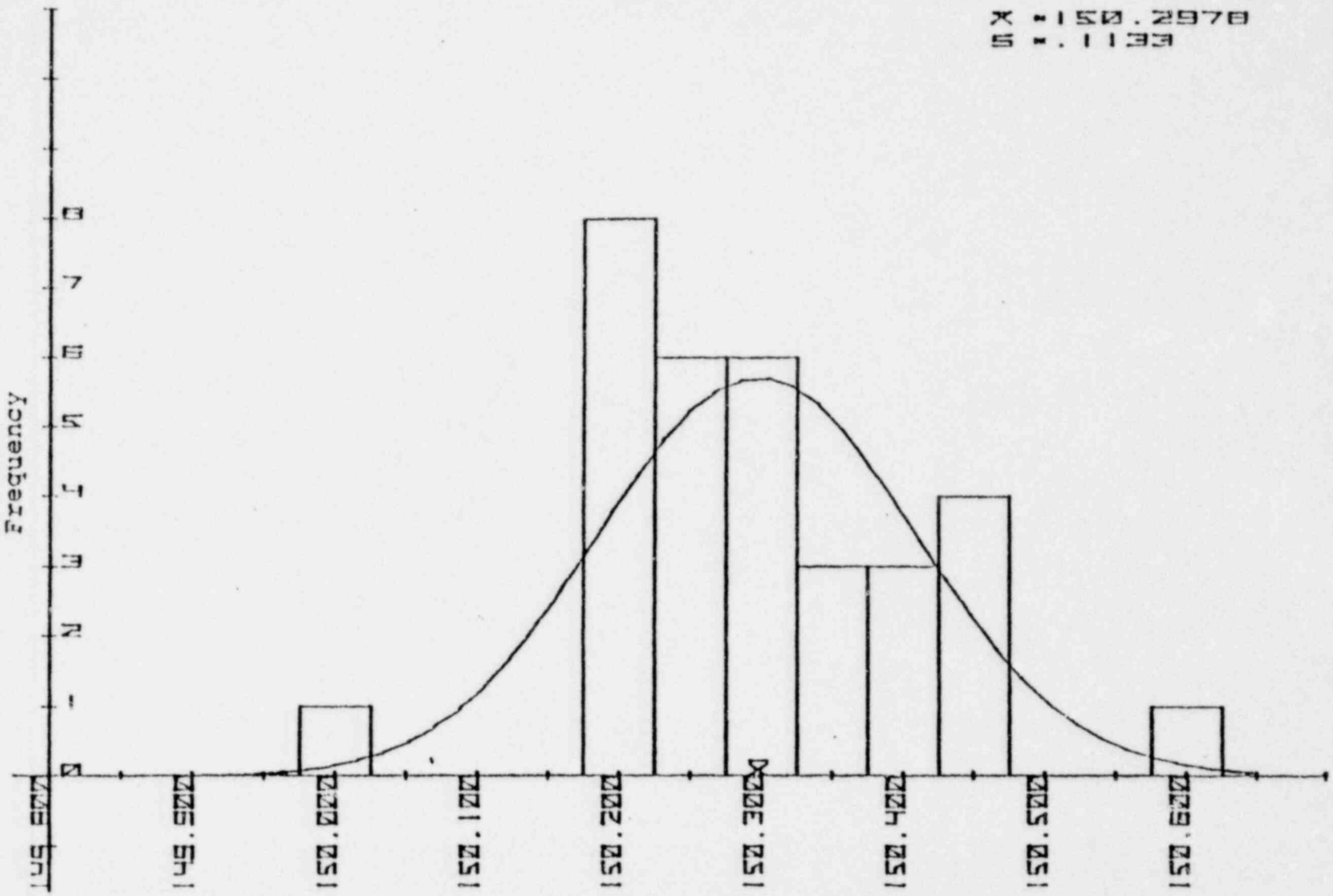

FIGURE 30 ROD LENGTH OF "B" ASSEMBLIES

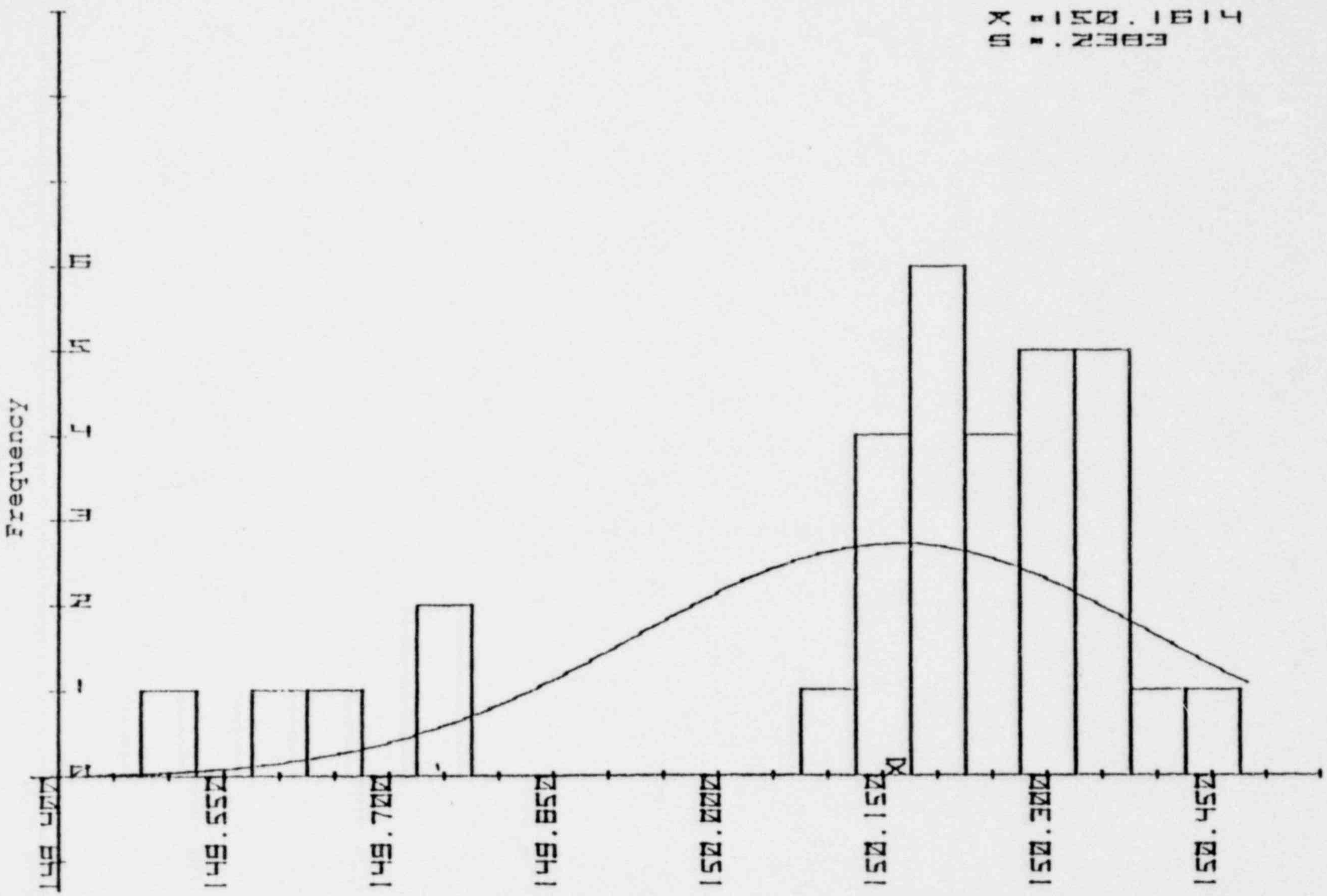

FIGURE 31 ROD LENGTH OF "C" ASSEMBLIES

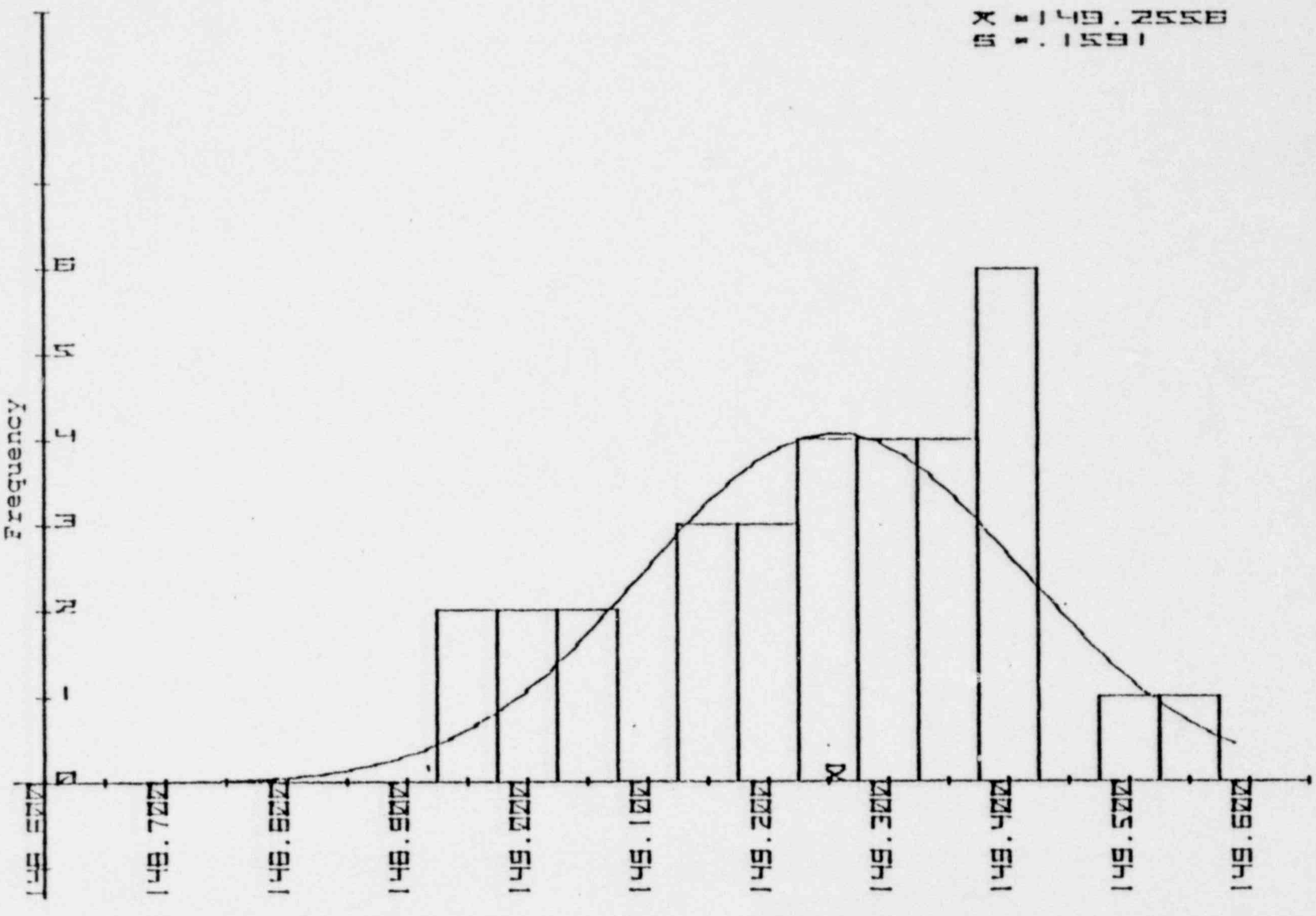

FIGURE 32 ROD LENGTH OF "D" ASSEMBLIES

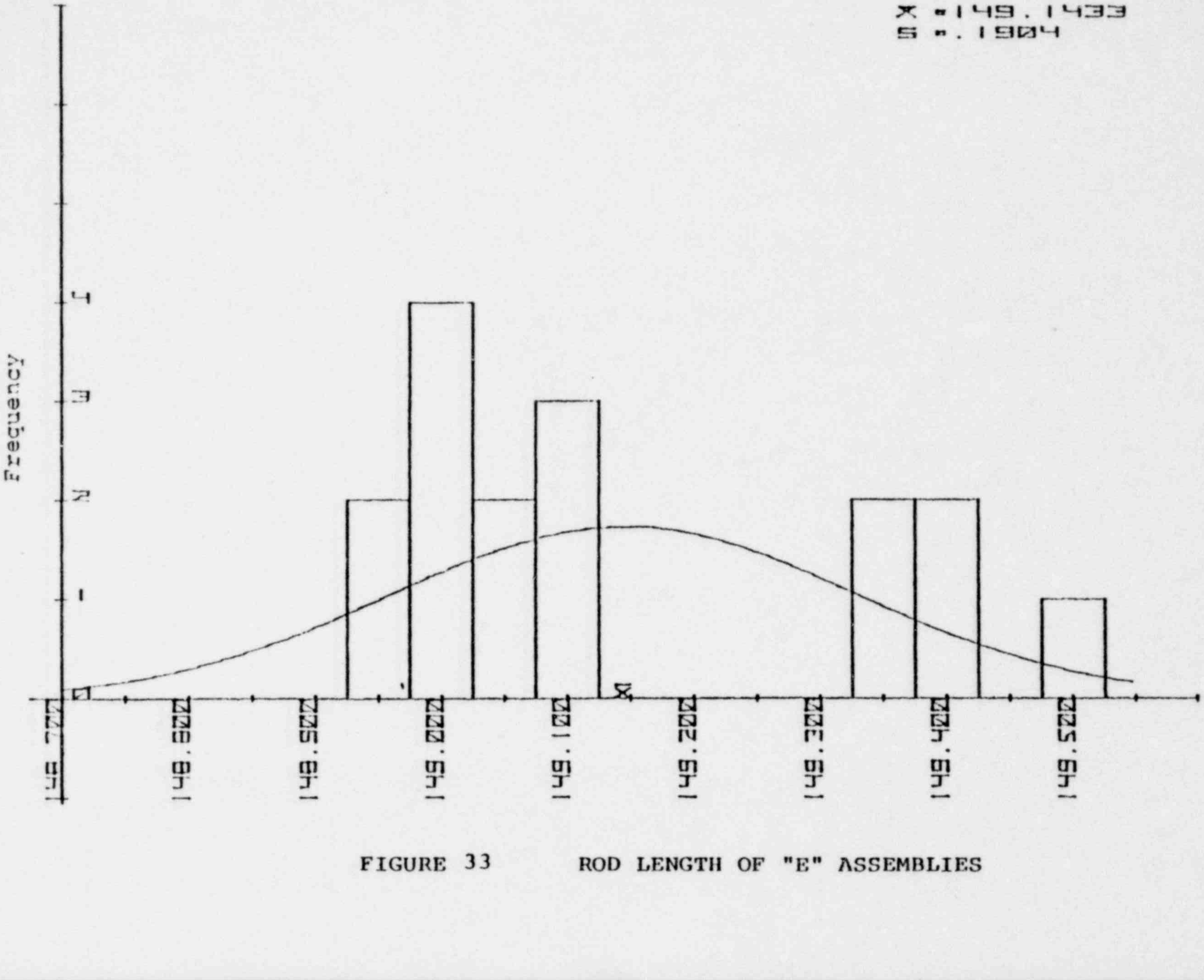

FIGURE 33 ROD LENGTH OF "E" ASSEMBLIES

1735 124

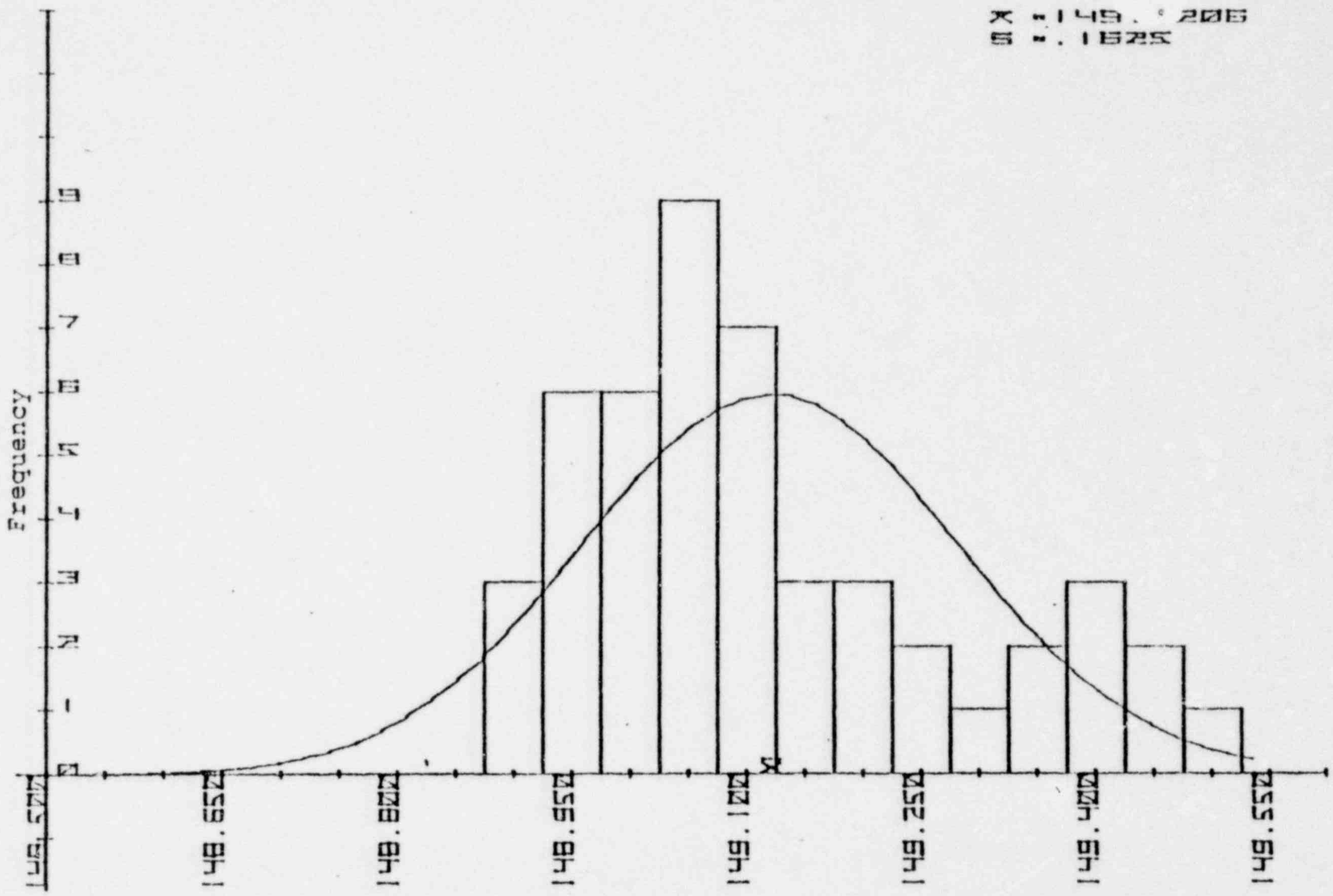

FIGURE 34 ROD LENGTH OF "D + E" ASSEMBLIES

1735 125

Assembly Bow

Table 14 is a summary of the assembly bow of individual assemblies measured. Figures 35 through 41 show the assembly bow of the individual faces measured. Assembly D-71 appeared to have the most significant bow on the face measured, .185 inches. No problems were encountered during the handling of assembly D-71 and subsequent placement of this assembly in to its designated spent fuel storage rack location. This bow measurement would be typical of the bowing seen when the assembly is free standing, i.e., in storage racks or in reactor core. During the movement of the assembly, the assembly is no longer free standing and, because of its elasticity, would have a tendency to straighten itself out and reduce the actual bow of the assembly.

