

Callaway Cycle 6

CDE-93-042

Callaway Cycle 6
Core Operating Limits Report
(Revision 4)

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1.0 CORE OPERATING LIMITS REPORT

This Core Operating Limits Report (COLR) for Callaway Plant Cycle 6 has been prepared in accordance with the requirements of Technical Specification 6.9.1.9.

The Core Operating Limits affecting the following Technical Specifications are included in this report.

- 3.1.1.3 Moderator Temperature Coefficient
- 3.1.3.5 Shutdown Rod Insertion Limit
- 3.1.3.6 Control Rod Insertion Limits
- 3.2.1 Axial Flux Difference
- 3.2.2 Heat Flux Hot Channel Factor
- 3.2.3 Nuclear Enthalpy Rise Hot Channel Factor
- 3.9.1 Refueling Boron Concentration

2.0 OPERATING LIMITS

The cycle-specific parameter limits for the specifications listed in Section 1.0 are presented in the subsections which follow. These limits have been developed using the NRC-approved methodologies specified in Technical Specification 6.9.1.9.

2.1 Moderator Temperature Coefficient (Specification 3.1.1.3)

- 2.1.1 The Moderator Temperature Coefficient shall be less positive than the limits shown in Figure 1. These limits shall be referred to as the Beginning of Cycle Life (BOL) Limit.

The Moderator Temperature Coefficient shall be less negative than $-41 \text{ pcm/}^{\circ}\text{F}$. This limit shall be referred to as the End of Cycle Life (EOL) Limit.

- 2.1.2 The MTC 300 ppm surveillance limit is $-32 \text{ pcm/}^{\circ}\text{F}$ (all rods withdrawn, Rated Thermal Power condition).

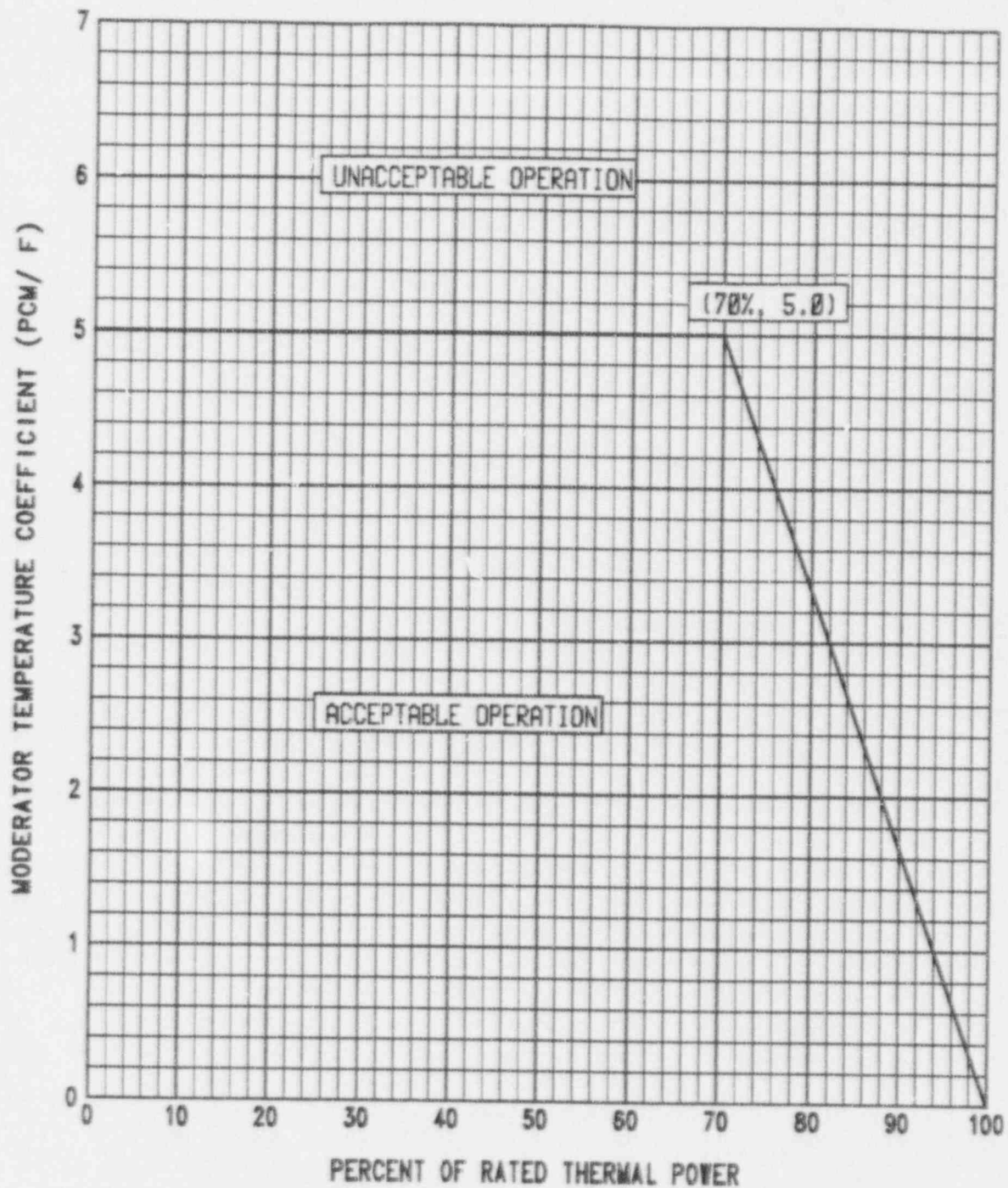


FIGURE 1

CALLAWAY UNIT 1 CYCLE 6

MODERATOR TEMPERATURE COEFFICIENT VS POWER LEVEL

2.2 Shutdown Rod Insertion Limits (Specification 3.1.3.5)

The shutdown rods shall be withdrawn to at least 225 steps.

2.3 Control Rod Insertion Limits (Specification 3.1.3.6)

The Control Bank Insertion Limits are specified by Figure 2.

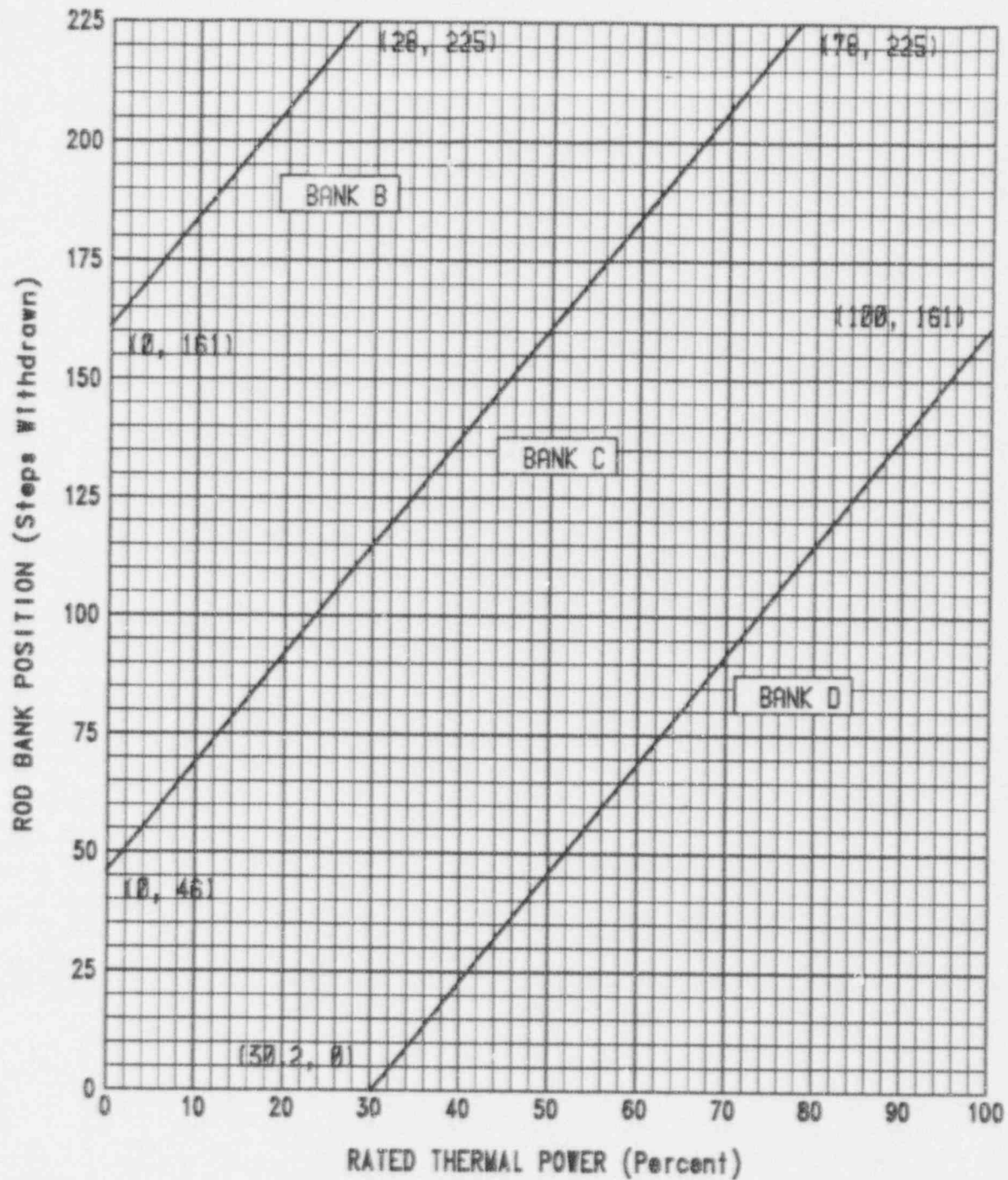


FIGURE 2

CALLAWAY UNIT 1 CYCLE 6
 ROD BANK INSERTION LIMITS VERSUS
 RATED THERMAL POWER - FOUR LOOP OPERATION

2.4 Axial Flux Difference (Specification 3.2.1)

- 2.4.1 The Axial Flux Difference (AFD) Limits are provided in Figure 3.
- 2.4.2 The target band during Restricted AFD Operation is $\pm 3\%$. The AFD limits provided in Figure 3 also remain applicable during Restricted AFD Operation.
- 2.4.3 The minimum allowable power level for Restricted AFD Operation, APL^{ND} , is 90% of RATED THERMAL POWER.

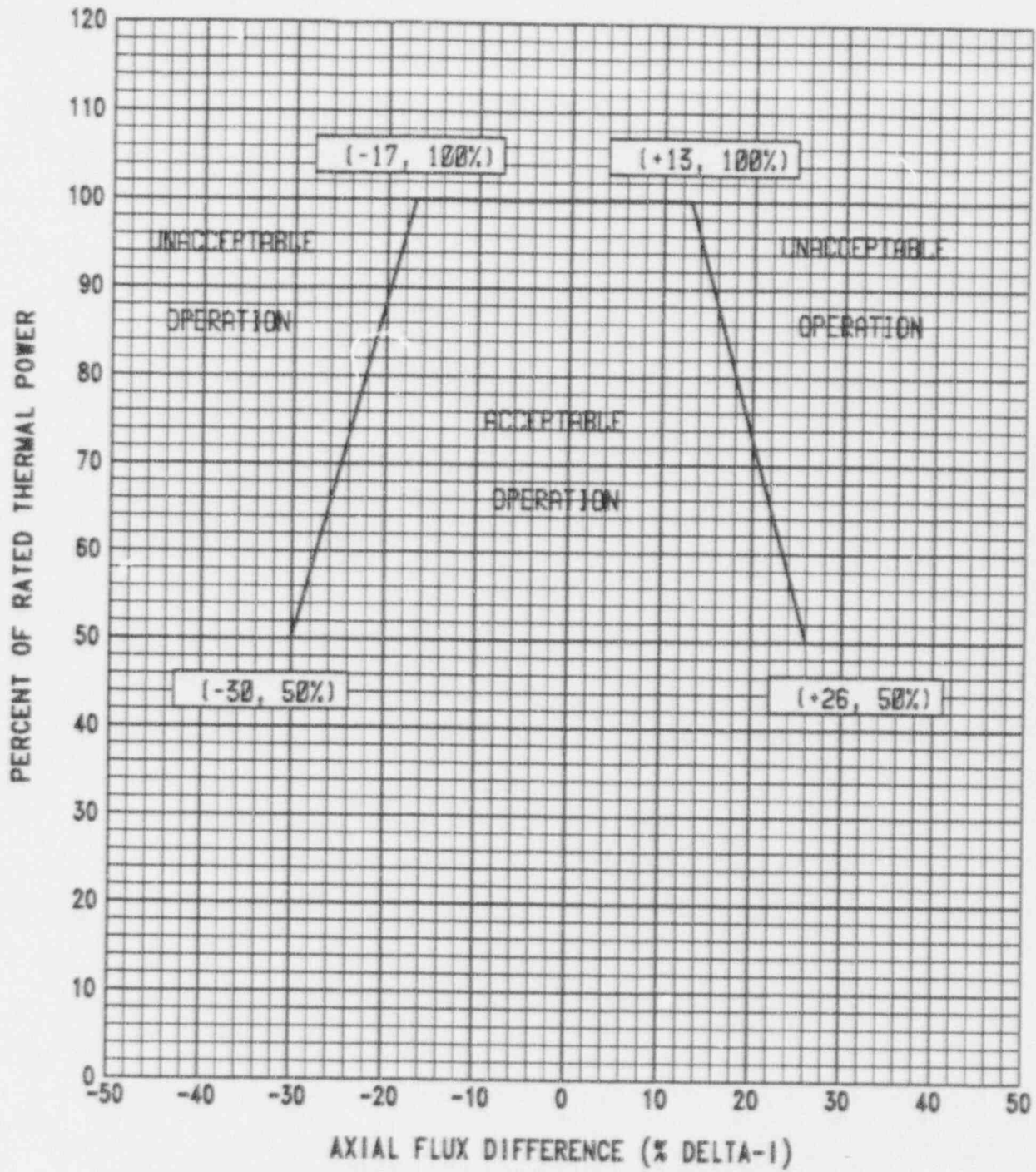


FIGURE 3

CALLAWAY UNIT 1 CYCLE 6
AXIAL FLUX DIFFERENCE LIMITS AS A FUNCTION OF
RATED THERMAL POWER FOR RAOC

2.5 Heat Flux Hot Channel Factor - $F_Q(Z)$
(Specification 3.2.2)

$$F_Q(Z) \leq \frac{F_Q^{RTP}}{P} * K(Z) \quad \text{for } P > 0.5$$

$$F_Q(Z) \leq \frac{F_Q^{RTP}}{0.5} * K(Z) \quad \text{for } P \leq 0.5$$

where: $P = \frac{\text{THERMAL POWER}}{\text{RATED THERMAL POWER}}$

2.5.1 $F_Q^{RTP} = 2.50$

2.5.2 $K(Z)$ is provided in Figure 4.

2.5.3 The $W(z)$ functions that are to be used in Technical Specifications 4.2.2.2, 4.2.2.3, and 4.2.2.4 for F_Q surveillance are shown in Figures 5 through 31.

The Normal Operation $W(z)$ values have been determined for several burnups up to 16000 MWD/MTU in Cycle 6. This permits determination of $W(z)$ at any cycle burnup up to 16000 MWD/MTU through the use of three point interpolation. For cycle burnups greater than 16000 MWD/MTU, use of the 16000 MWD/MTU $W(z)$ values without interpolation or extrapolation is conservative. The $W(z)_{NO}$ values were determined assuming Cycle 6 operates with the RAOC strategy. The appropriate $W(z)_{NO}$ functions for interpolation should be chosen based on the measured steady state axial offset.

The Restricted AFD Operation $W(z)$ values, $W(z)_{RAFD}$, have been determined for several burnups up to 18000 MWD/MTU in Cycle 6. This permits determination of $W(z)$ at any cycle burnup up to 18000 MWD/MTU through the use of 3 point interpolation. For cycle burnups greater than 18000 MWD/MTU, use of the 18000 MWD/MTU $W(z)$ values without interpolation or extrapolation is conservative.

The $W(z)$ values are provided for 73 axial points assuming the core height boundaries of 0 and 12 feet and intervals of .167 feet between the core boundaries.

