# CALLAWAY CYCLE 9

# CORE OPERATING LIMITS REPORT

March 1997

## 1.0 CORE OPERATING LIMITS REPORT

This Core Operating Limits Report (COLR) for Callaway Plant Cycle 9 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 Limits |
| 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 -47.9 pcm/°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2.1.2 The MTC 300 ppm surveillance limit is -40.4 pcm/°F (all rods withdrawn, Rated Thermal Power condition).

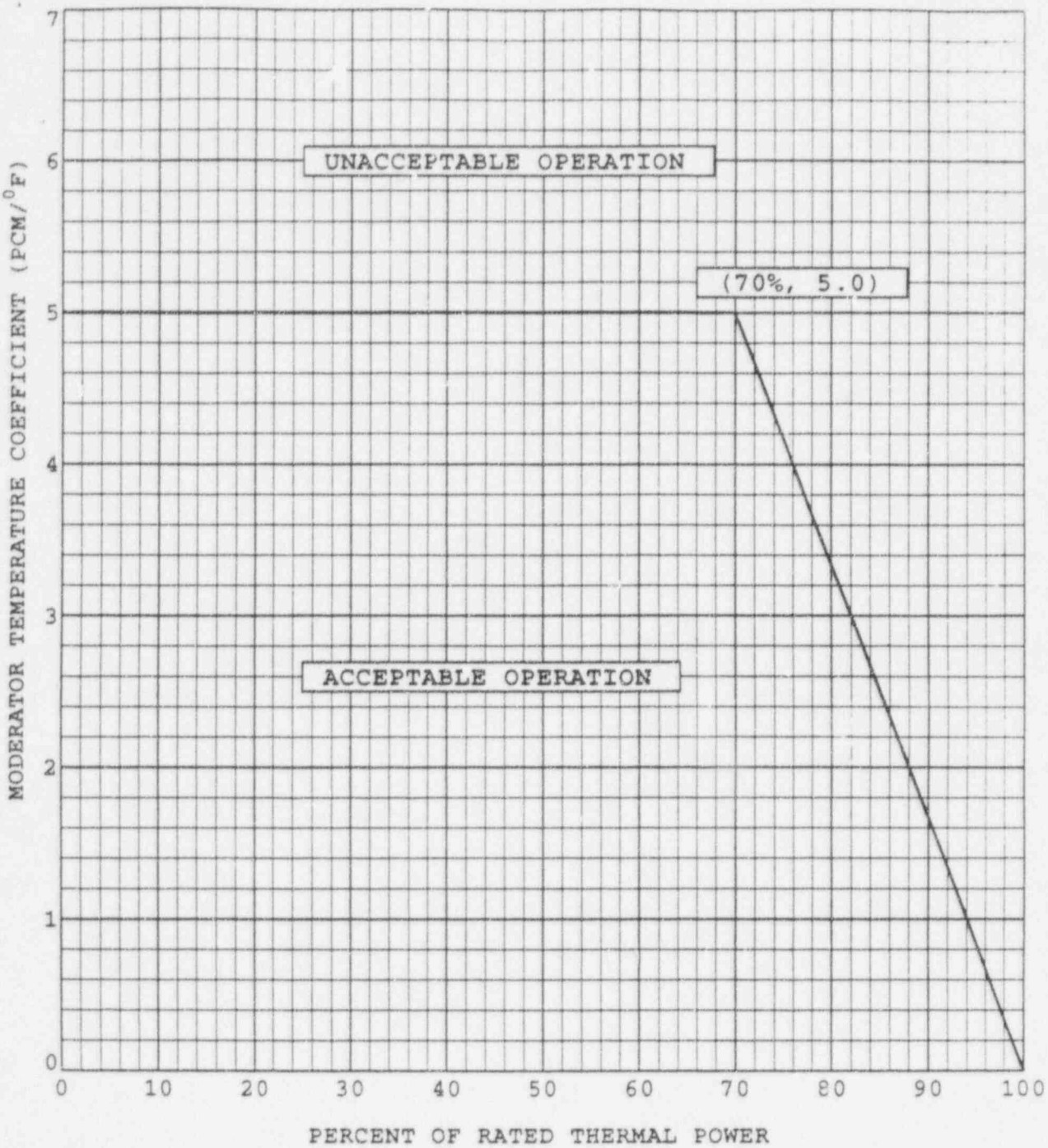



Figure 1

Callaway Cycle 9
Moderator Temperature Coefficient
Versus 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The shutdown rods shall be withdrawn to at least 225 steps.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.