TABLE 14

MAXIMUM ASSEMBLY BOW

	Inches
B-41	.118
B-49	.042
C-06	.163
C-23	.129*
D-11	.148
D-71	.185
E-38	.079

* 0.64 inches in positive direction and 0.65 inches in negative direction.

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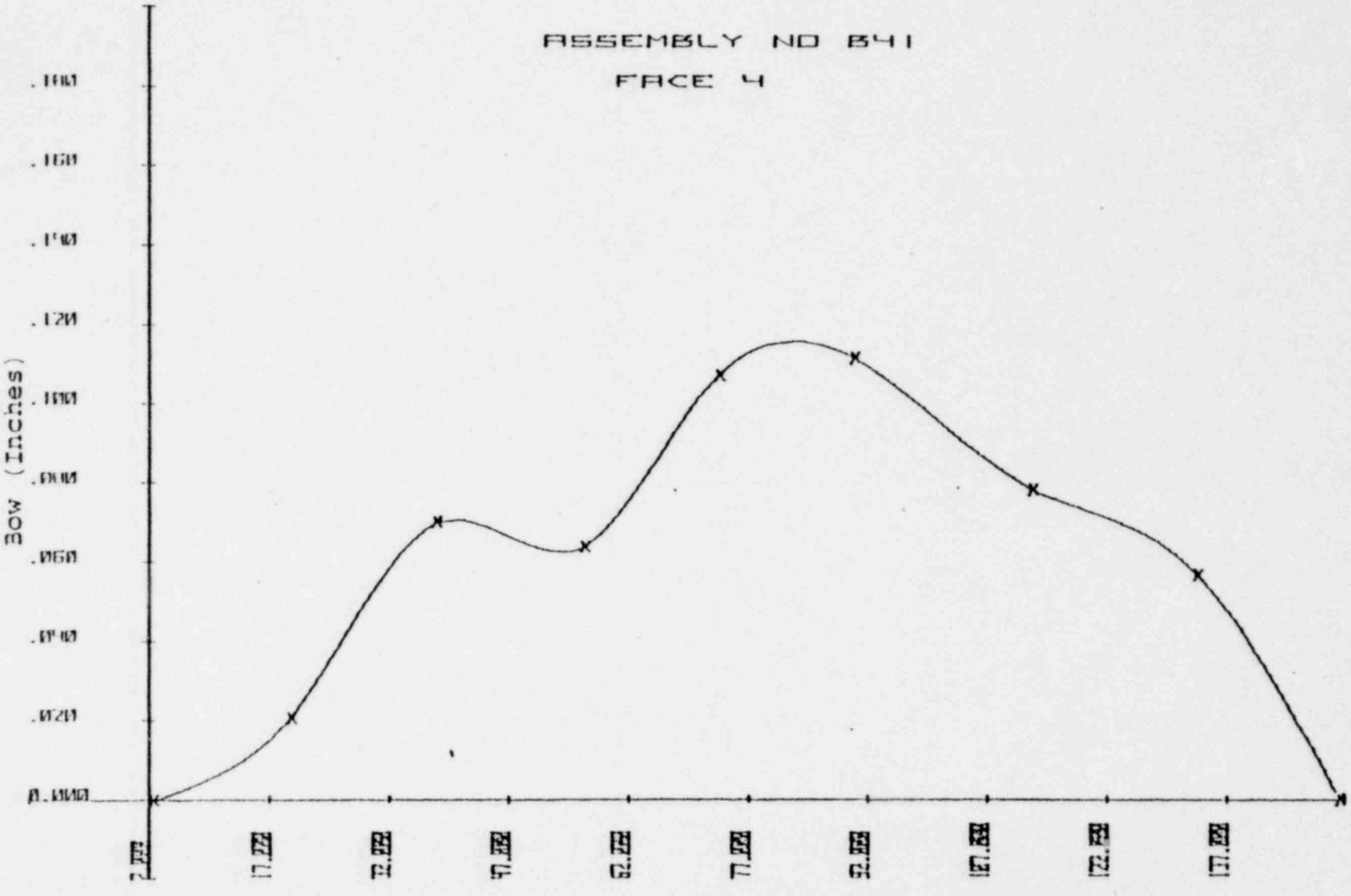