2.6 Nuclear Enthalpy Rise Hot Channel Factor - $F_{\Delta H}^N$
(Specification 3.2.3)

$$F_{\Delta H}^N \leq F_{\Delta H}^{RTP} [1 + PF_{\Delta H}(1-P)]$$

where: $P = \frac{\text{THERMAL POWER}}{\text{RATED THERMAL POWER}}$

2.6.1 $F_{\Delta H}^{RTP} = 1.59$

2.6.2 $PF_{\Delta H} = 0.3$

2.7 Refueling Boron Concentration
(Specification 3.9.1)

2.7.1 The refueling boron concentration to maintain $K_{\text{eff}} \leq 0.95$ shall be ≥ 2000 ppm.

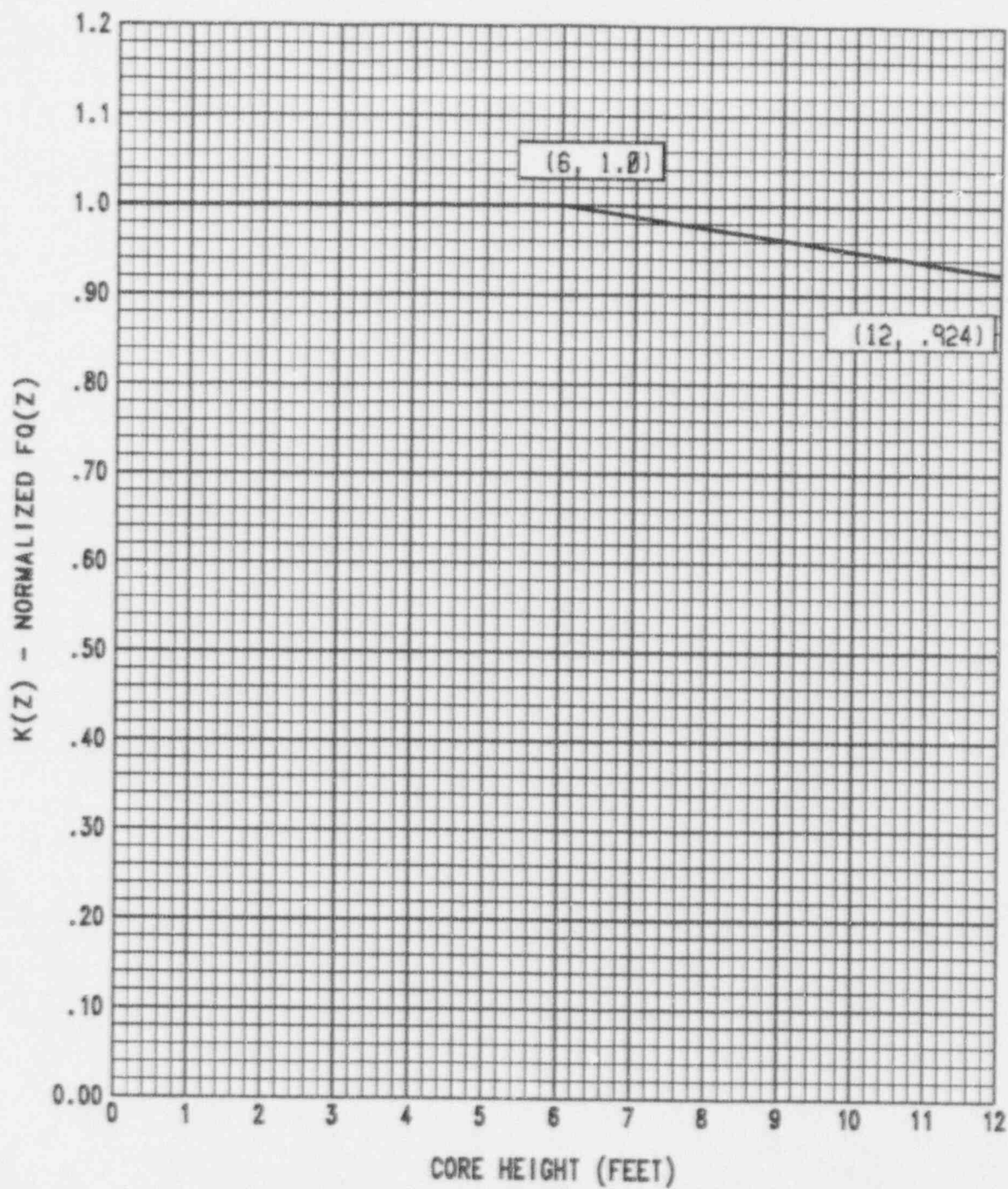
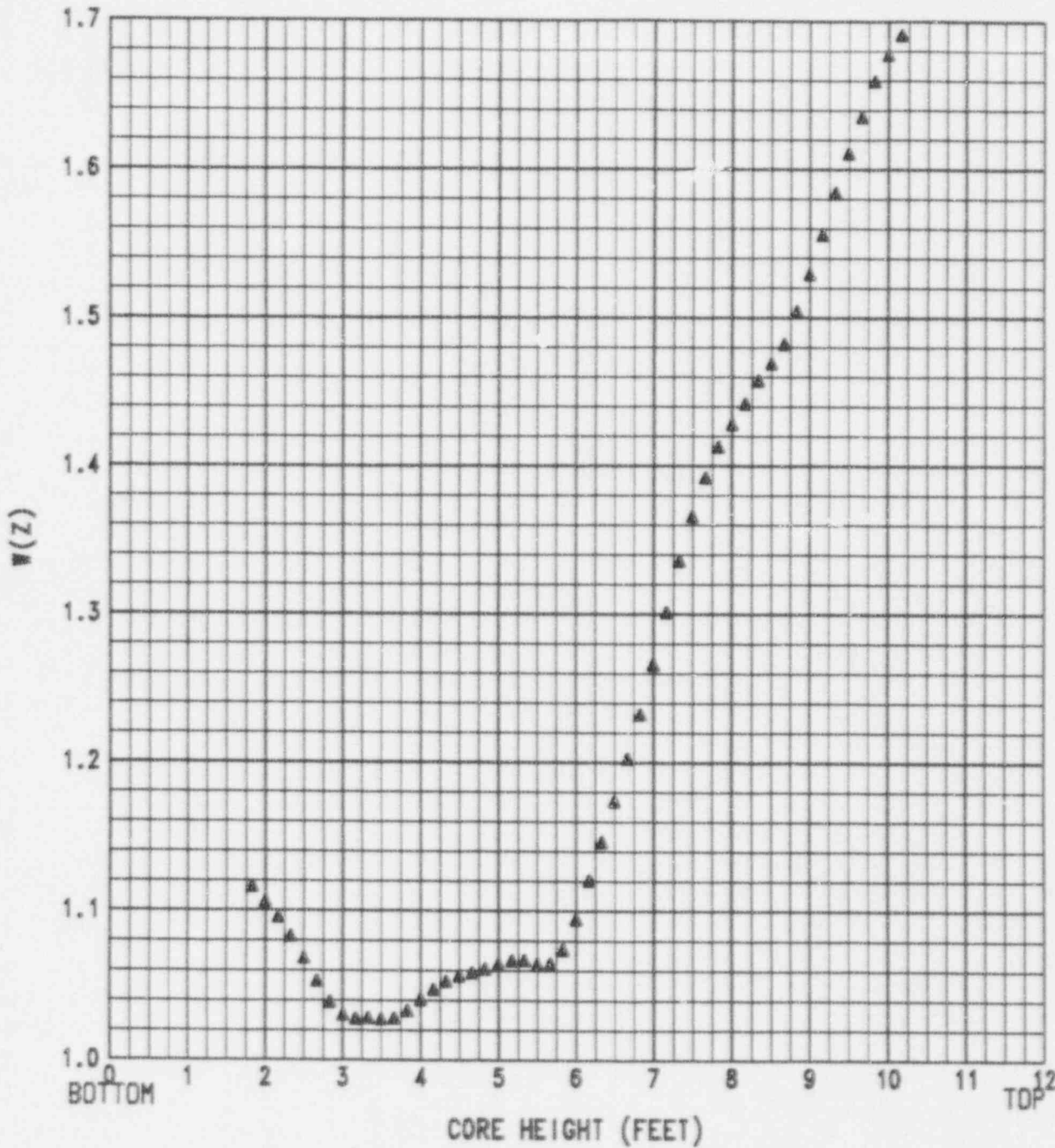


FIGURE 4

CALLAWAY UNIT 1 CYCLE 6

 $K(Z) - \text{NORMALIZED } FQ(Z)$ AS A FUNCTION OF CORE HEIGHT



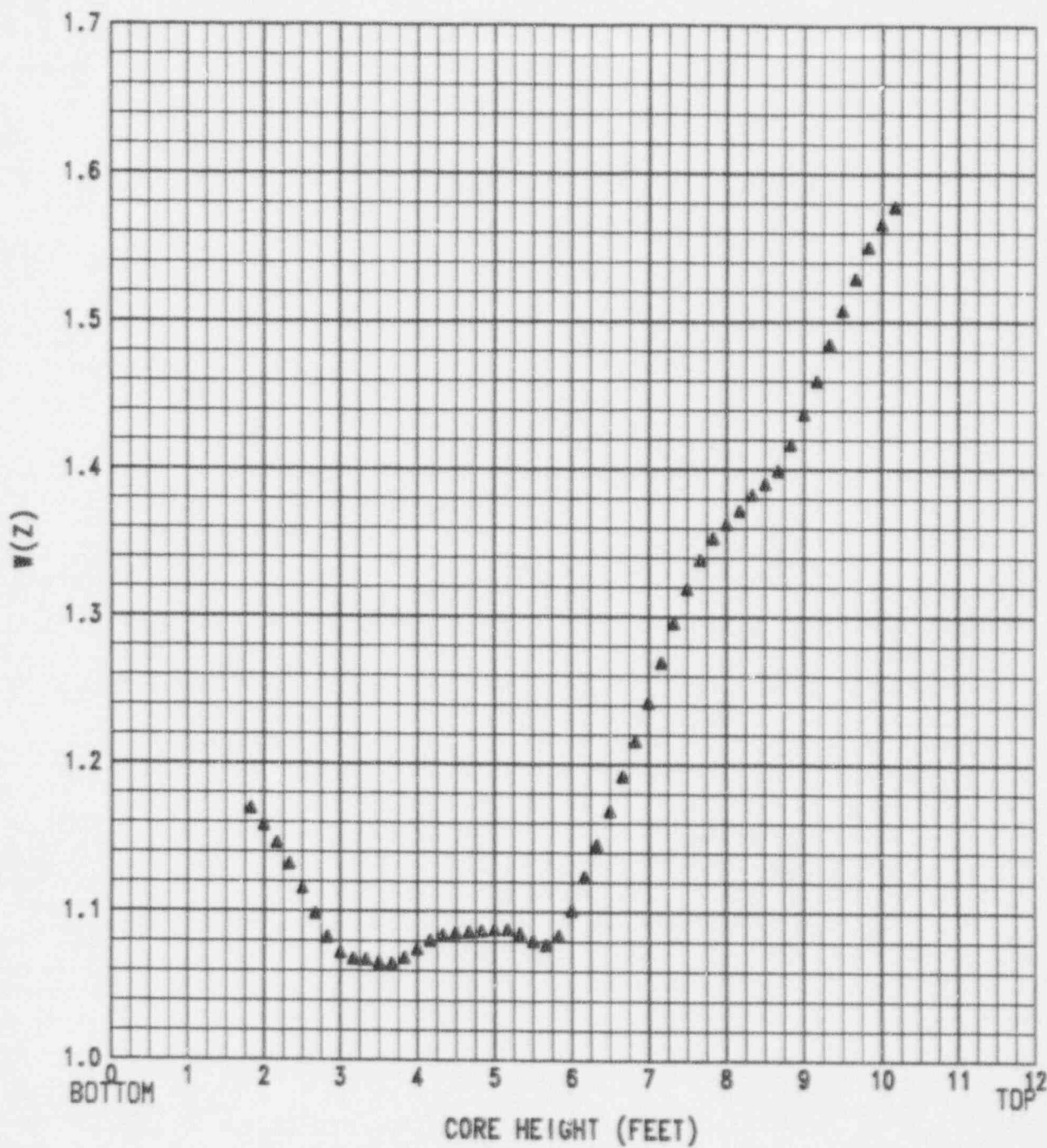
HEIGHT (FEET)	-16 AD W(Z)
* 0.000	1.0000
* 0.167	1.0000
* 0.333	1.0000
* 0.500	1.0000
* 0.667	1.0000
* 0.833	1.0000
* 1.000	1.0000
* 1.167	1.0000
* 1.333	1.0000
* 1.500	1.0000
* 1.667	1.0000
1.833	1.1181
2.000	1.1080
2.167	1.0958
2.333	1.0829
2.500	1.0683
2.667	1.0529
2.833	1.0390
3.000	1.0305
3.167	1.0277
3.333	1.0254
3.500	1.0278
3.667	1.0280
3.833	1.0331
4.000	1.0404
4.167	1.0473
4.333	1.0527
4.500	1.0582
4.667	1.0584
4.833	1.0610
5.000	1.0643
5.167	1.0686
5.333	1.0669
5.500	1.0646
5.667	1.0648
5.833	1.0740
6.000	1.0845
6.167	1.1205
6.333	1.1483
6.500	1.1738
6.667	1.2024
6.833	1.2323
7.000	1.2680
7.167	1.3010
7.333	1.3356
7.500	1.3657
7.667	1.3920
7.833	1.4128
8.000	1.4279
8.167	1.4420
8.333	1.4577
8.500	1.4681
8.667	1.4822
8.833	1.5042
9.000	1.5281
9.167	1.5557
9.333	1.5848
9.500	1.6107
9.667	1.6353
9.833	1.6597
10.000	1.6775
10.167	1.6908
* 10.333	1.0000
* 10.500	1.0000
* 10.667	1.0000
* 10.833	1.0000
* 11.000	1.0000
* 11.167	1.0000
* 11.333	1.0000
* 11.500	1.0000
* 11.667	1.0000
* 11.833	1.0000
* 12.000	1.0000

FIGURE 5

CALLAWAY UNIT 1 CYCLE 6

W(Z) AT 8000 MW'D/MTU (Measured A.O. = -16% +/- 2%)
NO

* Top and bottom 15% excluded as per Tech Spec 4.2.2.2G



HEIGHT (FEET)	-12 AD W(Z)
* 0.000	1.0000
* 0.167	1.0000
* 0.333	1.0000
* 0.500	1.0000
* 0.667	1.0000
* 0.833	1.0000
* 1.000	1.0000
* 1.167	1.0000
* 1.333	1.0000
* 1.500	1.0000
* 1.667	1.0000
1.833	1.1882
2.000	1.1580
2.167	1.1481
2.333	1.1318
2.500	1.1155
2.667	1.0984
2.833	1.0828
3.000	1.0723
3.167	1.0680
3.333	1.0676
3.500	1.0656
3.667	1.0647
3.833	1.0688
4.000	1.0748
4.167	1.0802
4.333	1.0841
4.500	1.0852
4.667	1.0881
4.833	1.0888
5.000	1.0878
5.167	1.0878
5.333	1.0855
5.500	1.0805
5.667	1.0776
5.833	1.0840
6.000	1.1012
6.167	1.1236
6.333	1.1454
6.500	1.1682
6.667	1.1917
6.833	1.2156
7.000	1.2420
7.167	1.2691
7.333	1.2957
7.500	1.3188
7.667	1.3388
7.833	1.3533
8.000	1.3630
8.167	1.3718
8.333	1.3828
8.500	1.3901
8.667	1.3991
8.833	1.4168
9.000	1.4375
9.167	1.4598
9.333	1.4848
9.500	1.5078
9.667	1.5281
9.833	1.5506
10.000	1.5881
10.167	1.5776
* 10.333	1.0000
* 10.500	1.0000
* 10.667	1.0000
* 10.833	1.0000
* 11.000	1.0000
* 11.167	1.0000
* 11.333	1.0000
* 11.500	1.0000
* 11.667	1.0000
* 11.833	1.0000
* 12.000	1.0000

FIGURE 6

CALLAWAY UNIT 1 CYCLE 6

W(Z)_{NO} AT 8000 MWD/MTU (Measured A.O. = -12% +/- 2%)

* Top and bottom 15% excluded as per Tech Spec 4.2.2.2G

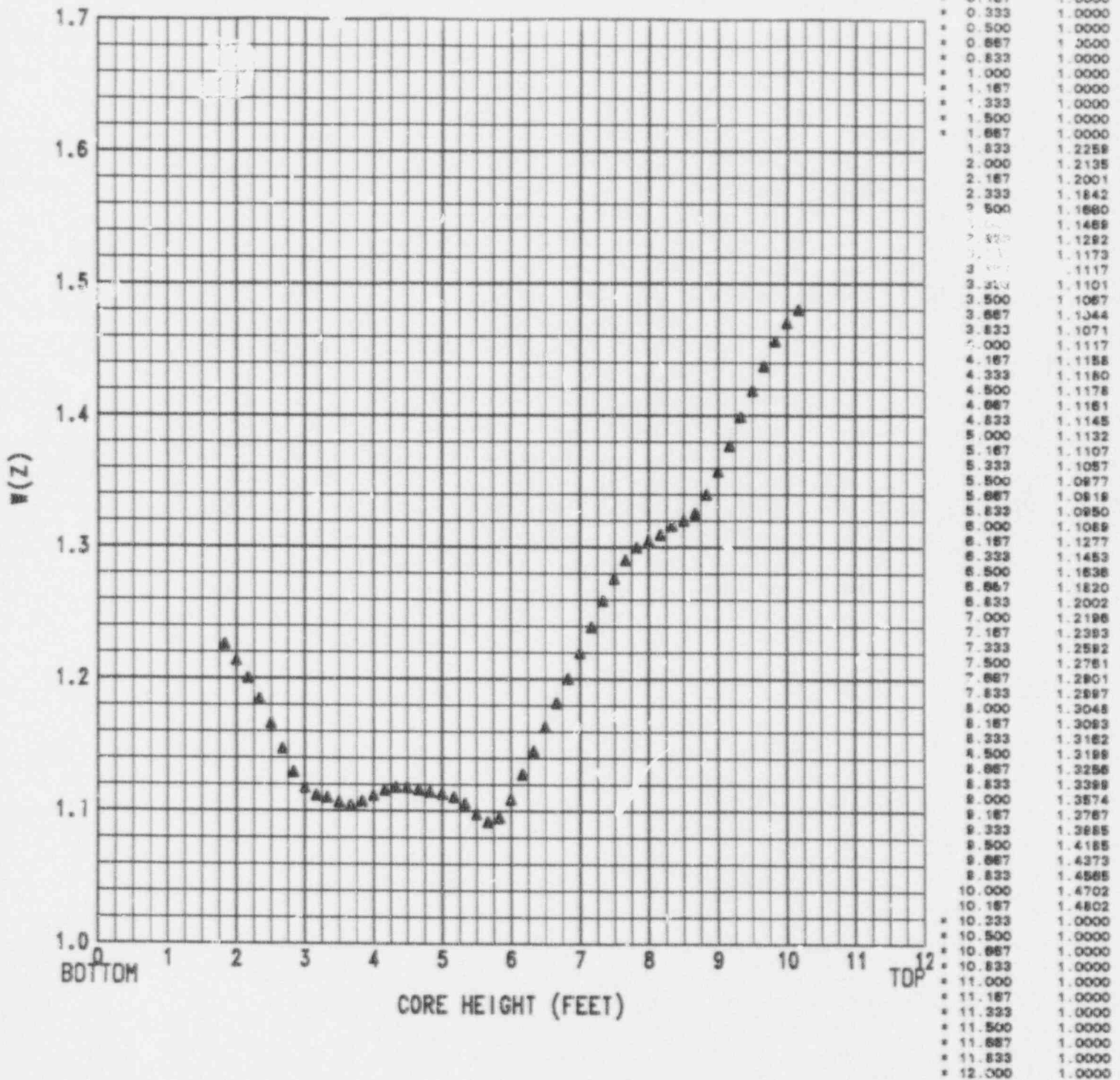


FIGURE 7

CALLAWAY UNIT 1 CYCLE 6

W(Z)_{NO} AT 8000 MWD/MTU (Measured A.O. = -8% +/- 2%)