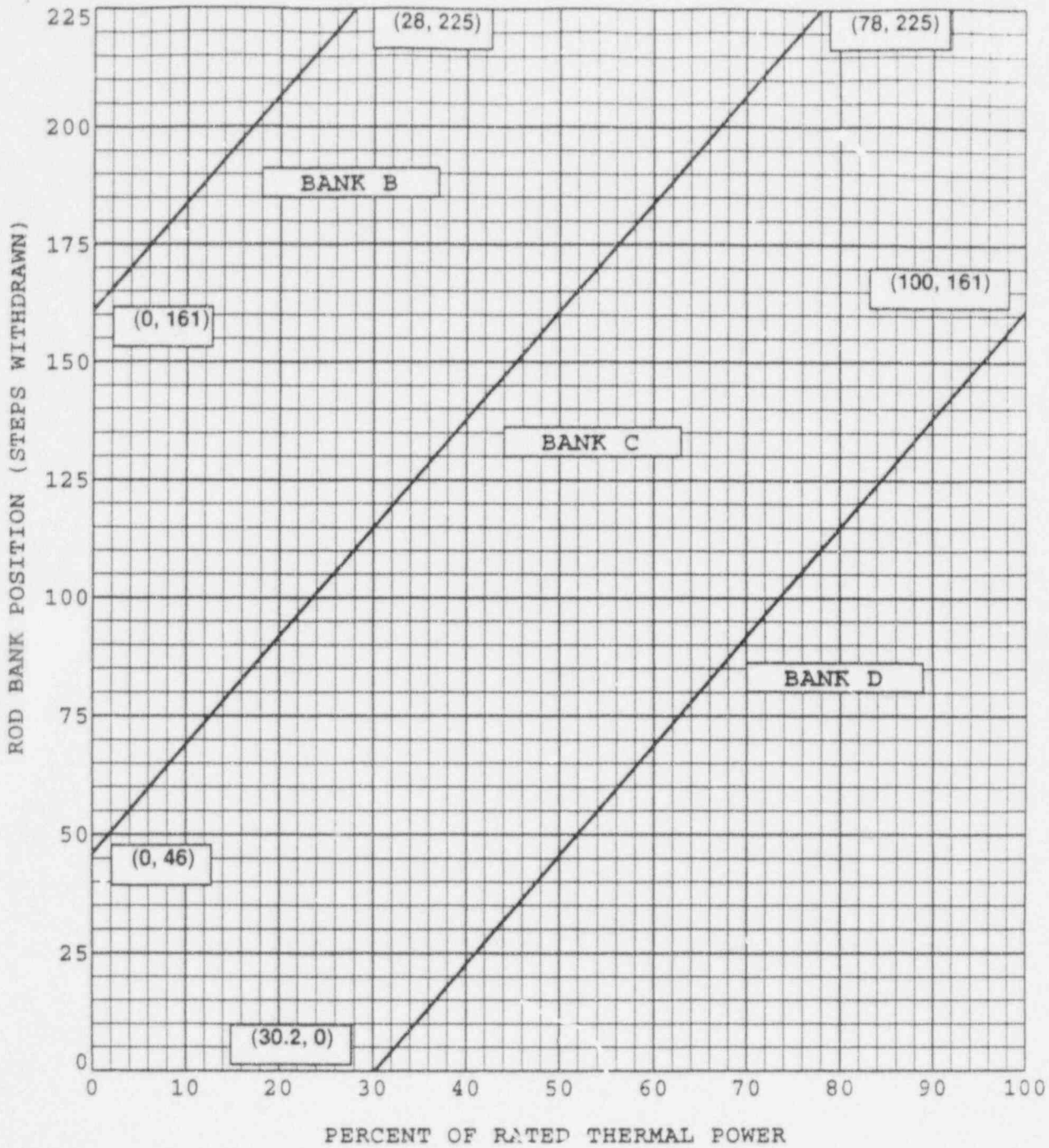



Figure 2

Callaway Cycle 9
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 ±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, $APL^{NP}$, is 90% of RATED THERMAL POWER.