FIGURE 35 ASSEMBLY BOW OF FACE 4, ASSEMBLY B-41

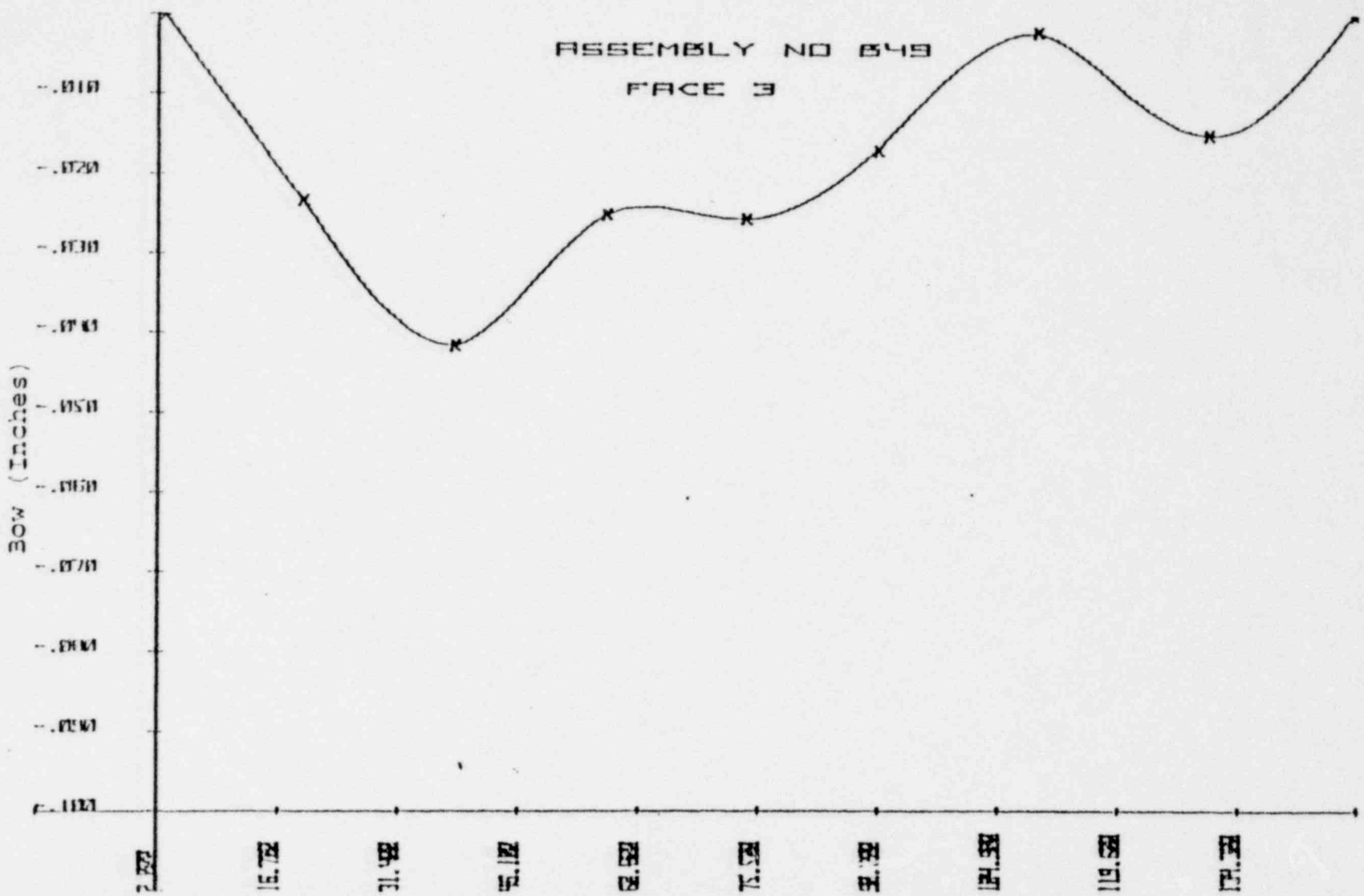

FIGURE 36 ASSEMBLY BOW OF FACE 3, ASSEMBLY B-49

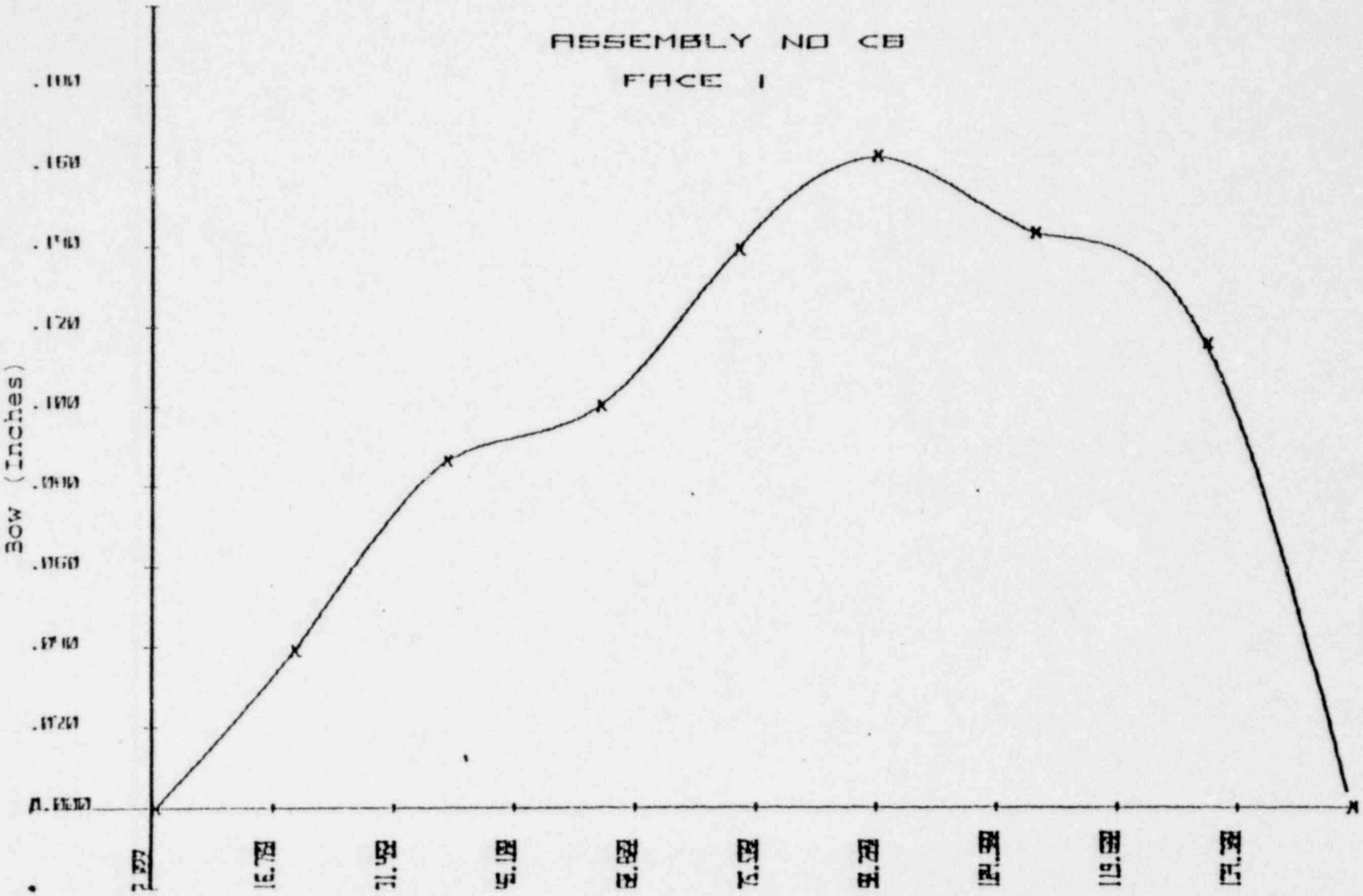

FIGURE 37 ASSEMBLY BOW OF FACE 1, ASSEMBLY C-06

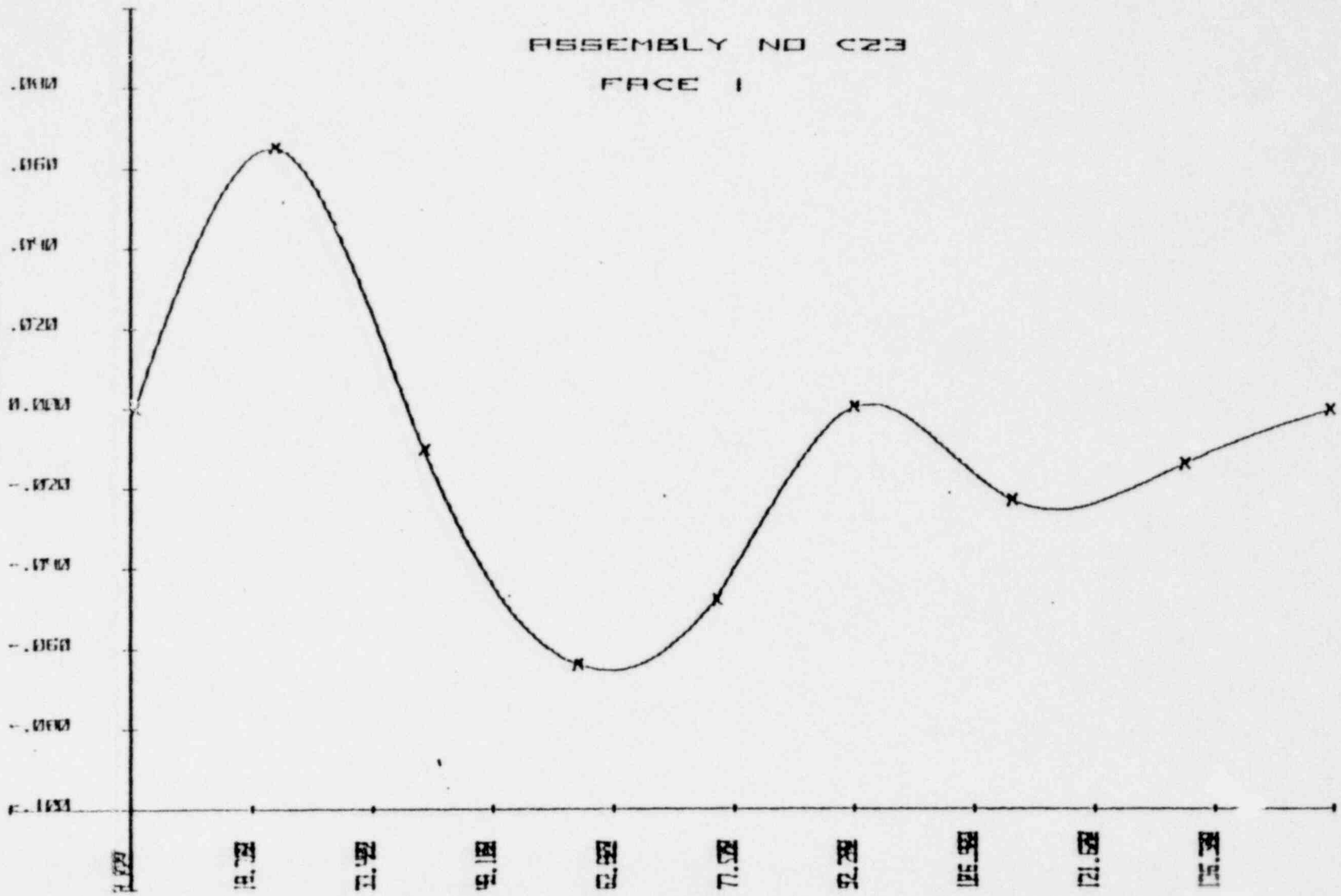

FIGURE 38 ASSEMBLY BOW OF FACE 1, ASSEMBLY C-23

1735 130

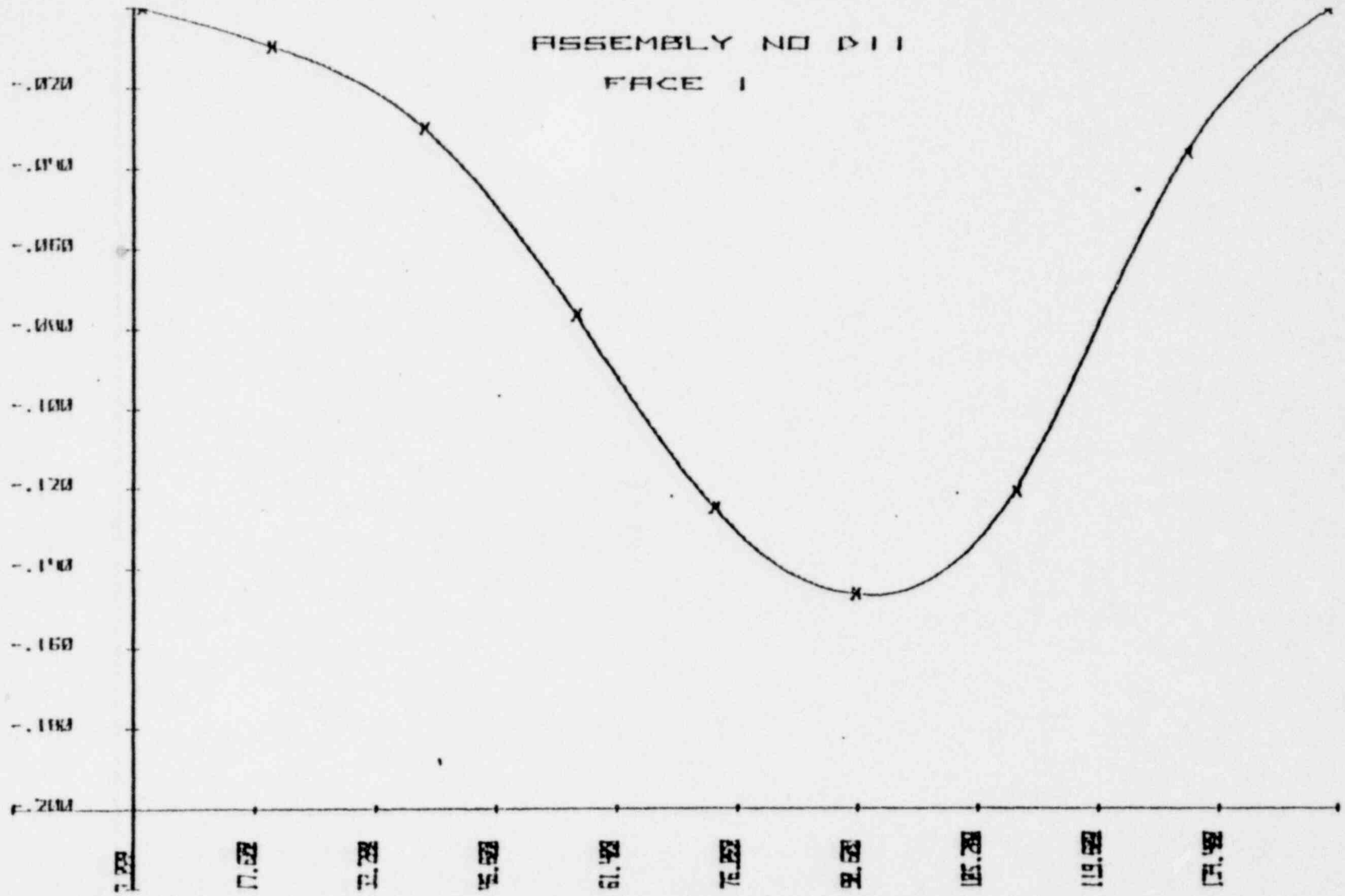

FIGURE 39 ASSEMBLY BOW OF FACE 1, ASSEMBLY D-11

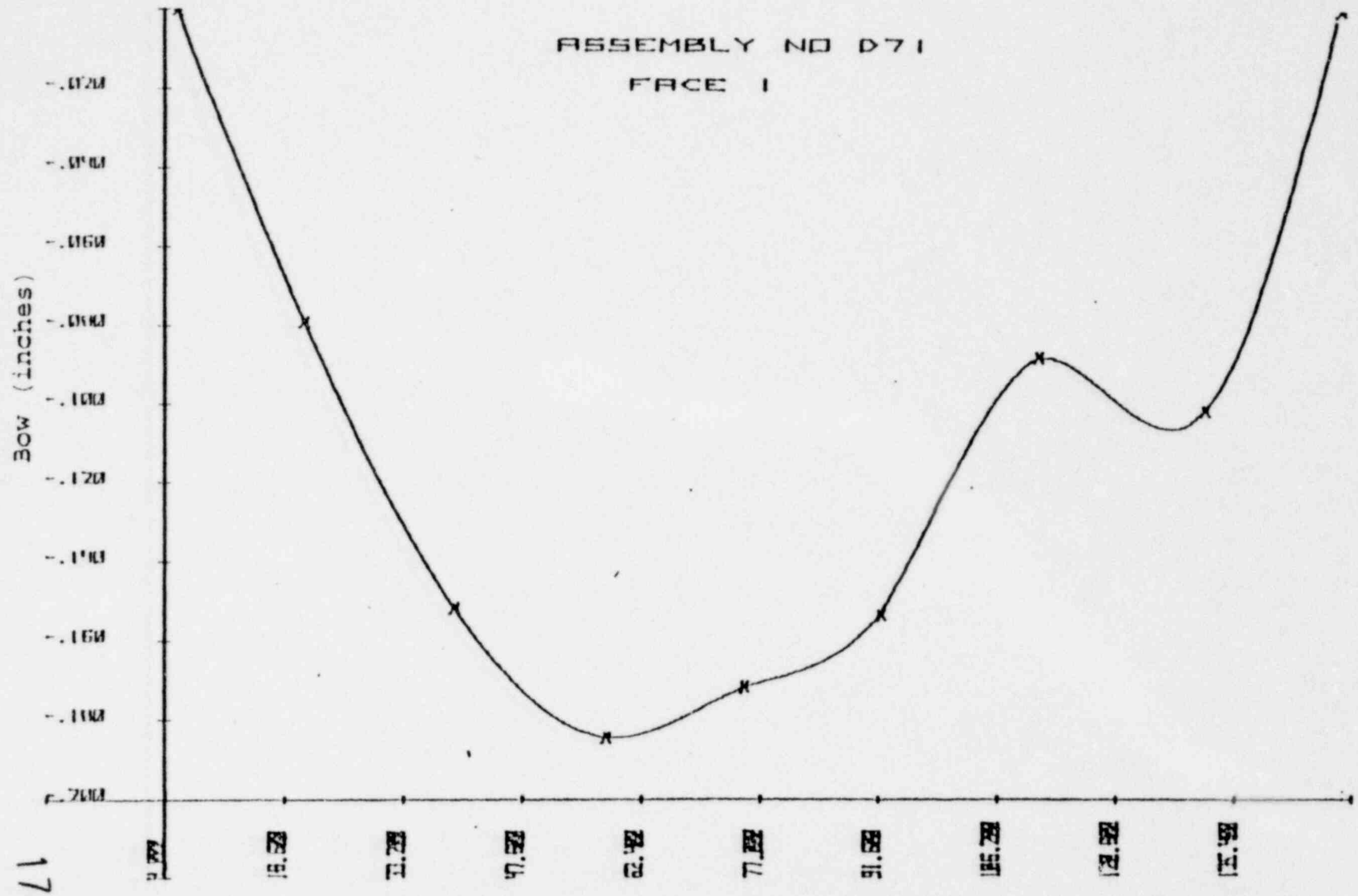

FIGURE 40 ASSEMBLY BOW OF FACE 1, ASSEMBLY D-71

1735 132

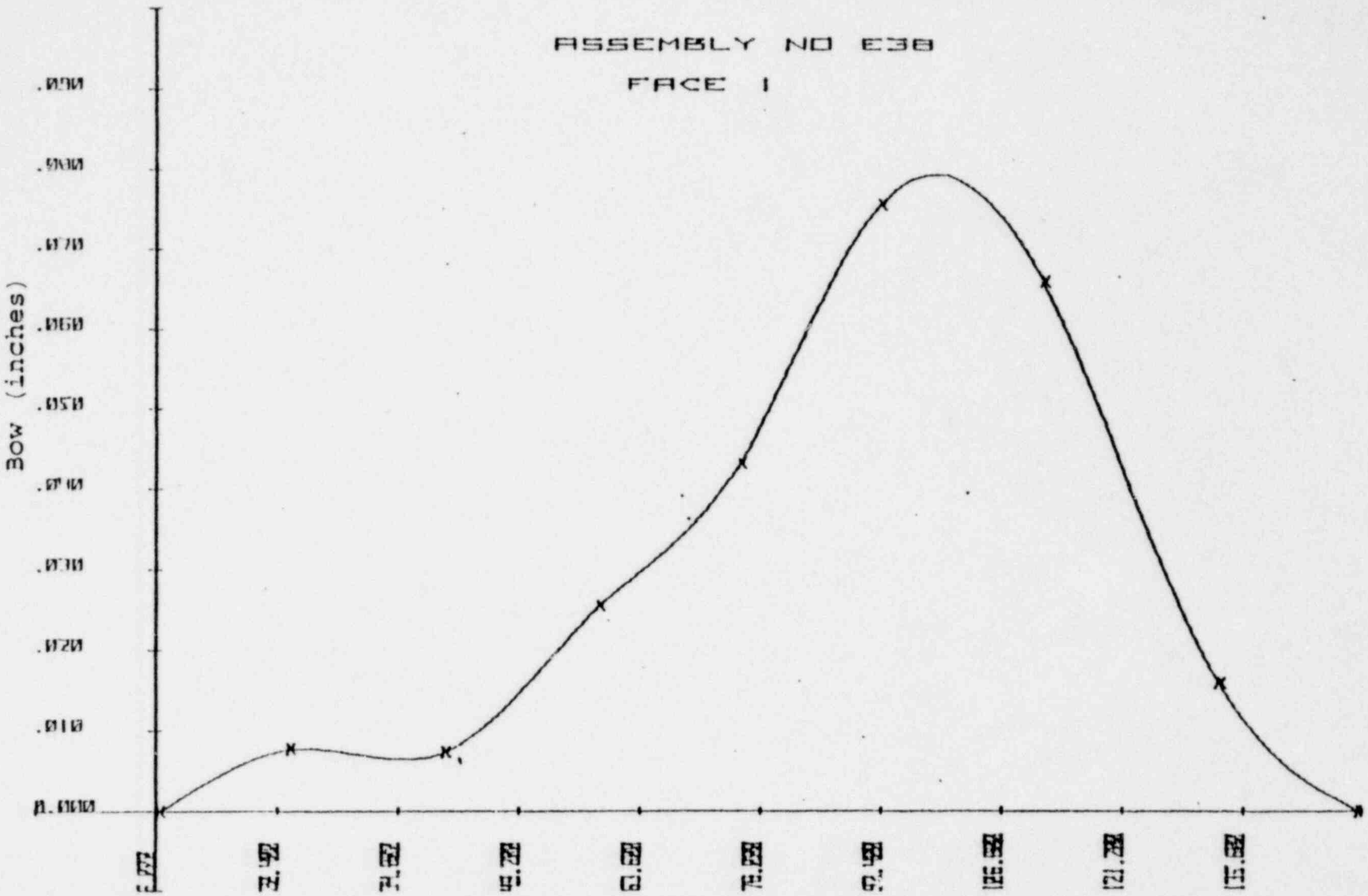

FIGURE 41 ASSEMBLY BOW OF FACE 1, ASSEMBLY E-38

1735 133

Guide Thimbles Length

Guide thimble length measurements were made on each face of the seven fuel assemblies inspected. The measured values are shown in Table 16 and summarized in Table 15.

TABLE 15

AVERAGE GUIDE THIMBLE LENGTHS MEASURED FOR THE 7 FUEL ASSEMBLIES EXAMINED