* Top and bottom 15% excluded as per Tech Spec 4.2.2.2G

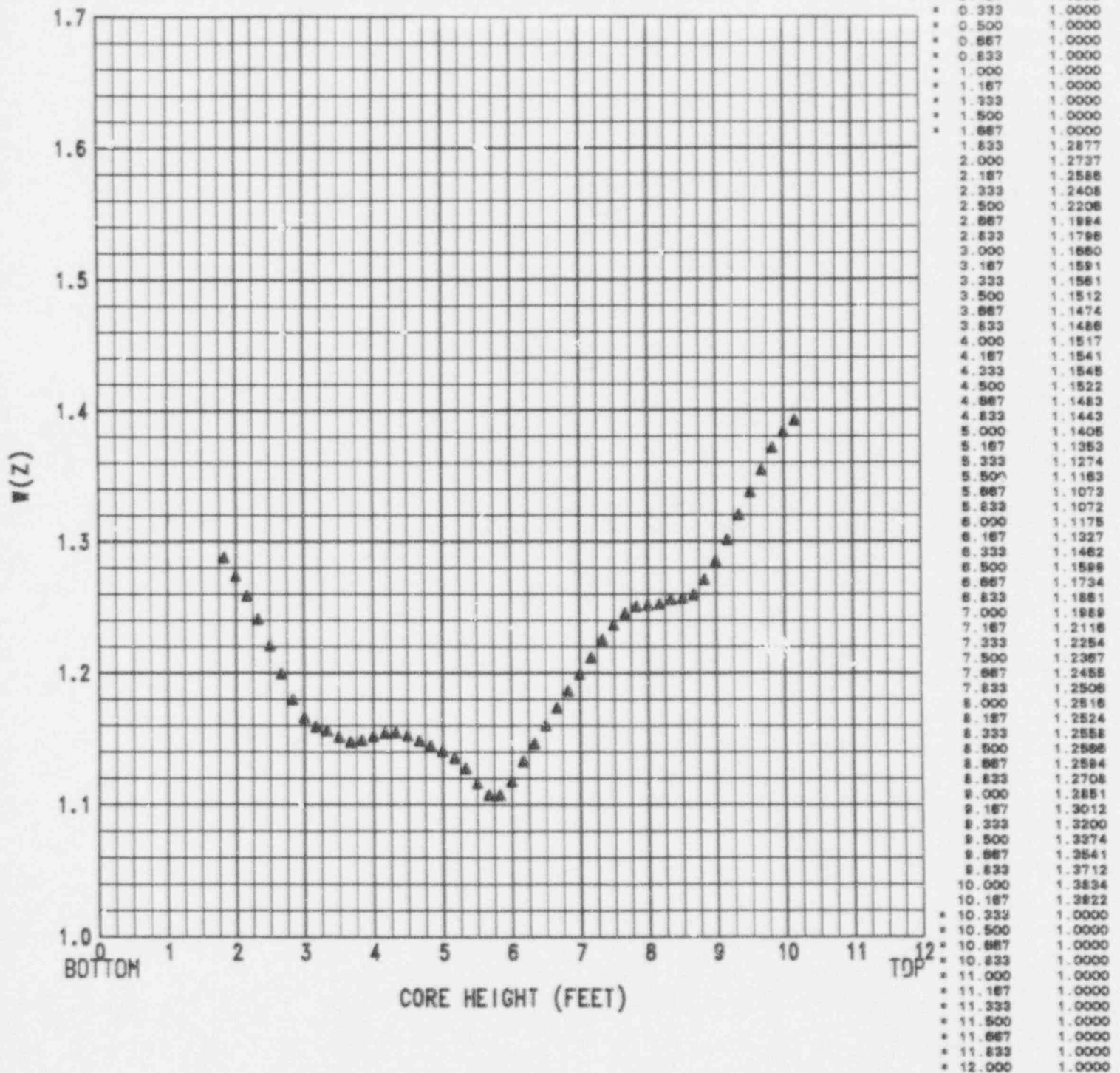


FIGURE 8

CALLAWAY UNIT 1 CYCLE 6

 $W(Z)_{NO}$ At 8000 MWD/MTU (Measured A.O. = -4% +/- 2%)

* Top and bottom 15% excluded as per Tech Spec 4.2.2.2G

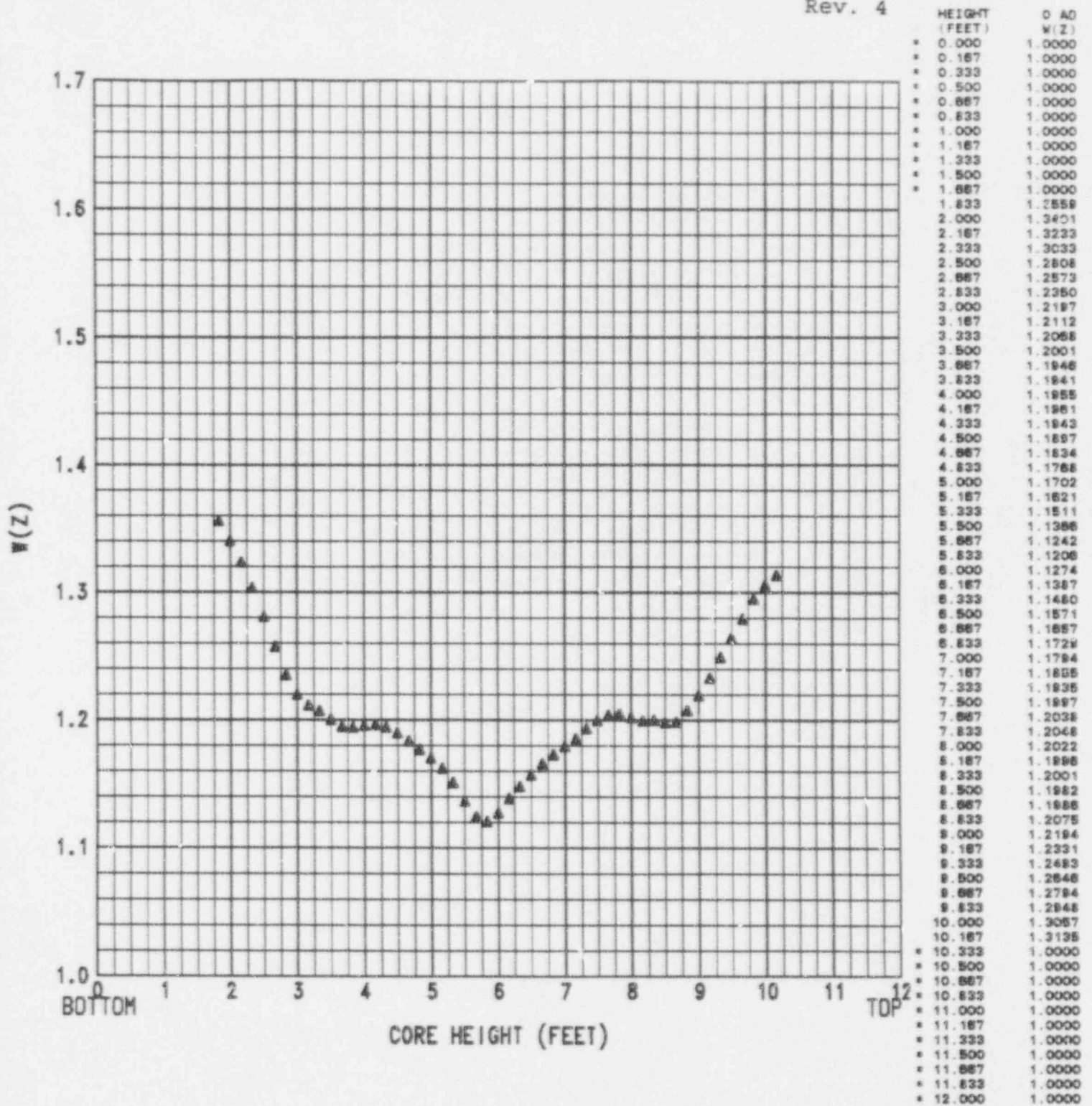


FIGURE 9

CALLAWAY UNIT 1 CYCLE 6

 $W(Z)_{NO}$ AT 8000 MWD/MTU (Measured A.O. = 0% +/- 2%)

* Top and bottom 15% excluded as per Tech Spec 4.2.2.2G

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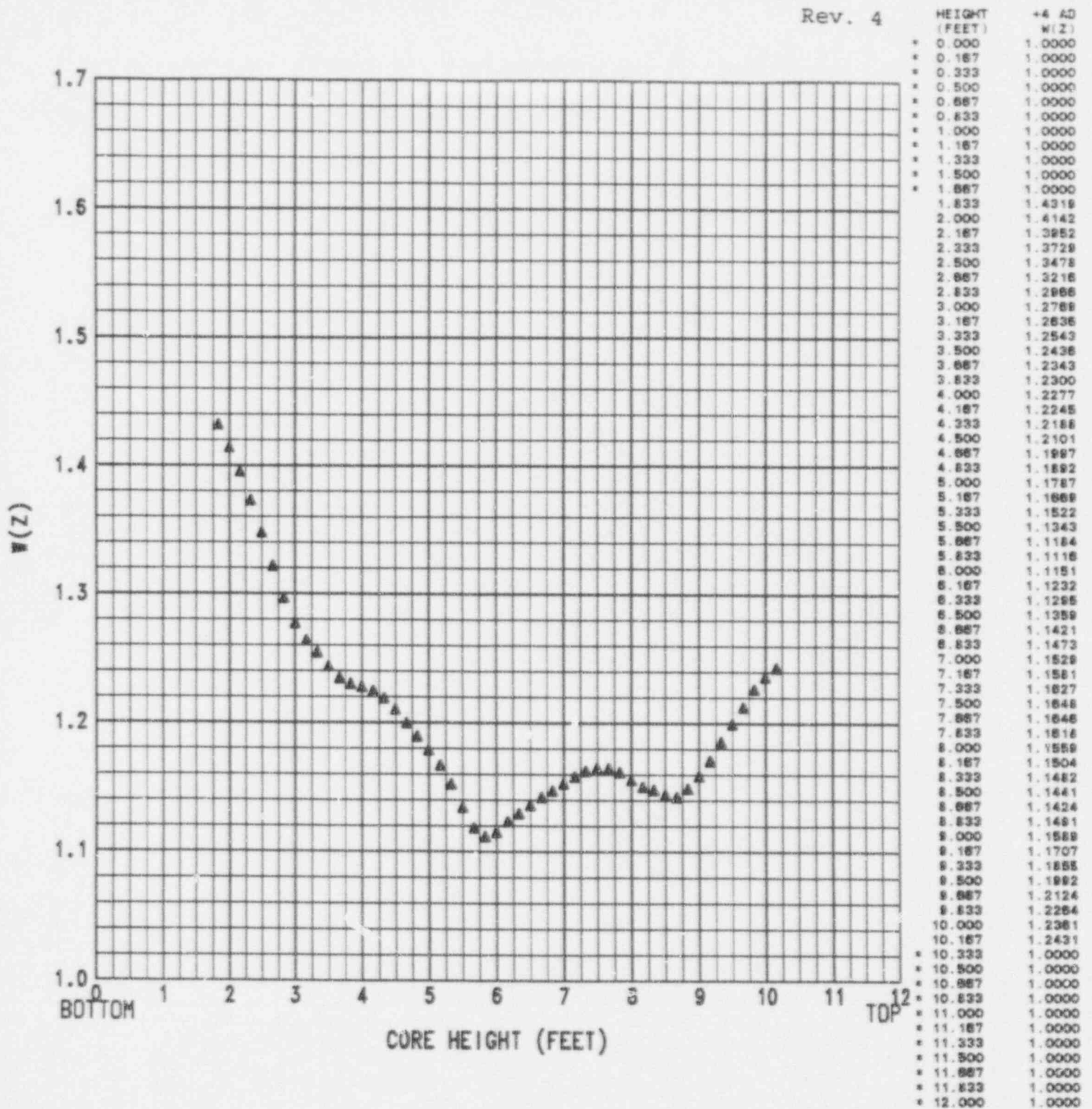


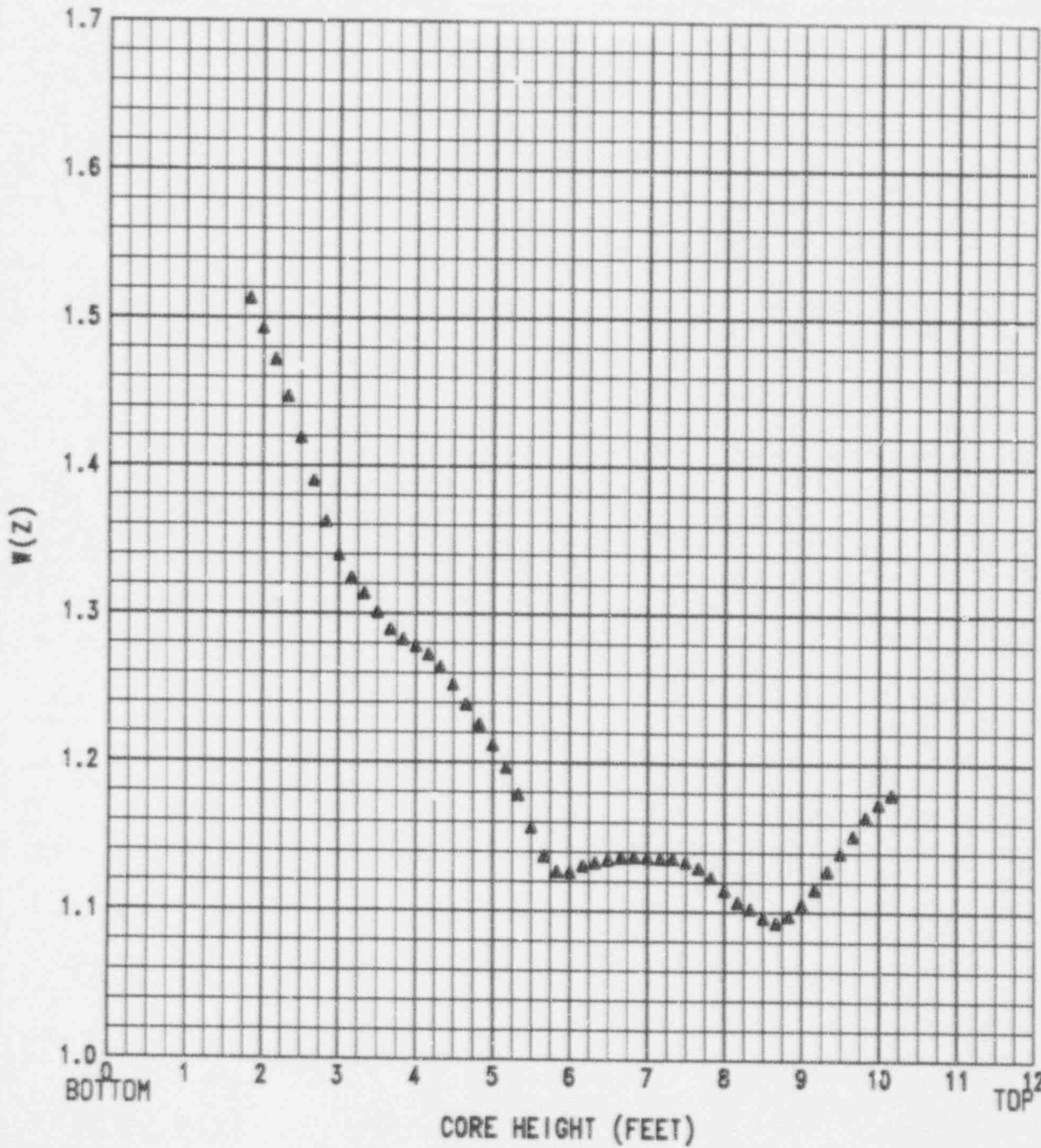
FIGURE 10

CALLAWAY UNIT 1 CYCLE 6

W(Z)_{NO} AT 8000 MWD/MTU (Measured A.O. = +4% +/- 2%)