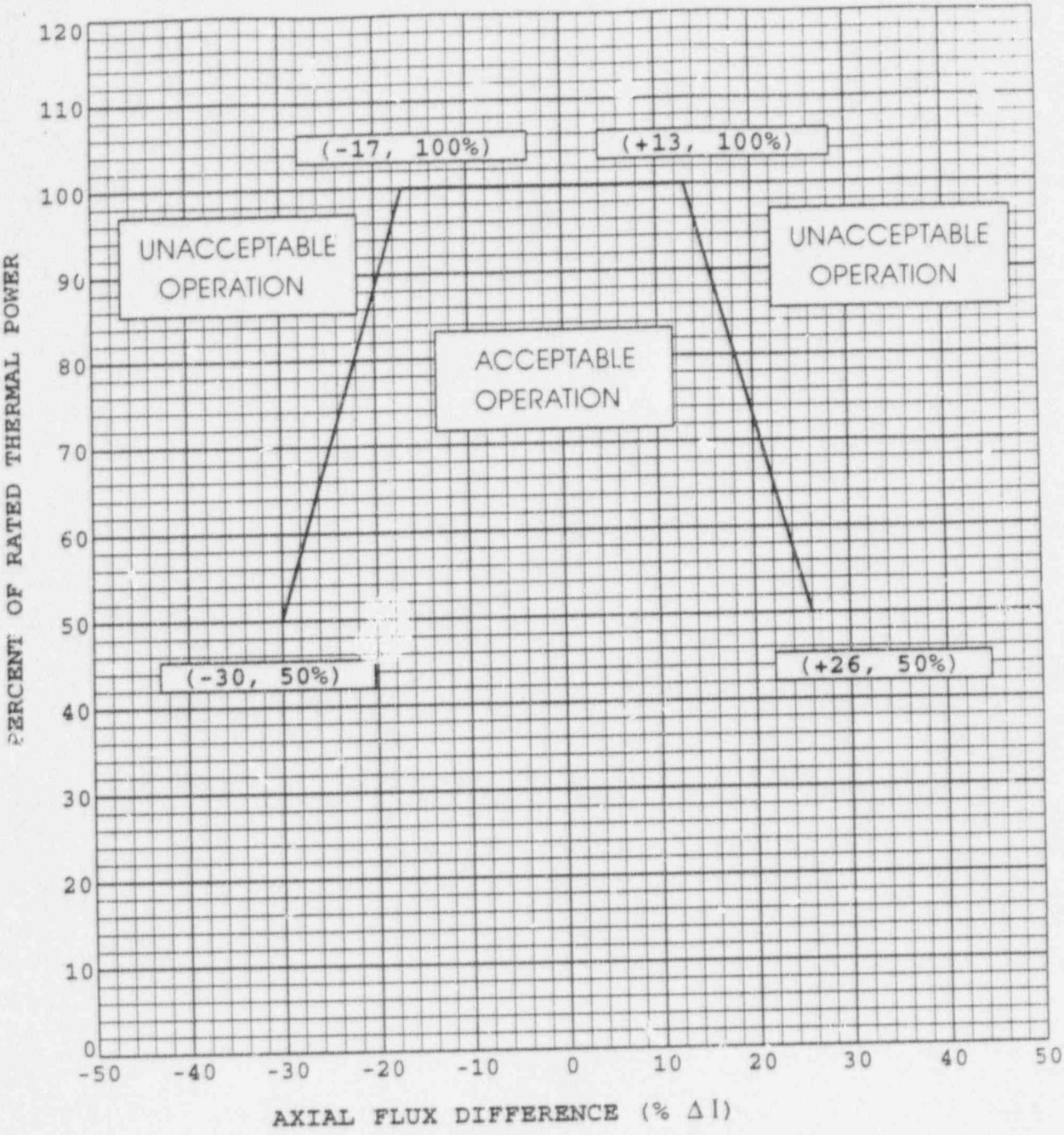



Figure 3

Callaway Cycle 9
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 17.

The Normal Operation W(z) values have been determined for several burnups up to 18000 MWD/MTU in Cycle 9. This permits determination of W(z) at any cycle burnup up to 18000 MWD/MTU through the use of three point interpolation. For cycle burnups greater than 18000 MWD/MTU, use of 18000 MWD/MTU W(z) values without interpolation or extrapolation is conservative. The $W(z)_{no}$ values were determined assuming Cycle 9 operates with RAOC strategy. Also included is a $W(z)_{no}$ function that bounds the $W(z)_{no}$ Curve for all Cycle 9 burnups. Use of the bounding $W(z)_{no}$ curve will be conservative for any Cycle 9 burnup; however, additional margin may be gained by using the burnup dependent $W(z)_{no}$ values.

The Normal Operation W(z) values have also been determined for a range of measured axial offset values for Cycle 9. For measured axial offset values within ±3% of the predicted axial offset value, Figures 5 through 9 are applicable. Additional W(z) values are provided in Figures 10 through 13 applicable to measured axial offsets within ±3% of a measured-predicted axial offset difference of -2.7%. Figures 14 through 17 provide W(z) values applicable to measured axial offsets within ±3% of a measured-predicted axial offset difference of -7.0%. For purposes of burnup interpolation, a consistent set of W(z) values should be used based on the difference between the measured and predicted axial offset. The W(z) set selected should be the set closest to the actual measured-predicted axial offset difference.