(Uncorrected for Temperature)

Assy. Type	Measured Guide Thimble Length (Inches)	Standard Deviation (One Sigma)	Design Value (Inches)
B	150.499	±0.056	150.417
C	150.557	±0.092	150.417
D	150.558	±0.117	150.577
E	150.858	±0.086	150.577

Using the existing system, it was impossible to measure the actual assembly length because both the upper and the lower nozzle are partially covered from the view of the television camera system. Because of the inability to measure actual assembly length, the distance between the two nozzles known as the guide thimble length was used. Thus, the actual assembly length for these assemblies would be measured guide thimble length, plus the known lengths of the upper and lower nozzles.* Since the guide thimbles and encoder racks are both stainless steel, no temperature correction was applied or is necessary.

*Combined upper and lower nozzle fabrication lengths are 9.683" for the B and C assemblies, and 9.518" for the D and E assemblies.

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TABLE 16

GUIDE THIMBLE LENGTH
(Uncorrected for Temperature)

Assembly No.	Face	Readings (Inches)
B-41	1	150.5774
B-41	2	150.5389
B-41	3	150.4633
B-41	4	150.4052
B-49	1	150.5304
B-49	2	150.5304
B-49	3	150.4963
B-49	4	150.4538
C-06	1	150.5544
C-06	2	150.4896
C-06	3	150.4978
C-06	4	150.4163
C-23	1	150.6588
C-23	2	150.6958
C-23	3	150.5462
C-23	4	150.5947
D-11	1	150.6324
D-11	2	150.5026
D-11	3	150.9670
D-11	4	150.5359
D-71	1	150.4658
D-71	2	150.4603
D-71	3	150.4618
D-71	4	150.4353
E-38	1	150.9585
E-38	2	150.8695
E-38	3	150.7478
E-38	4	150.8565

1735 135

Assembly Twist

Seven assembly twist measurements (one per assembly) were made during the examination. Table 17 summarizes these measurements and Table 18 shows the raw data. The maximum twist measured was 5.11°.

TABLE 17

INDIAN POINT #2 FUEL ASSEMBLY TWIST

Assembly No.	Degrees Twist
B-41	5.11
B-49	2.05
C-06	2.17
C-23	1.83
D-11	1.67
D-71	1.56
E-38	2.46

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TABLE 18 ASSEMBLY TWIST RAW DATA

ASSEMBLY NO	E 41	B 49	D 11	C 6	C 23	D 71	E 38
RAW DATA, X,Y LOWER	6.6214	8.4440	1.8617	7.4329	[illegible]	[illegible]	5.9685
	2.4300	.6011	3.4720	[illegible]	[illegible]	[illegible]	4.8874
UPPER	7.0961	8.6050	1.9773	7.6063	6.2345	[illegible]	6.1648
	148.5420	150.7420	150.4277	150.7325	150.3615	152.6880	150.5812
CORRT X LOWER	6.6814	8.5040	1.9264	7.4945	[illegible]	[illegible]	6.0251
UPPER	7.2181	8.7170	2.[illegible]	7.7201	6.3512	[illegible]	6.2[illegible]
TWIST (DEGREES)	5.1148	2.0536	1.6720	2.1720	1.8295	1.5[illegible]	2.[illegible]

POOR ORIGINAL

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