* Top and bottom 15% excluded as per Tech Spec 4.2.2.2G

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HEIGHT (FEET)	+8 AO W(Z)
* 0.000	1.0000
* 0.167	1.0000
* 0.333	1.0000
* 0.500	1.0000
* 0.667	1.0000
* 0.833	1.0000
* 1.000	1.0000
* 1.167	1.0000
* 1.333	1.0000
* 1.500	1.0000
* 1.667	1.0000
1.833	1.5130
2.000	1.4931
2.167	1.4718
2.333	1.4470
2.500	1.4191
2.667	1.3899
2.833	1.3521
3.000	1.3398
3.167	1.3241
3.333	1.3138
3.500	1.3008
3.667	1.2892
3.833	1.2826
4.000	1.2780
4.167	1.2723
4.333	1.2638
4.500	1.2523
4.667	1.2388
4.833	1.2252
5.000	1.2115
5.167	1.1963
5.333	1.1781
5.500	1.1584
5.667	1.1389
5.833	1.1264
6.000	1.1262
6.167	1.1306
6.333	1.1326
6.500	1.1346
6.667	1.1361
6.833	1.1364
7.000	1.1361
7.167	1.1355
7.333	1.1355
7.500	1.1334
7.667	1.1293
7.833	1.1232
8.000	1.1146
8.167	1.1085
8.333	1.1021
8.500	1.0961
8.667	1.0928
8.833	1.0874
9.000	1.1054
9.167	1.1183
9.333	1.1278
9.500	1.1389
9.667	1.1516
9.833	1.1644
10.000	1.1732
10.167	1.1794
* 10.333	1.0000
* 10.500	1.0000
* 10.667	1.0000
* 10.833	1.0000
* 11.000	1.0000
* 11.167	1.0000
* 11.333	1.0000
* 11.500	1.0000
* 11.667	1.0000
* 11.833	1.0000
* 12.000	1.0000

FIGURE 11

CALLAWAY UNIT 1 CYCLE 6

$W(Z)_{NO}$ AT 8000 MWD/MTU (Measured A.O. = +8% +/- 2%)

* Top and bottom 15% excluded as per Tech Spec 4.2.2.2G

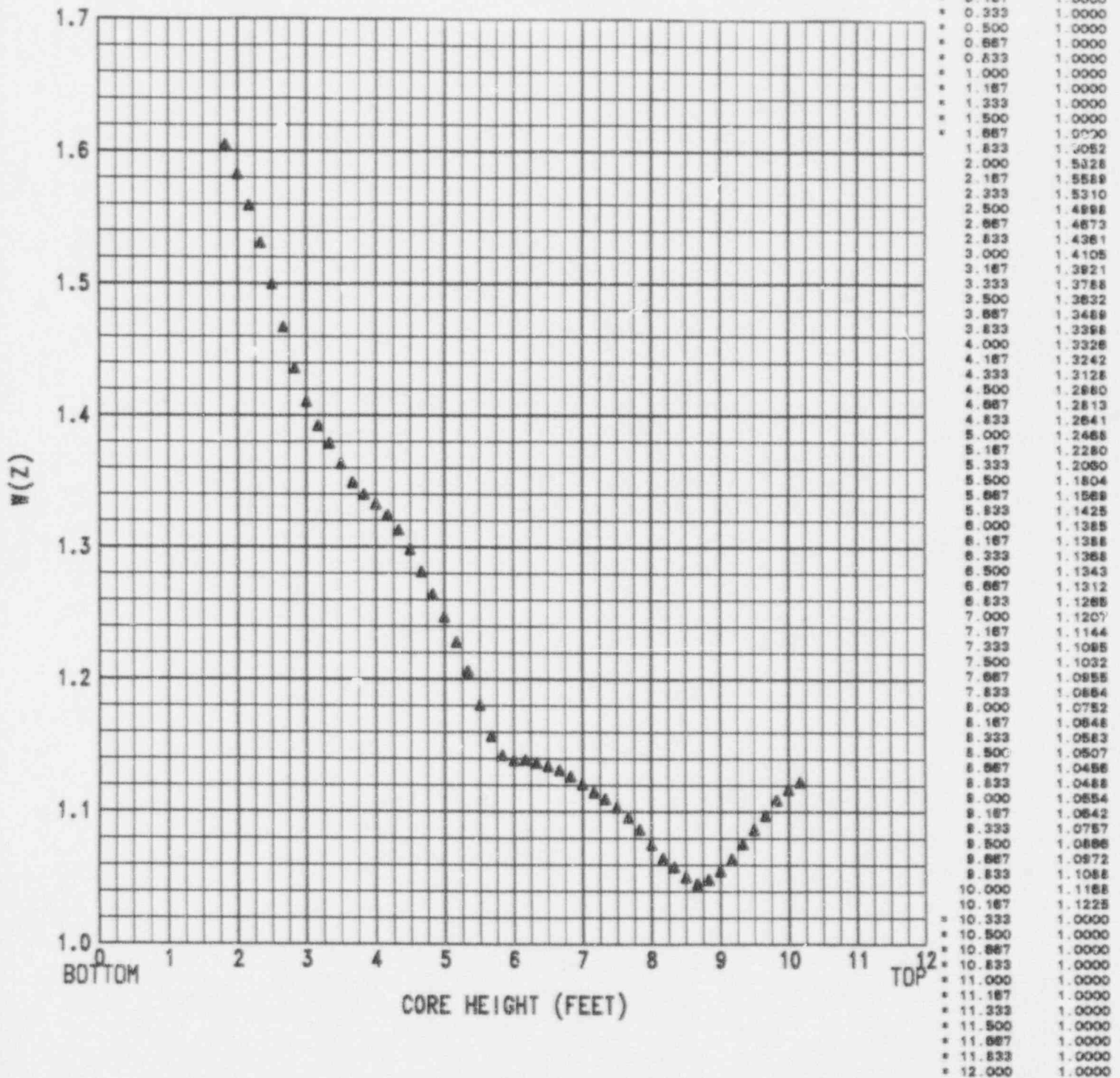


FIGURE 12

CALLAWAY UNIT 1 CYCLE 6

W(Z)_{NO} AT 8000 MWD/MTU (Measured A.O. = +12% +/- 2%)

* Top and bottom 15% excluded as per Tech Spec 4.2.2.2G

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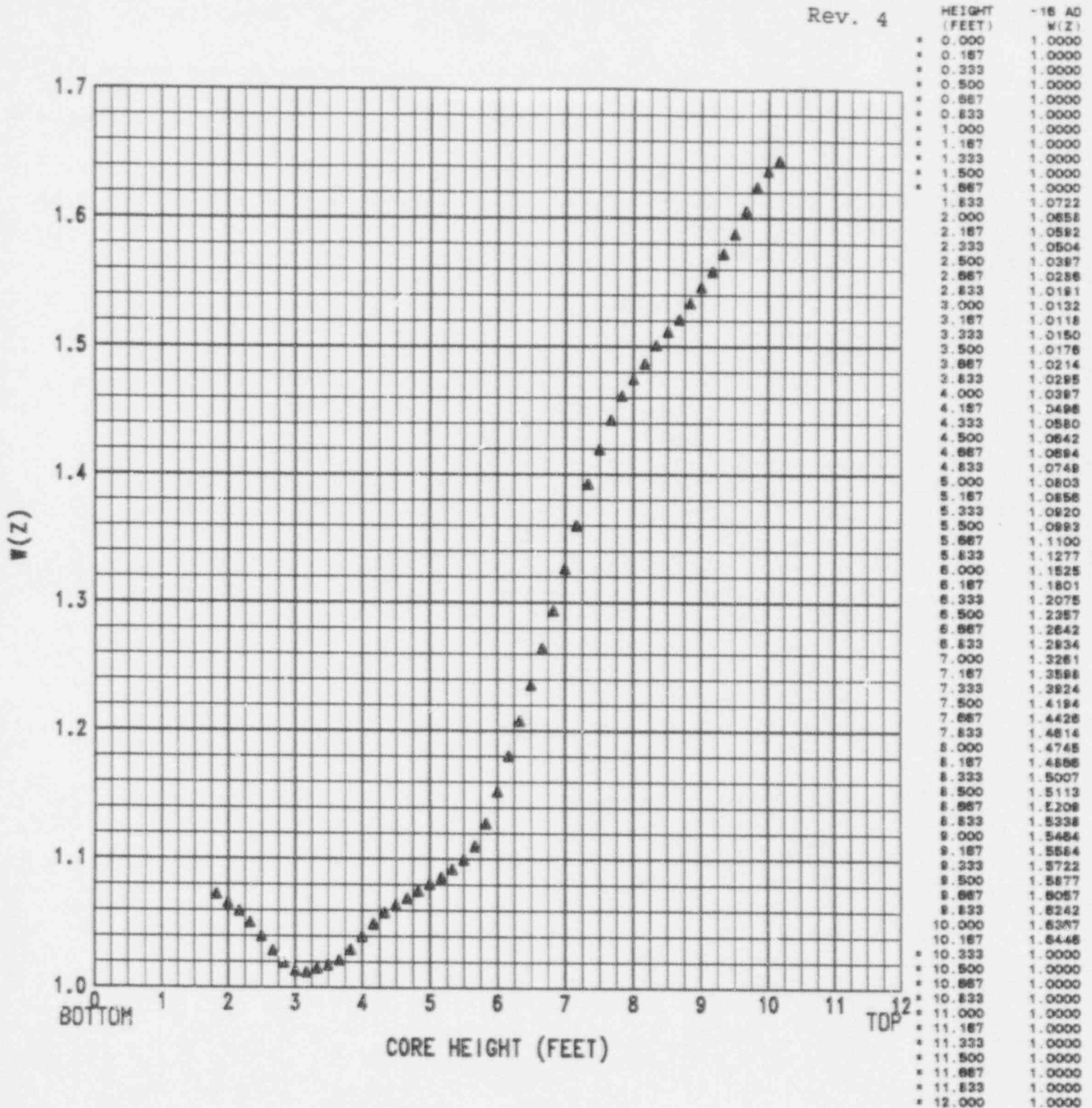


FIGURE 13

CALLAWAY UNIT 1 CYCLE 6

W(Z)_{NO} AT 12000 MWD/MTU (Measured A.O. = -16% +/- 2%)

* Top and bottom 15% excluded as per Tech Spec 4.2.2.2G

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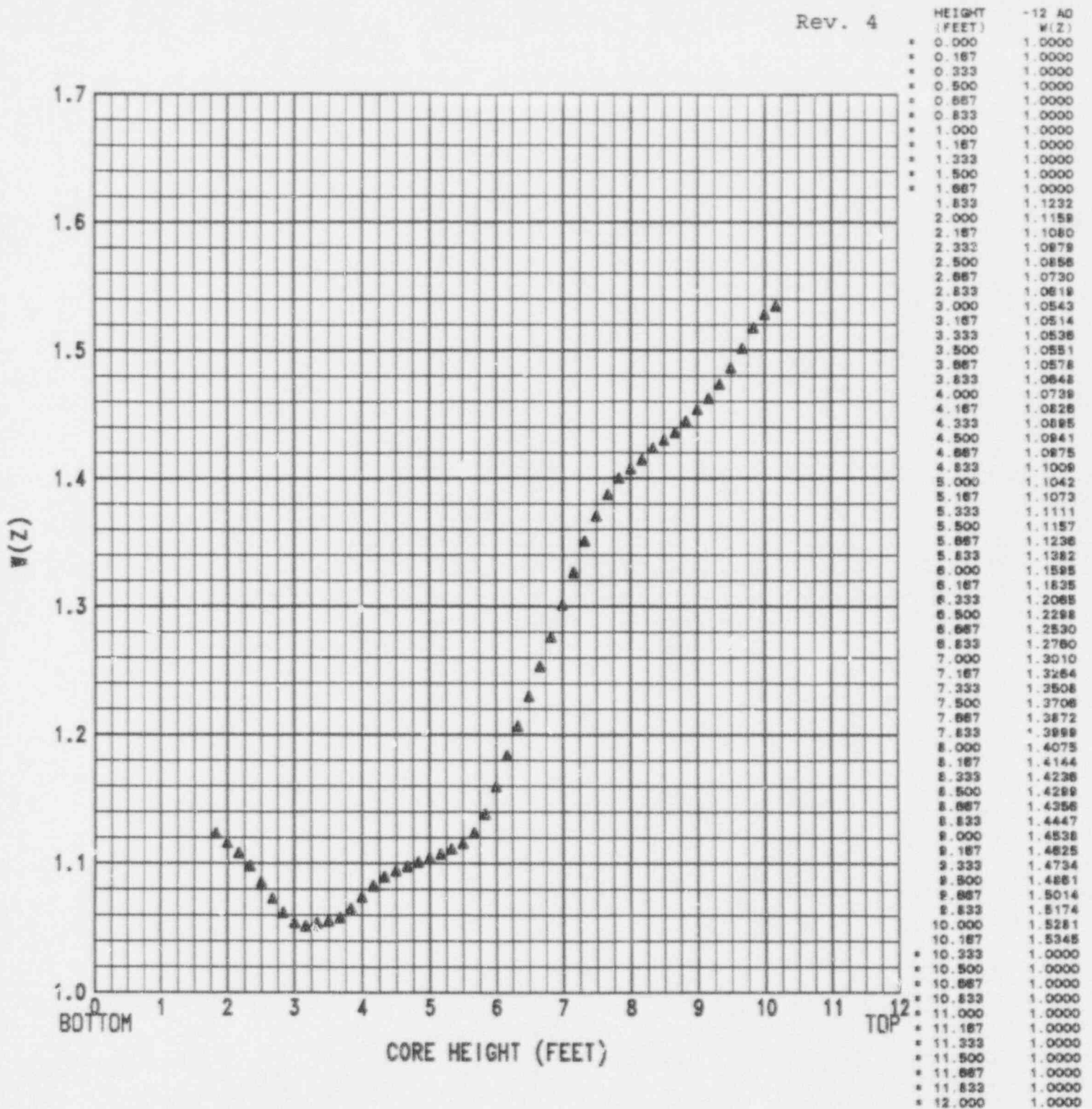


FIGURE 14

CALLAWAY UNIT 1 CYCLE 6

W(Z)_{NO} AT 12000 MWD/MTU (Measured A.O. = -12% +/- 2%)

* Top and bottom 15% excluded as per Tech Spec 4.2.2.2G

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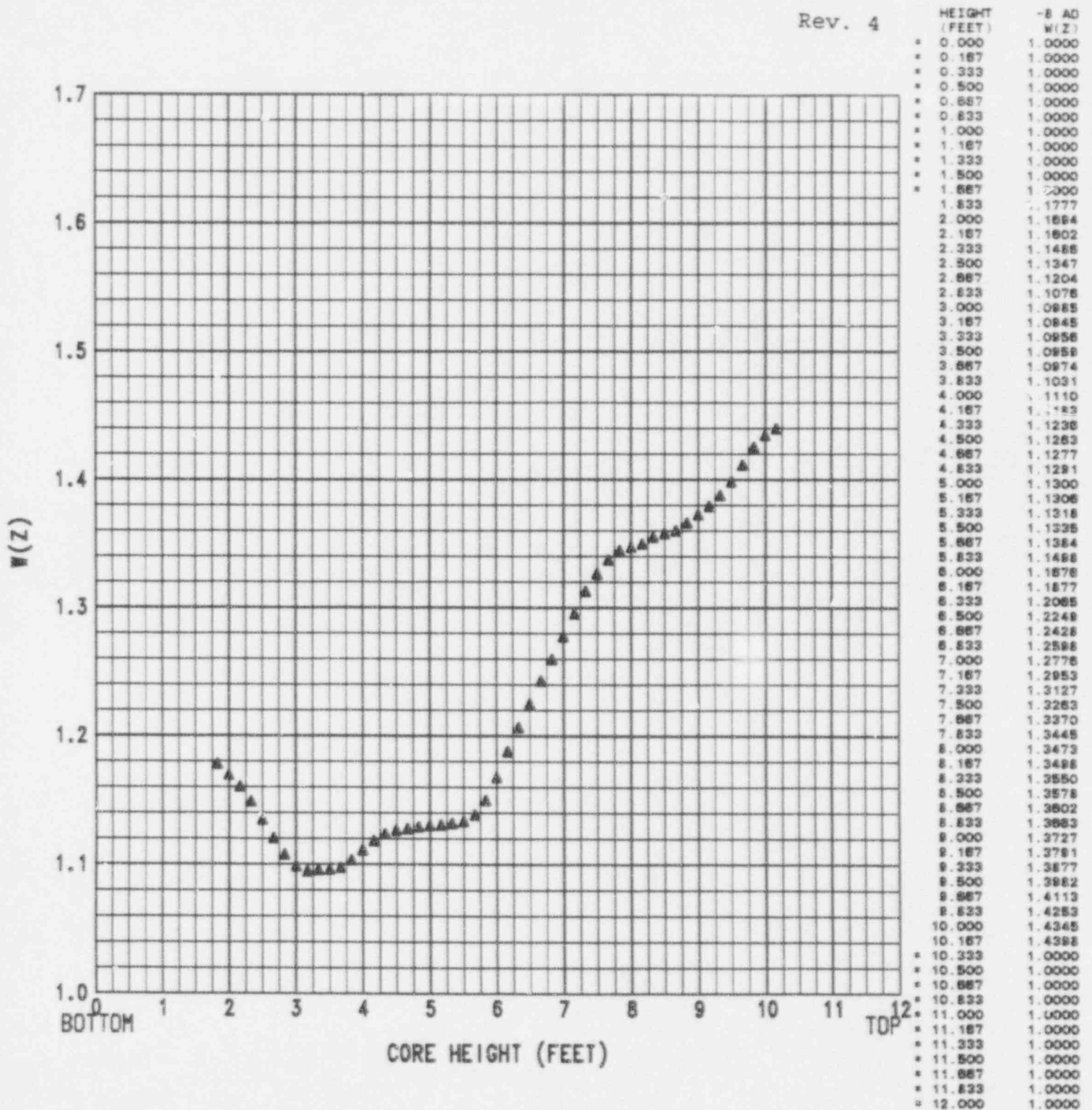


FIGURE 15

CALLAWAY UNIT 1 CYCLE 6

$W(Z)_{NO}$ AT 12000 MWD/MTU (Measured A.O. = -8% +/- 2%)

* Top and bottom 15% excluded as per Tech Spec 4.2.2.2G

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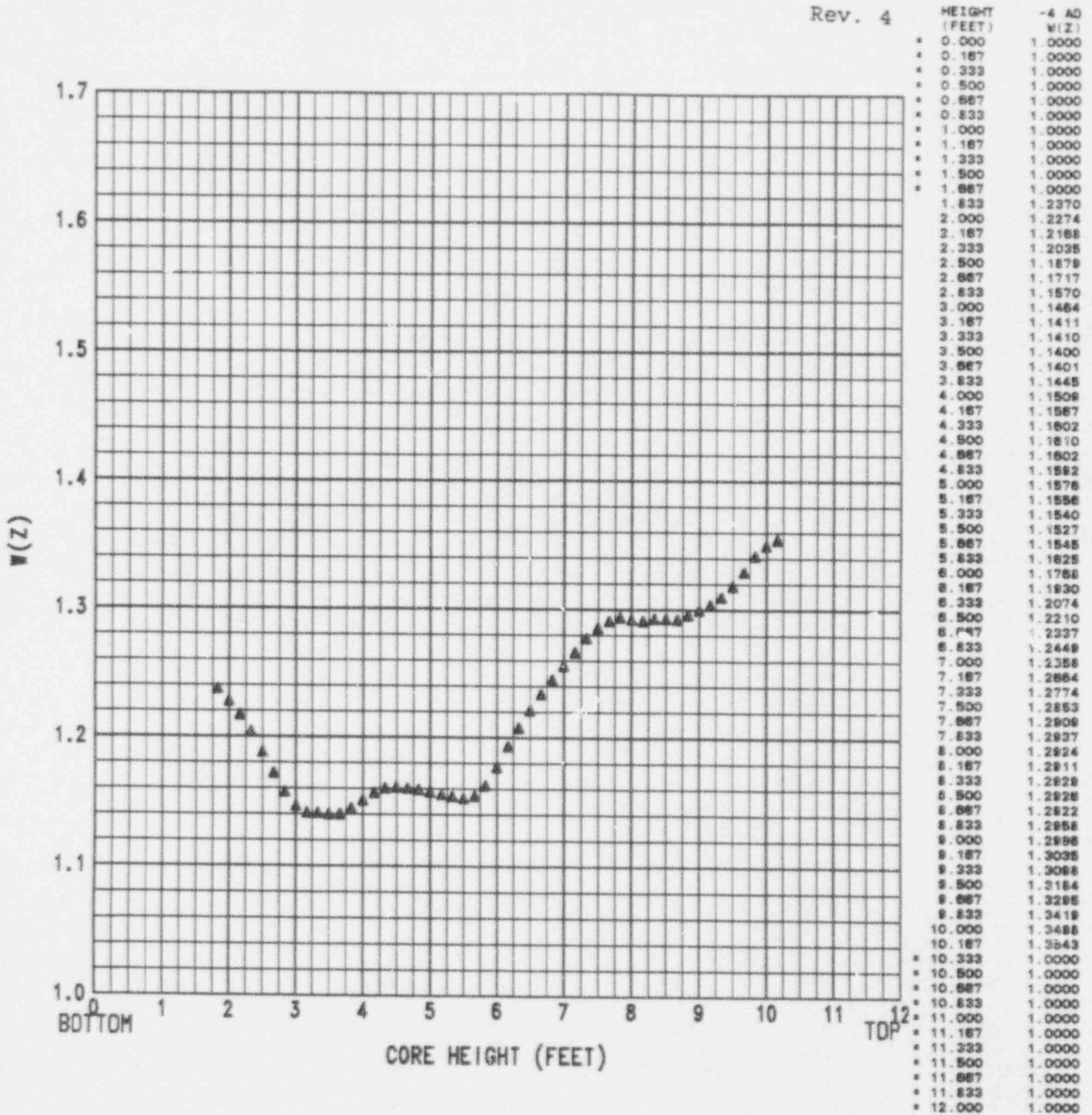


FIGURE 16

CALLAWAY UNIT 1 CYCLE 6

W(Z)_{NO} AT 12000 MWD/MTU (Measured A.O. = -4% +/- 2%)

* Top and bottom 15% excluded as per Tech Spec 4.2.2.2G

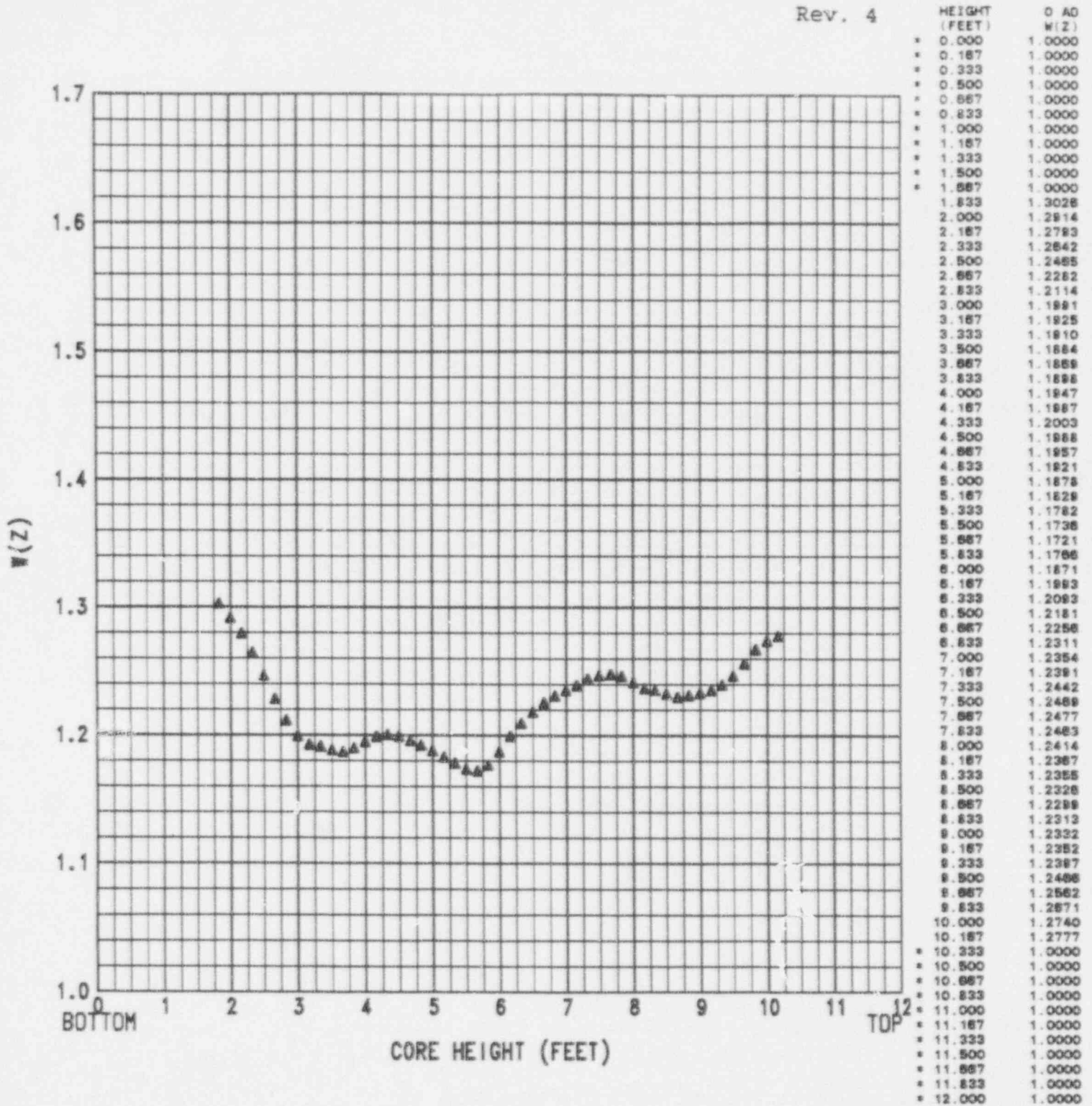


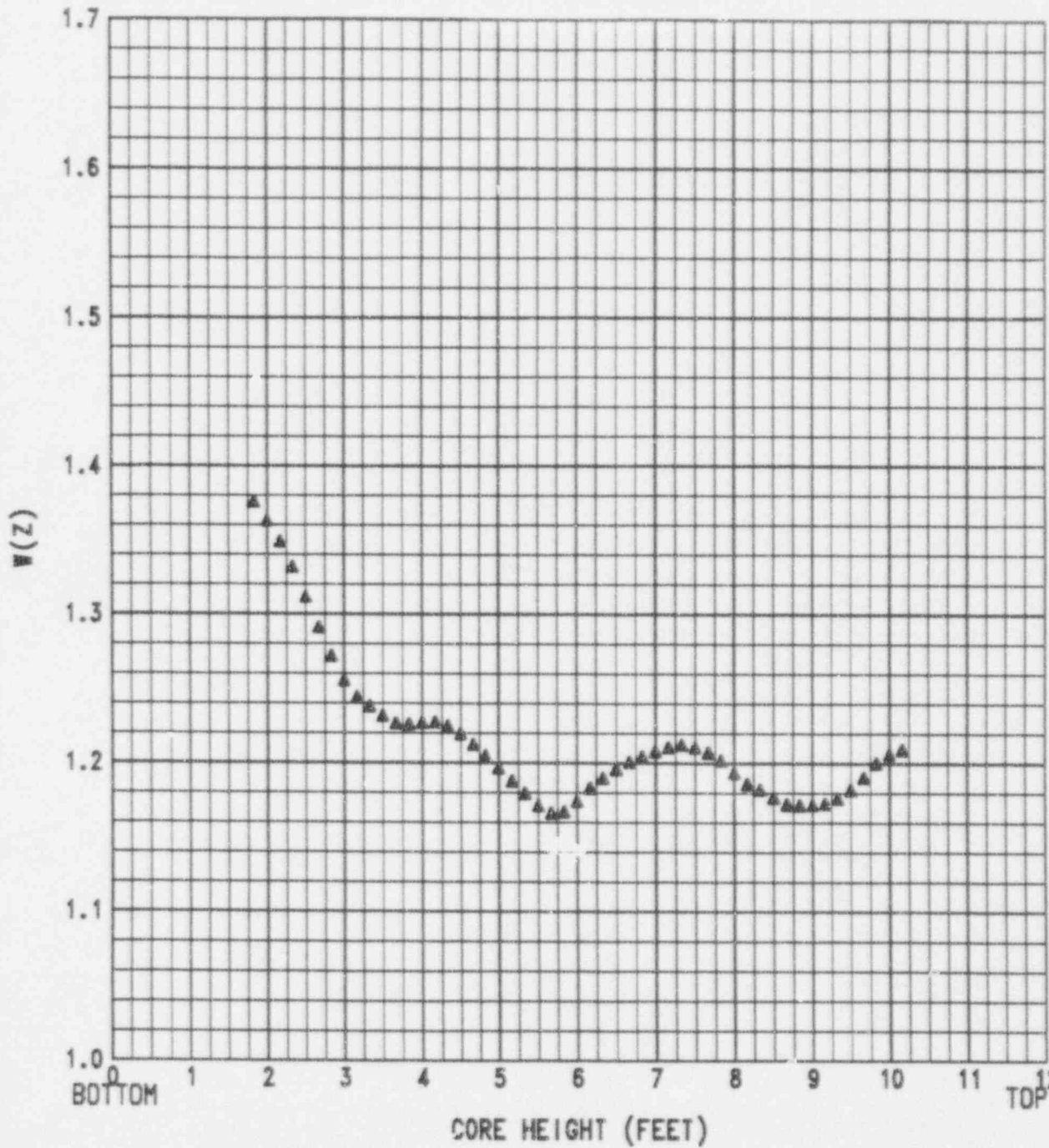
FIGURE 17

CALLAWAY UNIT 1 CYCLE 6

W(Z) AT 12000 MWD/MTU (Measured A.O. = 0% +/- 2%)
NO

* Top and bottom 15% excluded as per Tech Spec 4.2.2.2G

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HEIGHT (FEET)	+4 AD W(Z)
* 0.000	1.0000
* 0.167	1.0000
* 0.333	1.0000
* 0.500	1.0000
* 0.667	1.0000
* 0.833	1.0000
* 1.000	1.0000
* 1.167	1.0000
* 1.333	1.0000
* 1.500	1.0000
* 1.667	1.0000
1.833	1.3756
2.000	1.3828
2.167	1.3488
2.333	1.3317
2.500	1.3117
2.667	1.2810
2.833	1.2718
3.000	1.2554
3.167	1.2441
3.333	1.2378
3.500	1.2315
3.667	1.2264
3.833	1.2257
4.000	1.2288
4.167	1.2273
4.333	1.2248
4.500	1.2184
4.667	1.2122
4.833	1.2047
5.000	1.1985
5.167	1.1878
5.333	1.1794
5.500	1.1712
5.667	1.1681
5.833	1.1671
6.000	1.1742
6.167	1.1830
6.333	1.1888
6.500	1.1958
6.667	1.2007
6.833	1.2043
7.000	1.2077
7.167	1.2104
7.333	1.2122
7.500	1.2108
7.667	1.2070
7.833	1.2018
8.000	1.1938
8.167	1.1880
8.333	1.1821
8.500	1.1788
8.667	1.1722
8.833	1.1717
9.000	1.1720
9.167	1.1728
9.333	1.1783
9.500	1.1821
9.667	1.1804
9.833	1.2001
10.000	1.2081
10.167	1.2082
* 10.333	1.0000
* 10.500	1.0000
* 10.667	1.0000
* 10.833	1.0000
* 11.000	1.0000
* 11.167	1.0000
* 11.333	1.0000
* 11.500	1.0000
* 11.667	1.0000
* 11.833	1.0000
* 12.000	1.0000

FIGURE 18

CALLAWAY UNIT 1 CYCLE 6

$W(Z)_{NO}$ AT 12000 MWD/MTU (Measured A.O. = +4% +/- 2%)

* Top and bottom 15% excluded as per Tech Spec 4.2.2.2G

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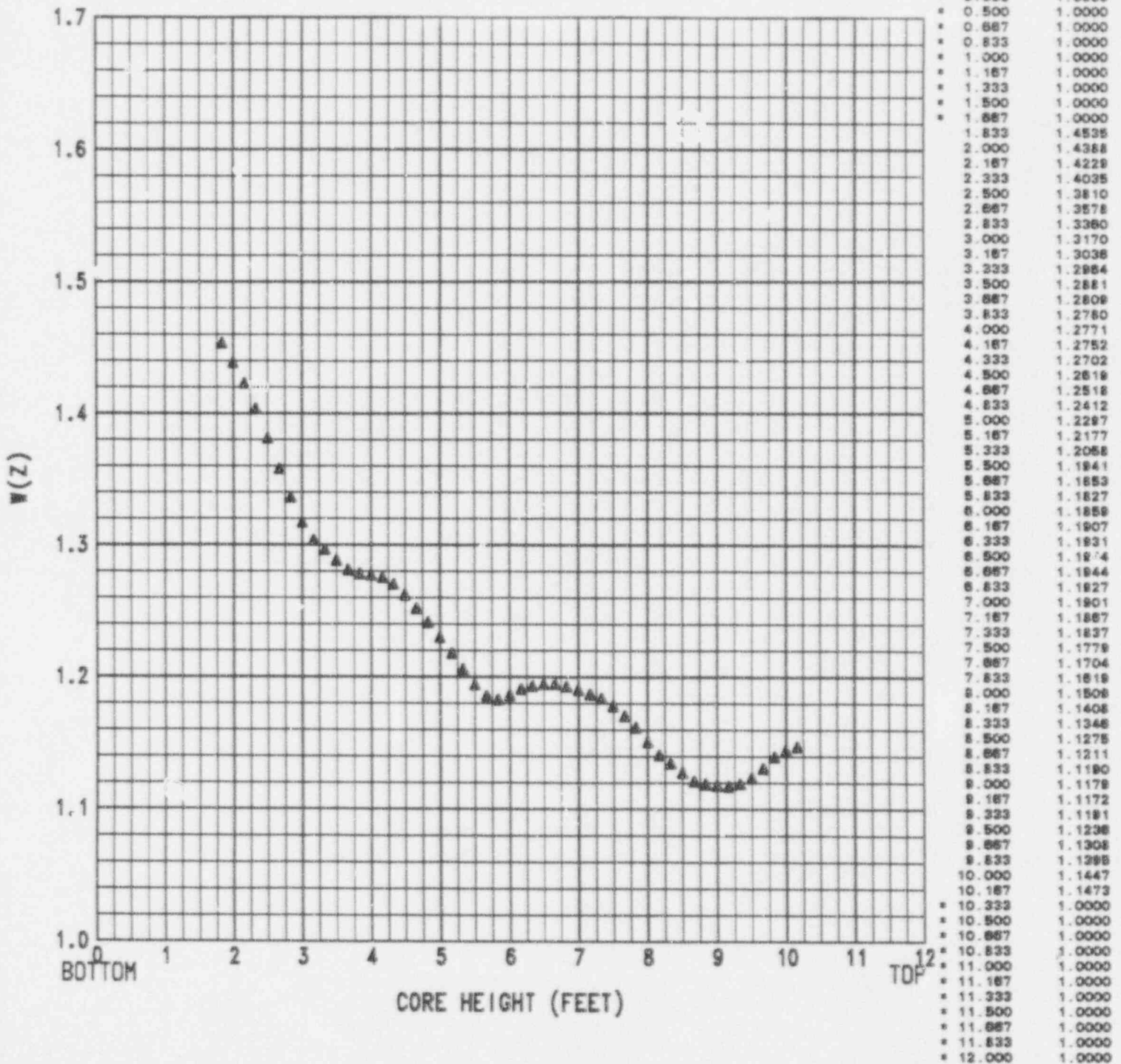


FIGURE 19

CALLAWAY UNIT 1 CYCLE 6

W(Z)_{NO} AT 12000 MWD/MTU (Measured A.O. = +8% +/- 2%)

* Top and bottom 15% excluded as per Tech Spec 4.2.2.2G

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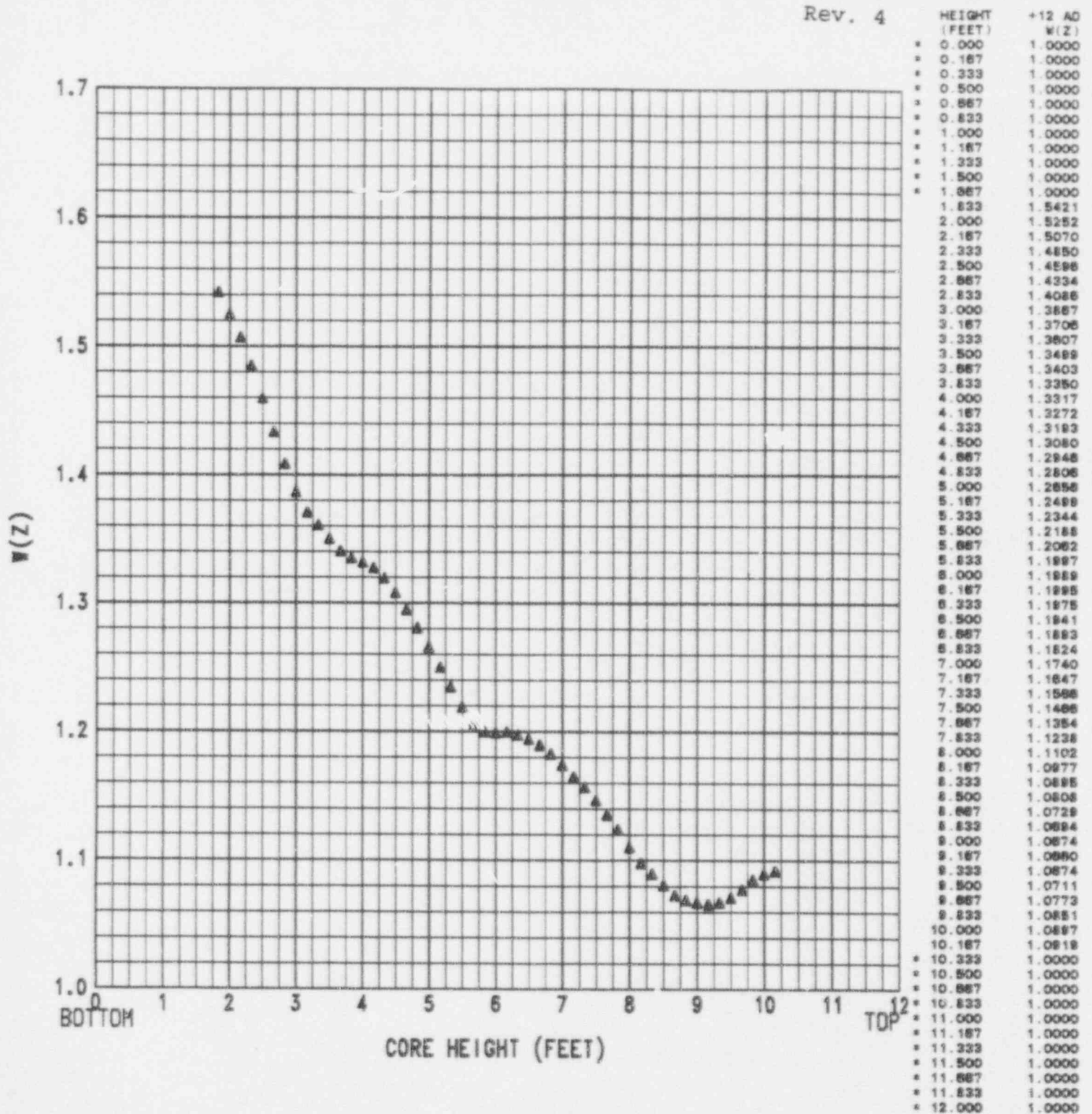


FIGURE 20

CALLAWAY UNIT 1 CYCLE 6

W(Z)_{NO} AT 12000 MWD/MTU (Measured A.O. = +12% +/- 2%)

* Top and bottom 15% excluded as per Tech Spec 4.2.2.2G

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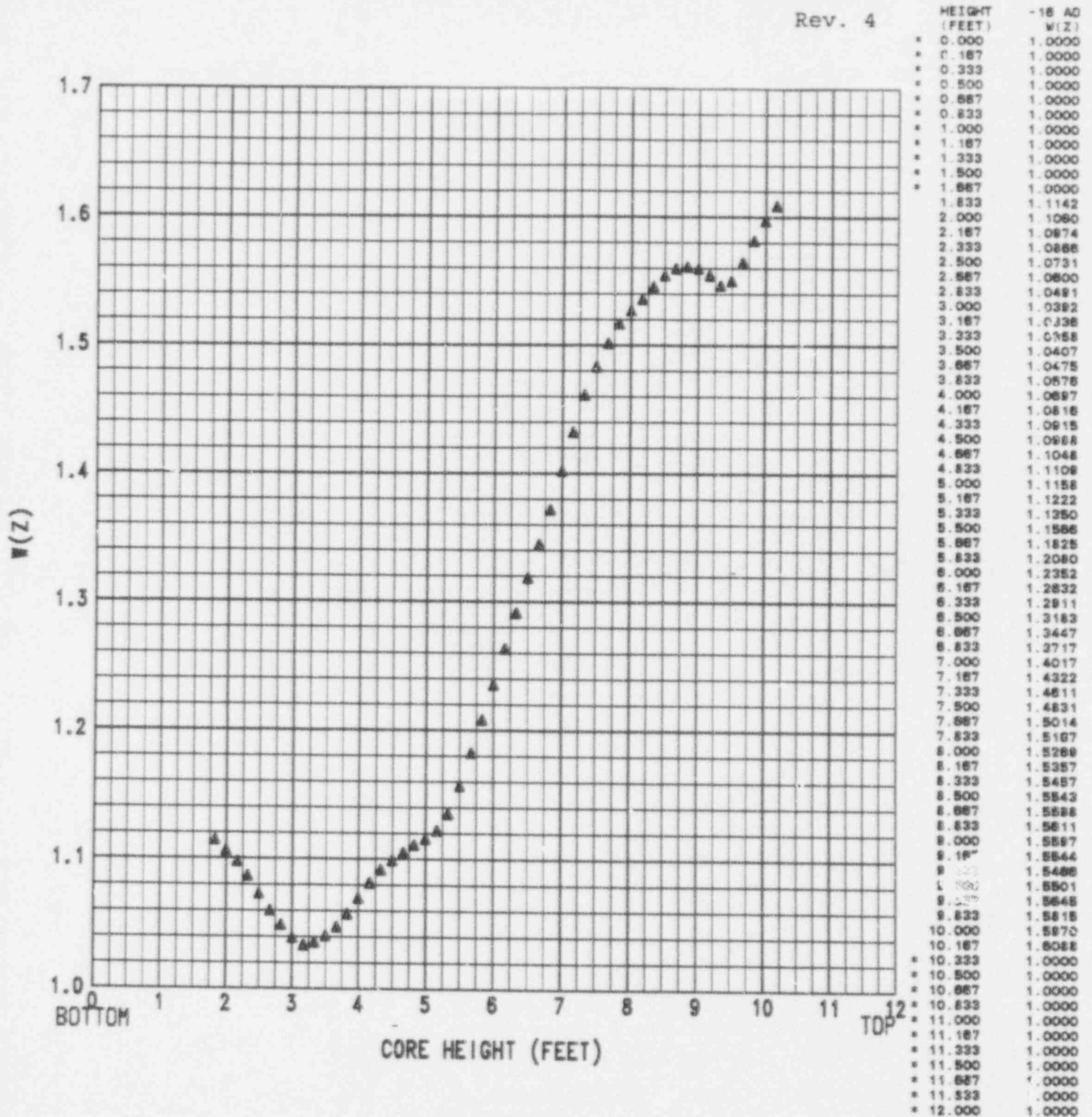


FIGURE 21

CALLAWAY UNIT 1 CYCLE 6

W(Z)_{NO} AT 16000 MWD/MTU (Measured A.O. = -16% +/- 2%)

* Top and bottom 15% excluded as per Tech Spec 4.2.2.2G

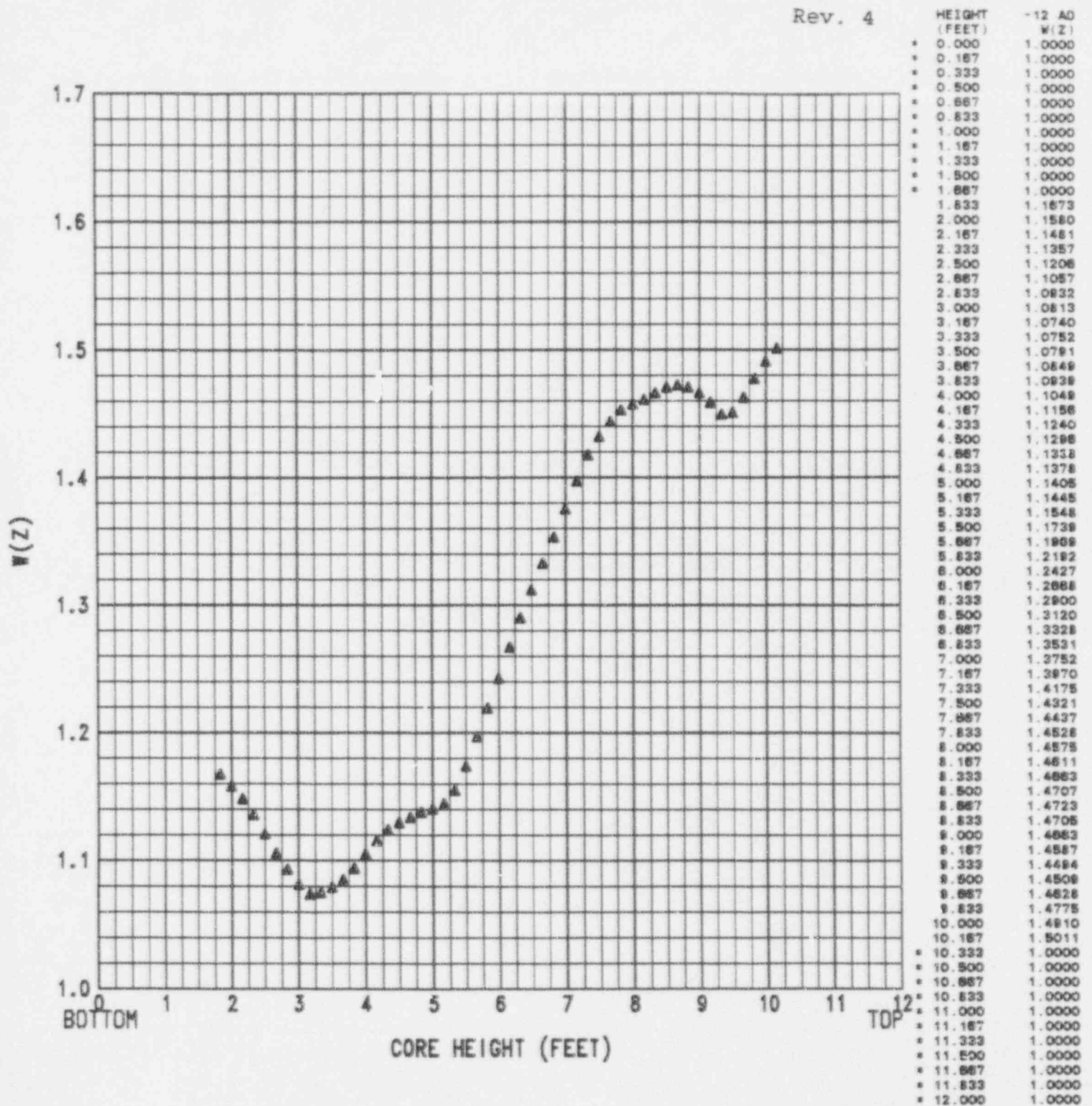


FIGURE 22

CALLAWAY UNIT 1 CYCLE 6

W(Z)_{NO} AT 16000 MWD/MTU (Measured A.O. = -12% +/- 2%)

* Top and bottom 15% excluded as per Tech Spec 4.2.2.2G

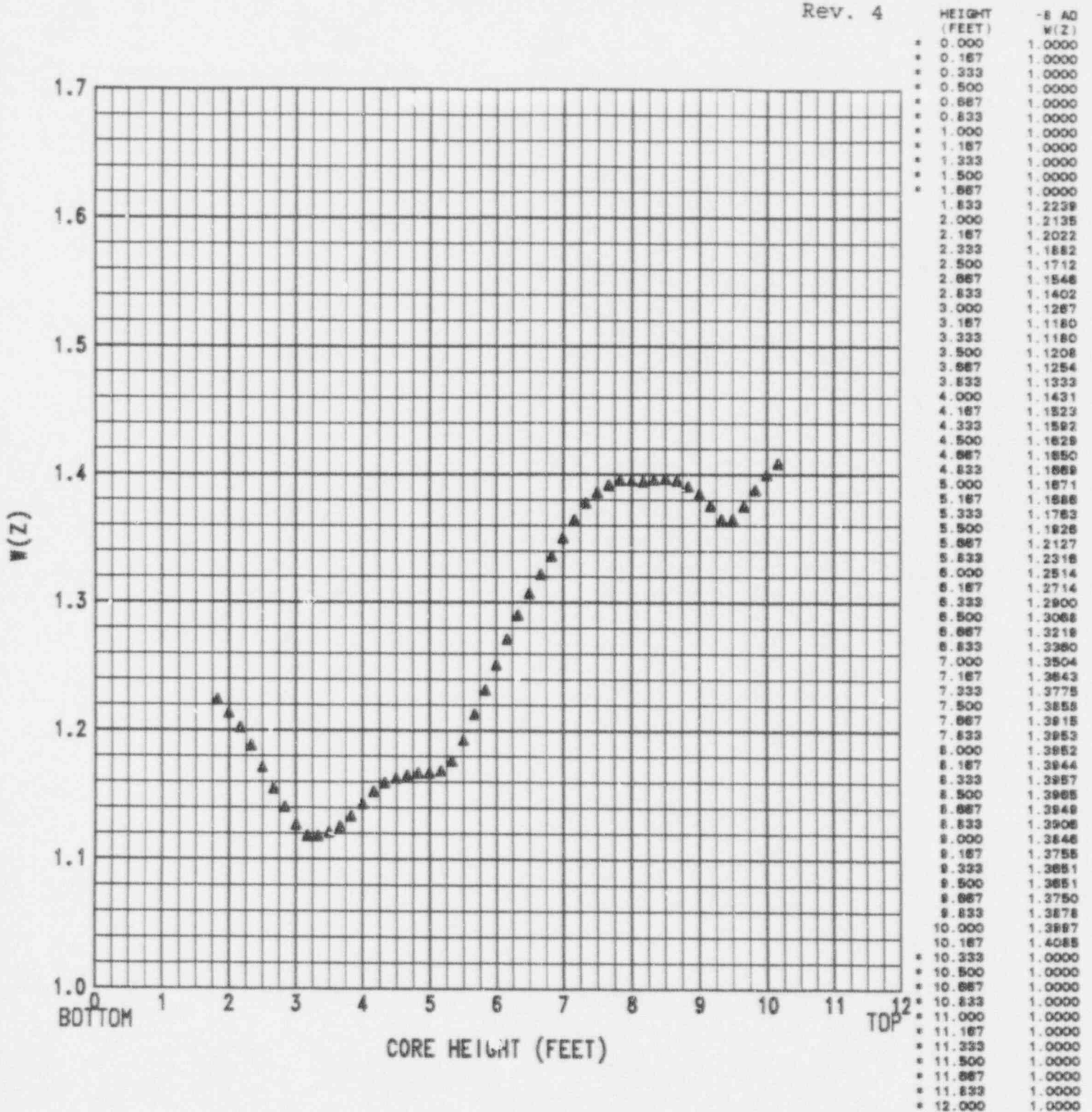


FIGURE 23

CALLAWAY UNIT 1 CYCLE 6

W(Z)_{NO} AT 16000 MWD/MTU (Measured A.O. = -8% +/- 2%)

* Top and bottom 15% excluded as per Tech Spec 4.2.2.2G

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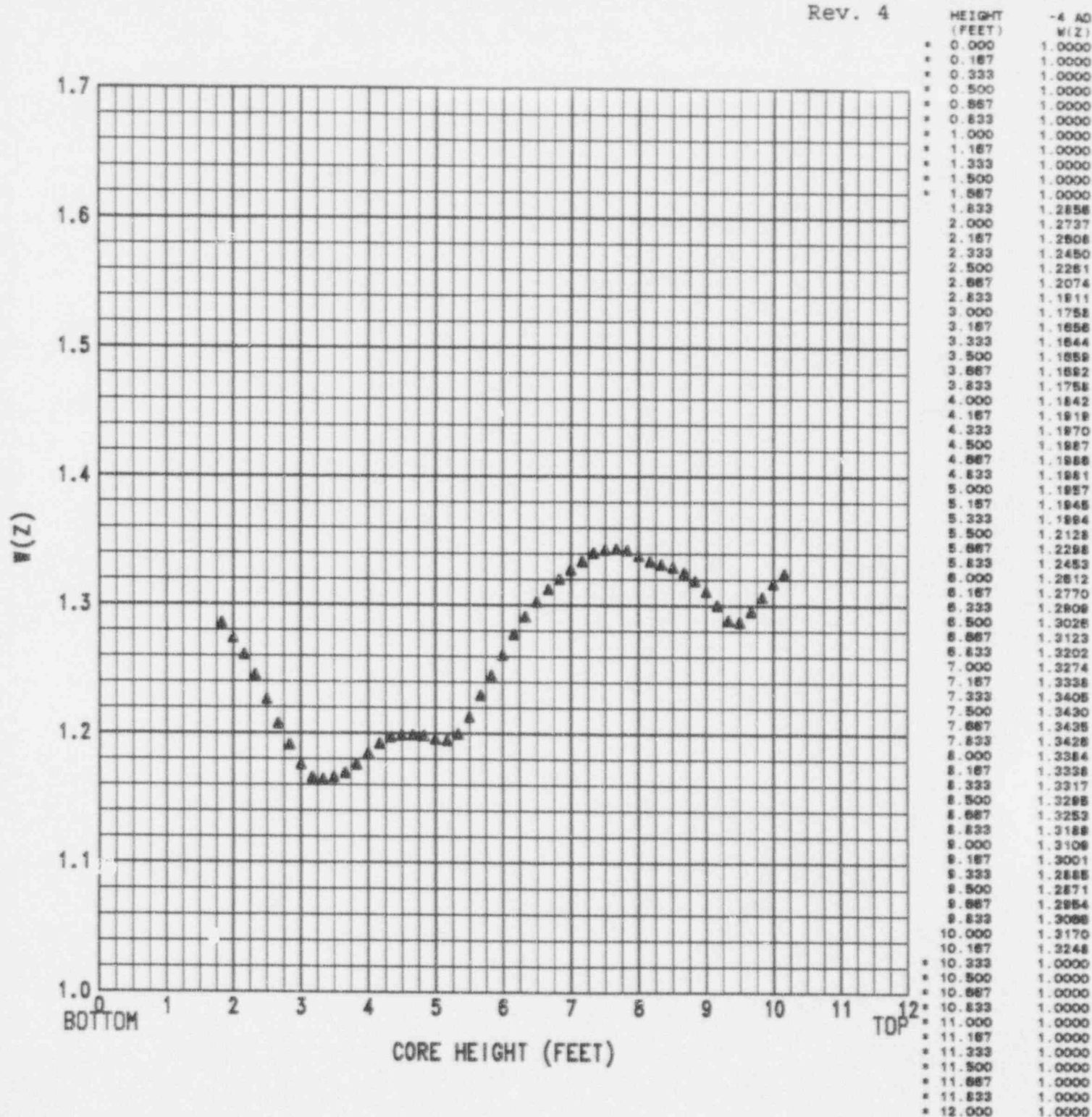


FIGURE 24

CALLAWAY UNIT 1 CYCLE 6

W(Z)_{NO} AT 16000 MWD/MTU (Measured A.O. = -4% +/- 2%)

* Top and bottom 15% excluded as per Tech Spec 4.2.2.2G

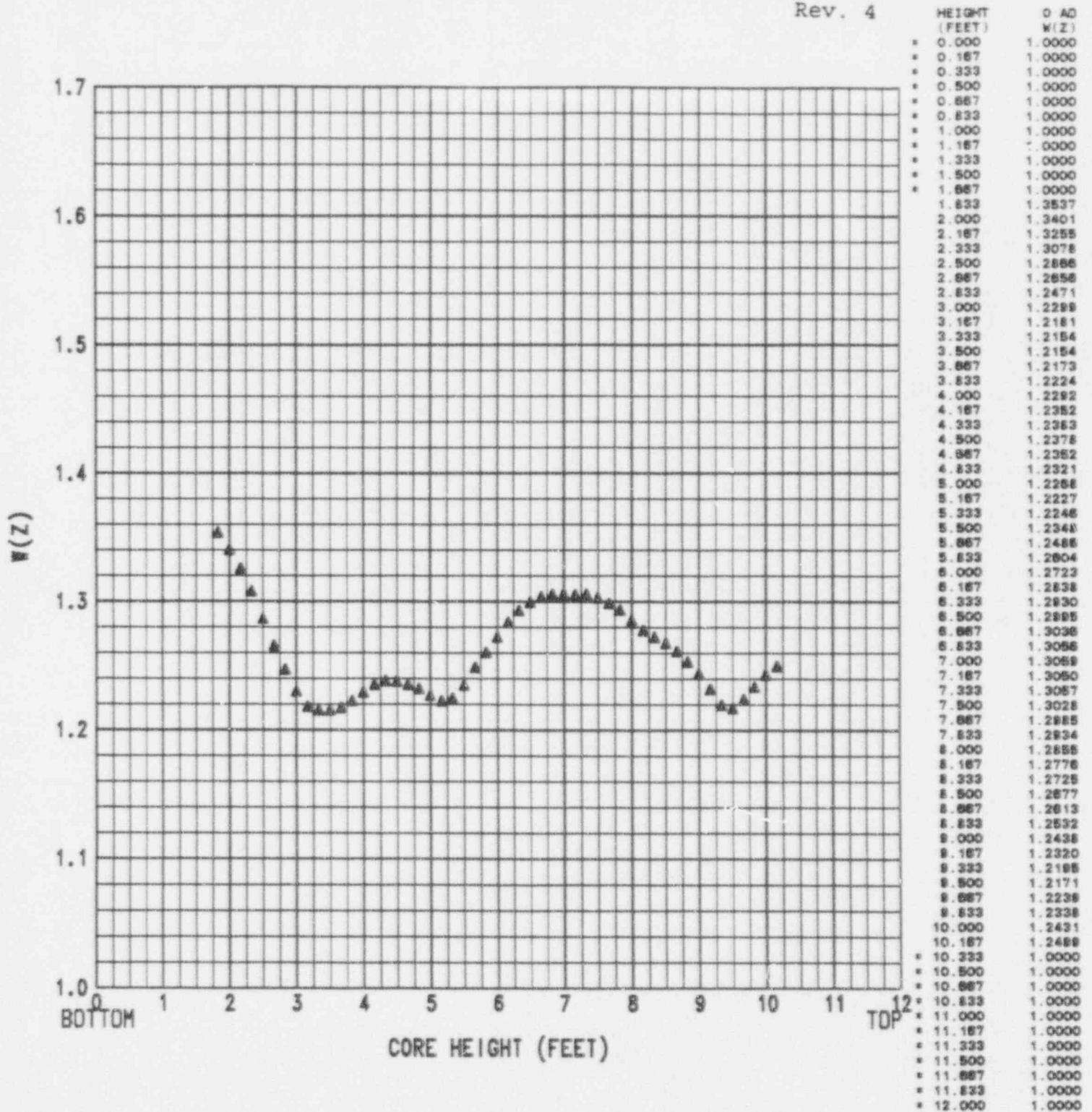
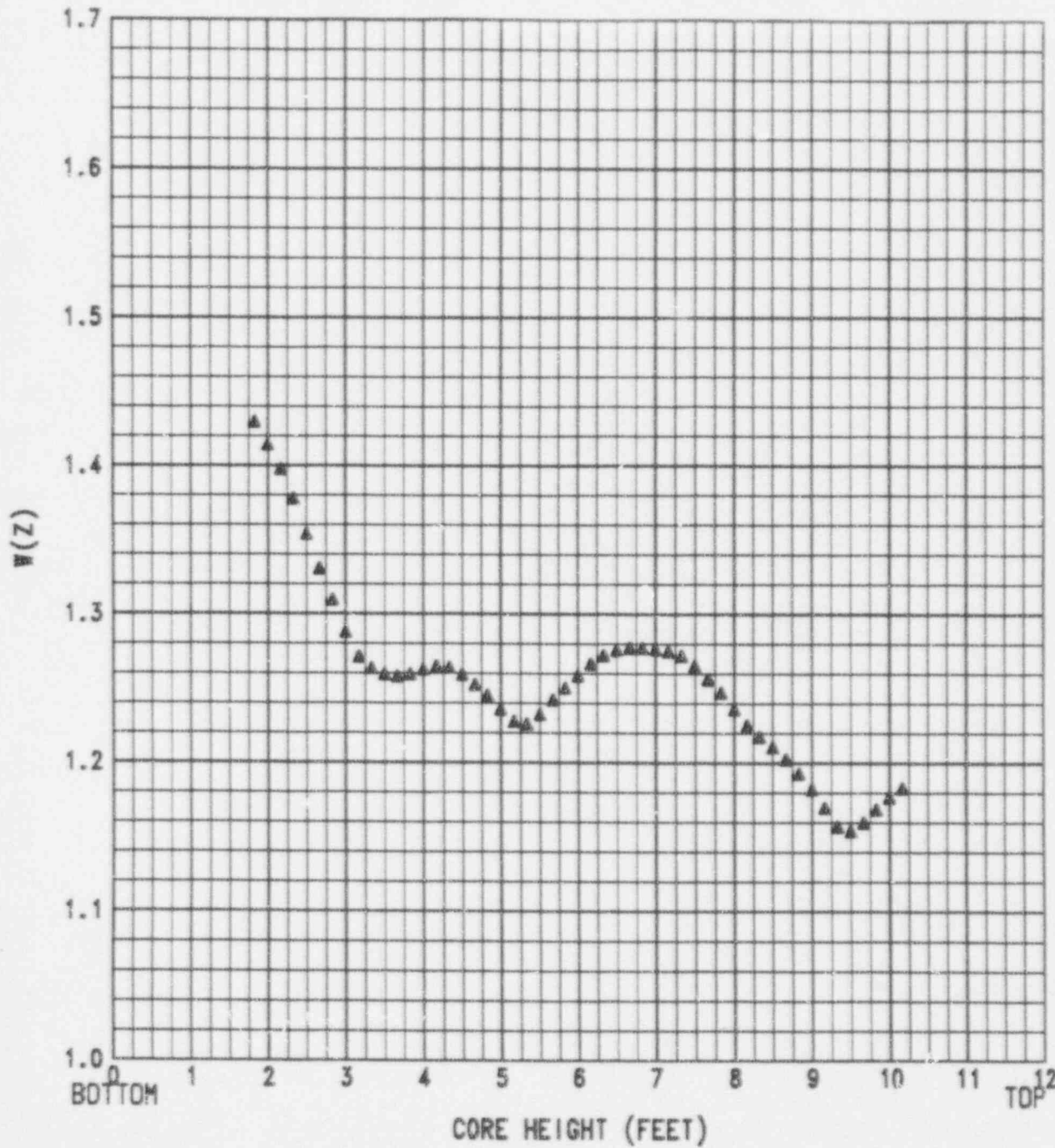


FIGURE 25

CALLAWAY UNIT 1 CYCLE 6

W(Z)_{NO} AT 16000 MWD/MTU (Measured A.O = 0% +/- 2%)

* Top and bottom 15% excluded as per Tech Spec 4.2.2.2G



HEIGHT (FEET)	+4 AD W(Z)
* 0.000	1.0000
* 0.187	1.0000
* 0.333	1.0000
* 0.500	1.0000
* 0.667	1.0000
* 0.833	1.0000
* 1.000	1.0000
* 1.167	1.0000
* 1.333	1.0000
* 1.500	1.0000
* 1.667	1.0000
1.833	1.4296
2.000	1.4142
2.167	1.3978
2.333	1.3778
2.500	1.3539
2.667	1.3304
2.833	1.3083
3.000	1.2878
3.167	1.2708
3.333	1.2633
3.500	1.2594
3.667	1.2578
3.833	1.2582
4.000	1.2624
4.167	1.2648
4.333	1.2637
4.500	1.2590
4.667	1.2523
4.833	1.2451
5.000	1.2358
5.167	1.2277
5.333	1.2258
5.500	1.2323
5.667	1.2422
5.833	1.2502
6.000	1.2584
6.167	1.2663
6.333	1.2722
6.500	1.2757
6.667	1.2772
6.833	1.2771
7.000	1.2765
7.167	1.2748
7.333	1.2720
7.500	1.2650
7.667	1.2582
7.833	1.2472
8.000	1.2381
8.167	1.2252
8.333	1.2175
8.500	1.2106
8.667	1.2022
8.833	1.1926
9.000	1.1822
9.167	1.1687
9.333	1.1572
9.500	1.1541
9.667	1.1568
9.833	1.1686
10.000	1.1788
10.167	1.1828
* 10.333	1.0000
* 10.500	1.0000
* 10.667	1.0000
* 10.833	1.0000
* 11.000	1.0000
* 11.167	1.0000
* 11.333	1.0000
* 11.500	1.0000
* 11.667	1.0000
* 11.833	1.0000
* 12.000	1.0000

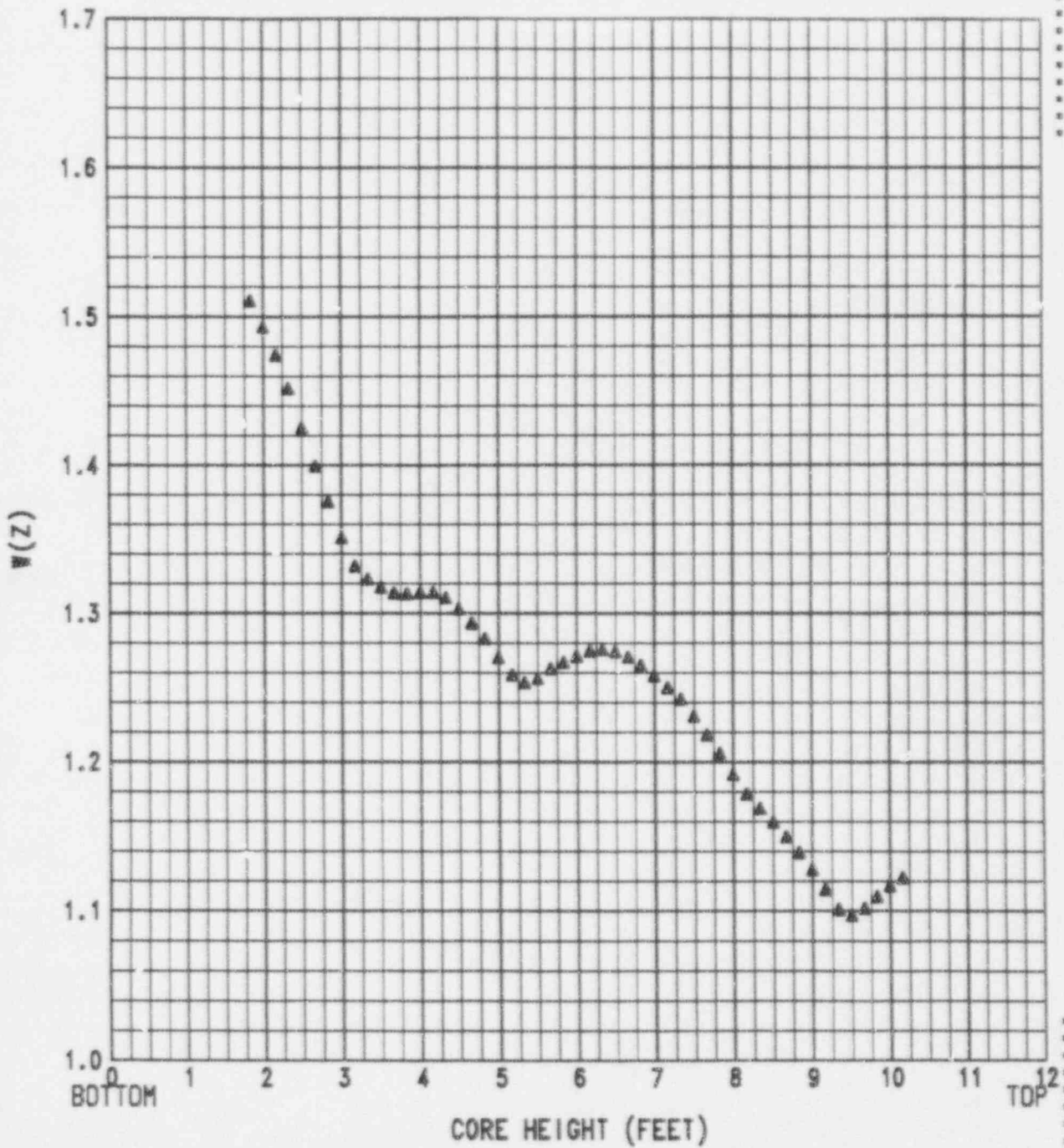
FIGURE 26

CALLAWAY UNIT 1 CYCLE 6

8

W(Z)_{NO} AT 16000 MWD/MTU (Measured A.O. = +4% +/- 2%)

* Top and bottom 15% excluded as per Tech Spec 4.2.2.2G



HEIGHT (FEET)	+8 A.O. W(Z)
* 0.000	1.0000
* 0.167	1.0000
* 0.333	1.0000
* 0.500	1.0000
* 0.667	1.0000
* 0.833	1.0000
* 1.000	1.0000
* 1.167	1.0000
* 1.333	1.0000
* 1.500	1.0000
* 1.667	1.0000
1.833	1.5106
2.000	1.4631
2.167	1.4743
2.333	1.4518
2.500	1.4255
2.667	1.3992
2.833	1.3753
3.000	1.3508
3.167	1.3318
3.333	1.3230
3.500	1.3174
3.667	1.3136
3.833	1.3130
4.000	1.3140
4.167	1.3140
4.333	1.3104
4.500	1.3029
4.667	1.2932
4.833	1.2826
5.000	1.2701
5.167	1.2566
5.333	1.2533
5.500	1.2564
5.667	1.2627
5.833	1.2669
6.000	1.2710
6.167	1.2745
6.333	1.2757
6.500	1.2743
6.667	1.2705
6.833	1.2649
7.000	1.2580
7.167	1.2489
7.333	1.2422
7.500	1.2306
7.667	1.2181
7.833	1.2058
8.000	1.1918
8.167	1.1784
8.333	1.1666
8.500	1.1567
8.667	1.1488
8.833	1.1390
9.000	1.1276
9.167	1.1143
9.333	1.1009
9.500	1.0970
9.667	1.1017
9.833	1.1085
10.000	1.1168
10.167	1.1223
* 10.333	1.0000
* 10.500	1.0000
* 10.667	1.0000
* 10.833	1.0000
* 11.000	1.0000
* 11.167	1.0000
* 11.333	1.0000
* 11.500	1.0000
* 11.667	1.0000
* 11.833	1.0000
* 12.000	1.0000

FIGURE 27

CALLAWAY UNIT 1 CYCLE 6

W(Z)_{NO} AT 16000 MWD/MTU (Measured A.O.= +8% +/- 2%)

* Top and bottom 15% excluded as per Tech Spec 4.2.2.2G

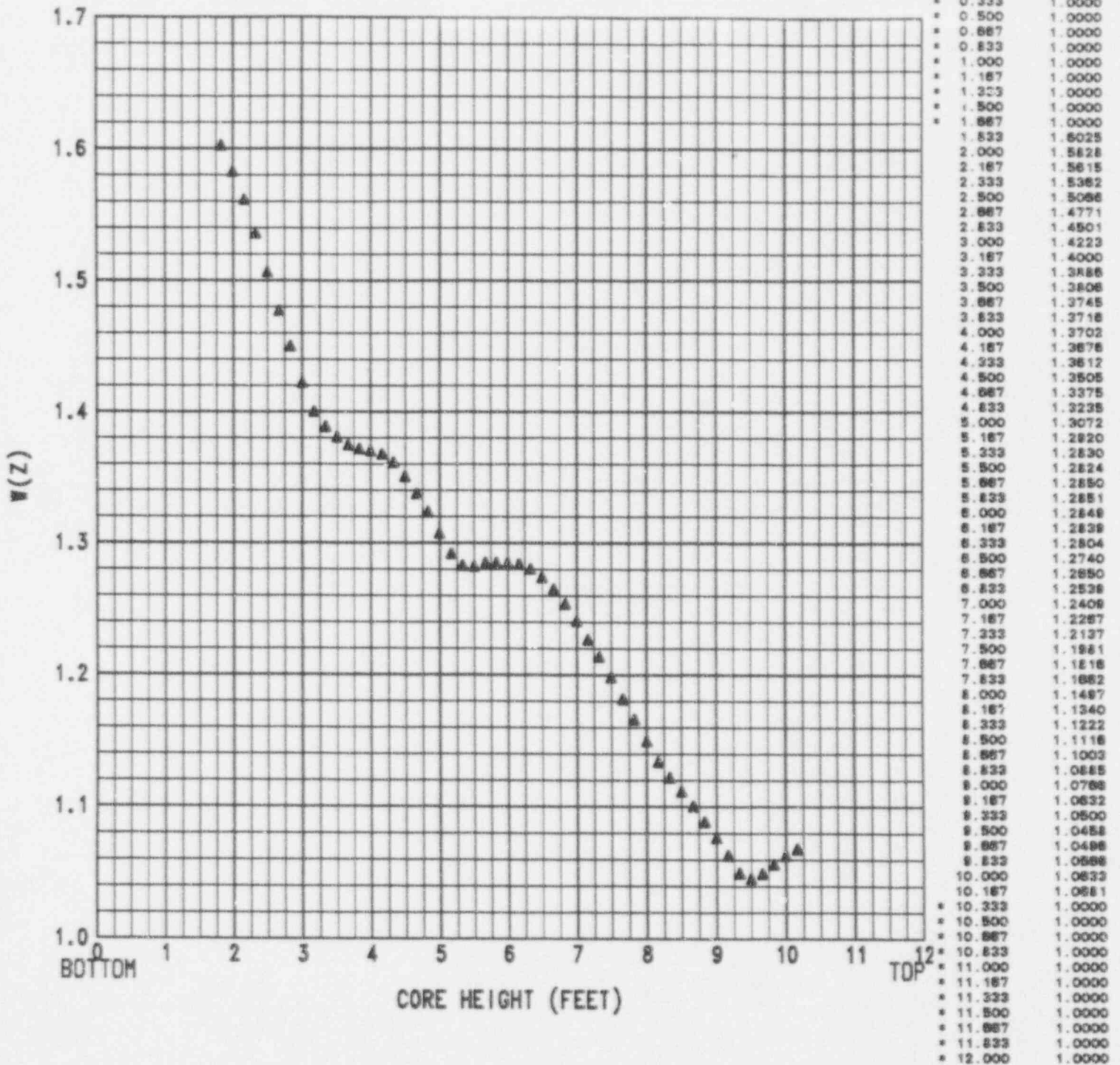


FIGURE 28

CALLAWAY UNIT 1 CYCLE 6

 $W(Z)_{NO}$ AT 16000 MWD/MTU (Measured A.O. = +12% +/- 2%)

* Top and bottom 15% excluded as per Tech Spec 4.2.2.2G

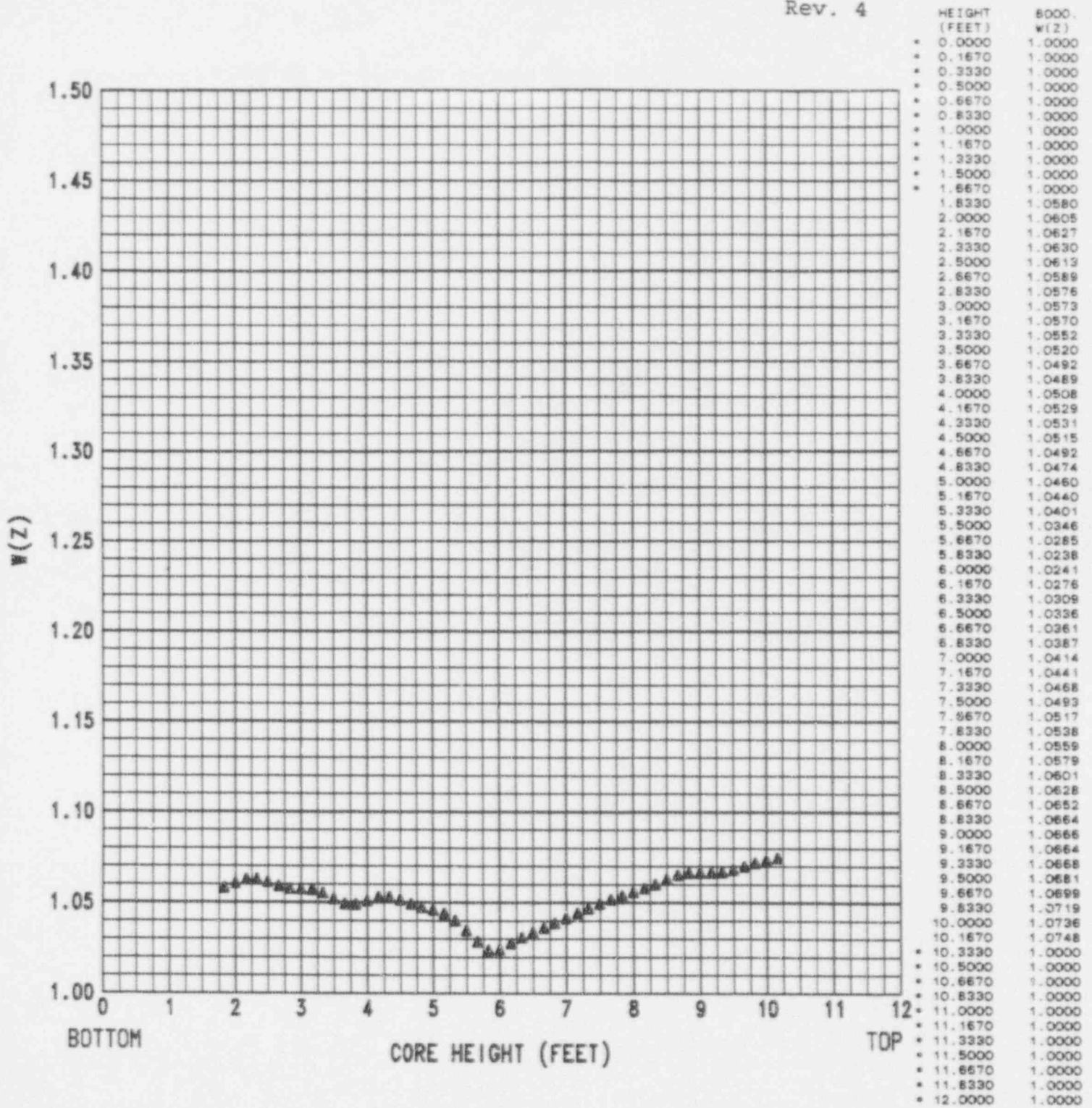


FIGURE 29

CALLAWAY UNIT 1 CYCLE 6

W(Z) AT 8000 MWD/MTU
RAPDO

* Top and bottom 15% excluded as per Tech Spec 4.2.2.2G

Rev. 4

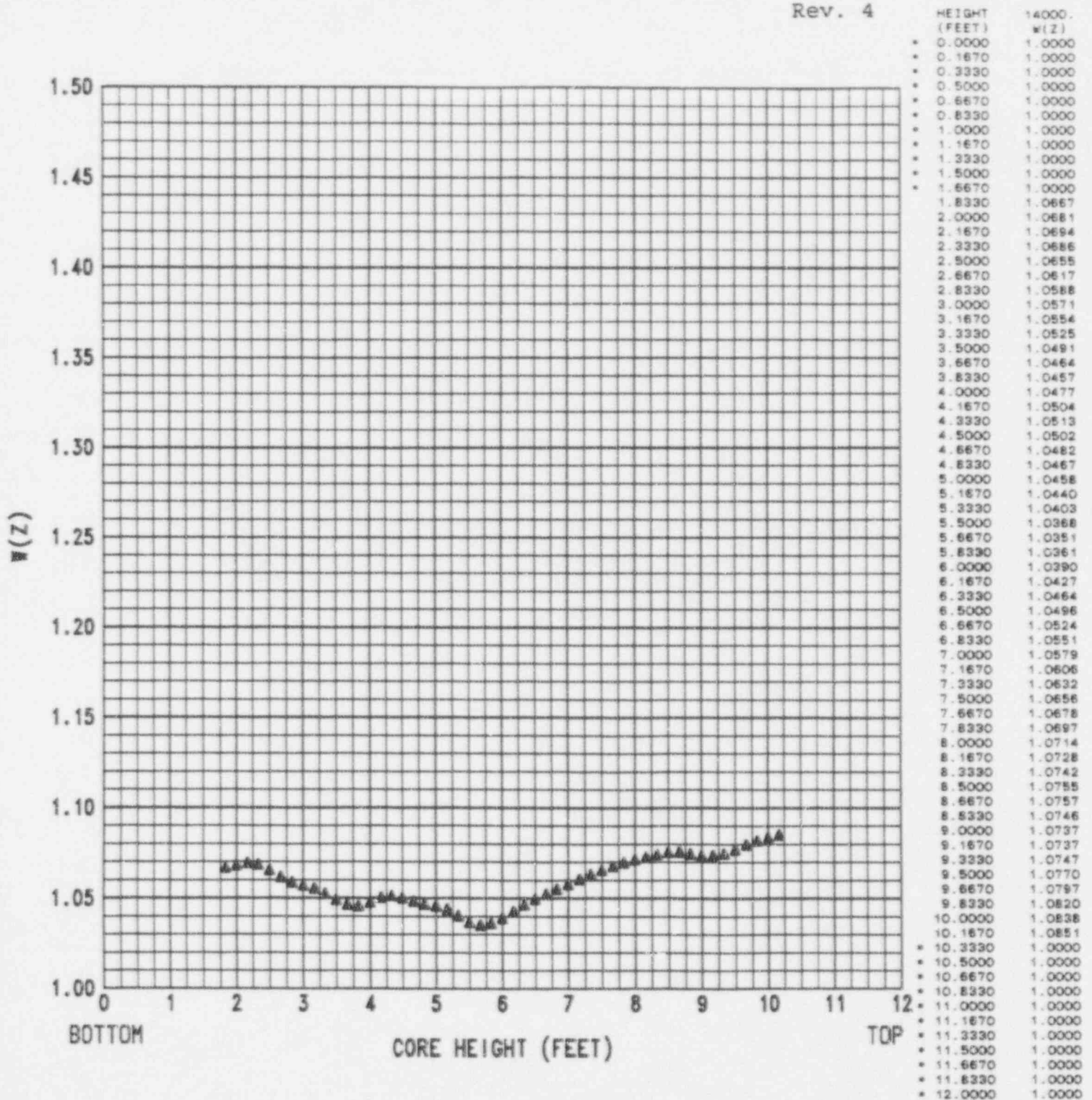


FIGURE 30

CALLAWAY UNIT 1 CYCLE 6

W(Z) AT 14000 MWD/MTU
RAPDO

* Top and bottom 15% excluded as per Tech Spec 4.2.2.2G

Rev. 4

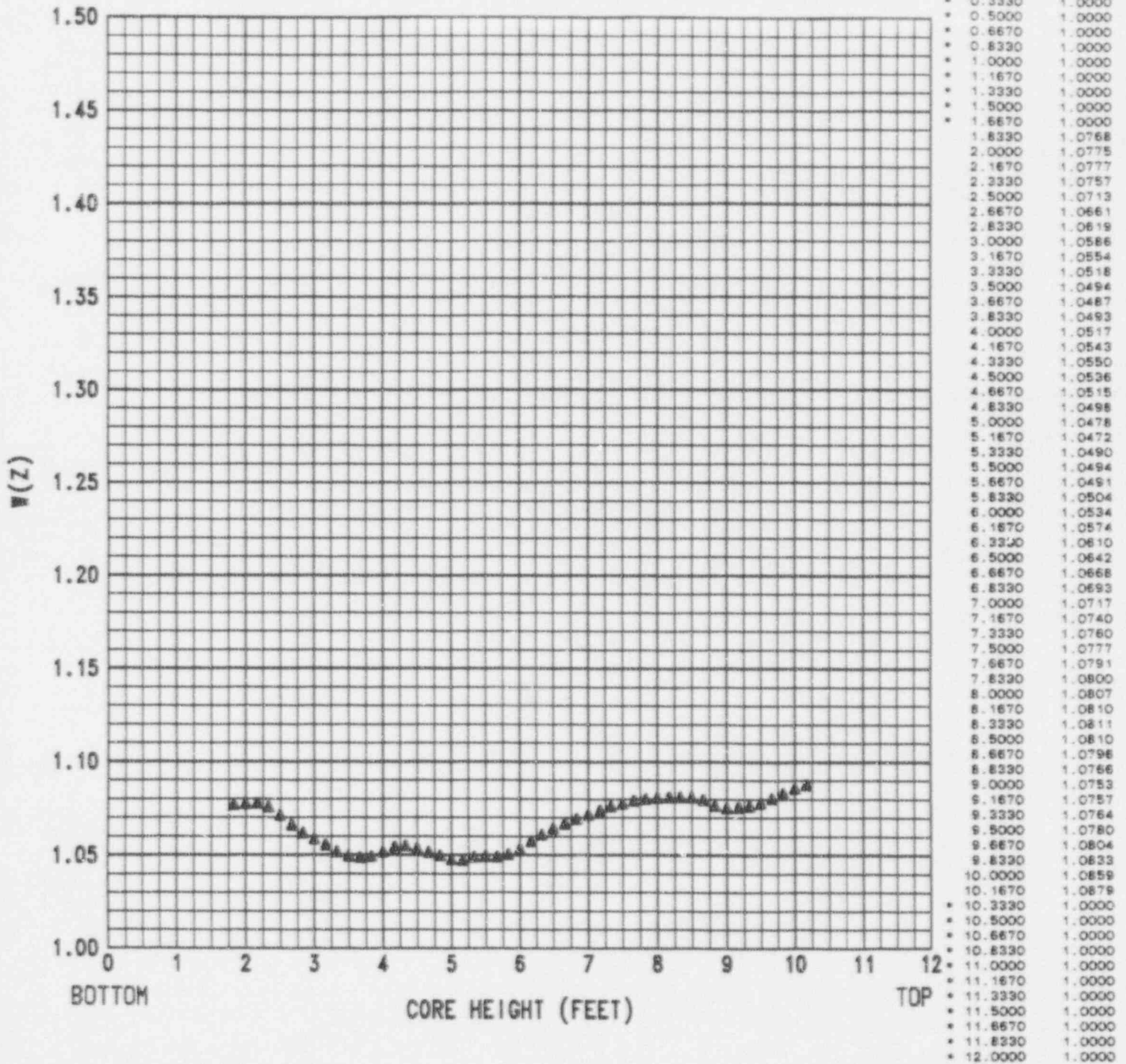


FIGURE 31

CALLAWAY UNIT 1 CYCLE 6

$W(Z)$ AT 18000 MWD/MTU
RAPDO

* Top and bottom 15% excluded as per Tech Spec 4.2.2.2G