Because significant margin exists between the analytically determined maximum $F_Q(z)*P_{rel}$ values and their limit, Restricted Axial Flux Difference (RAFDO) Operation is not expected to be required for Cycle 9. For this reason, no

$W(z)_{RAOC}$ values are supplied for Cycle 9.

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

Table A.1 shows the burnup dependent $F_Q$ penalty factors for Cycle 9. These values shall be used to increase $F_Q^M(z)$ when required by Technical Specification Surveillance Requirement 4.2.2.2.e. A 2% penalty factor shall be used at all cycle burnups that are outside the range of Table A.1.

TABLE A.1

$F_Q$ PENALTY FACTORS AS A FUNCTION OF CYCLE BURNUP

| Cycle Burnup (MWD/MTU) | $F_Q^M(z)$ Penalty Factor (%) |
|---|---|
| 150 | 2.04 |
| 4105 | 2.27 |
| 4277 | 2.90 |
| 4449 | 3.55 |
| 4620 | 4.16 |
| 4792 | 4.42 |
| 4964 | 4.32 |
| 5136 | 4.10 |
| 5308 | 3.79 |
| 5480 | 3.42 |
| 5652 | 2.99 |
| 5824 | 2.52 |
| 5996 | 2.10 |

Note: All cycle burnups outside the range of the above table shall use a 2% penalty factor for compliance with the 4.2.2.2.e Surveillance Requirement. Linear interpolation should be used for intermediate cycle burnups.

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 $K_{eff} \leq 0.95$ shall be $\geq$ 2000 ppm.

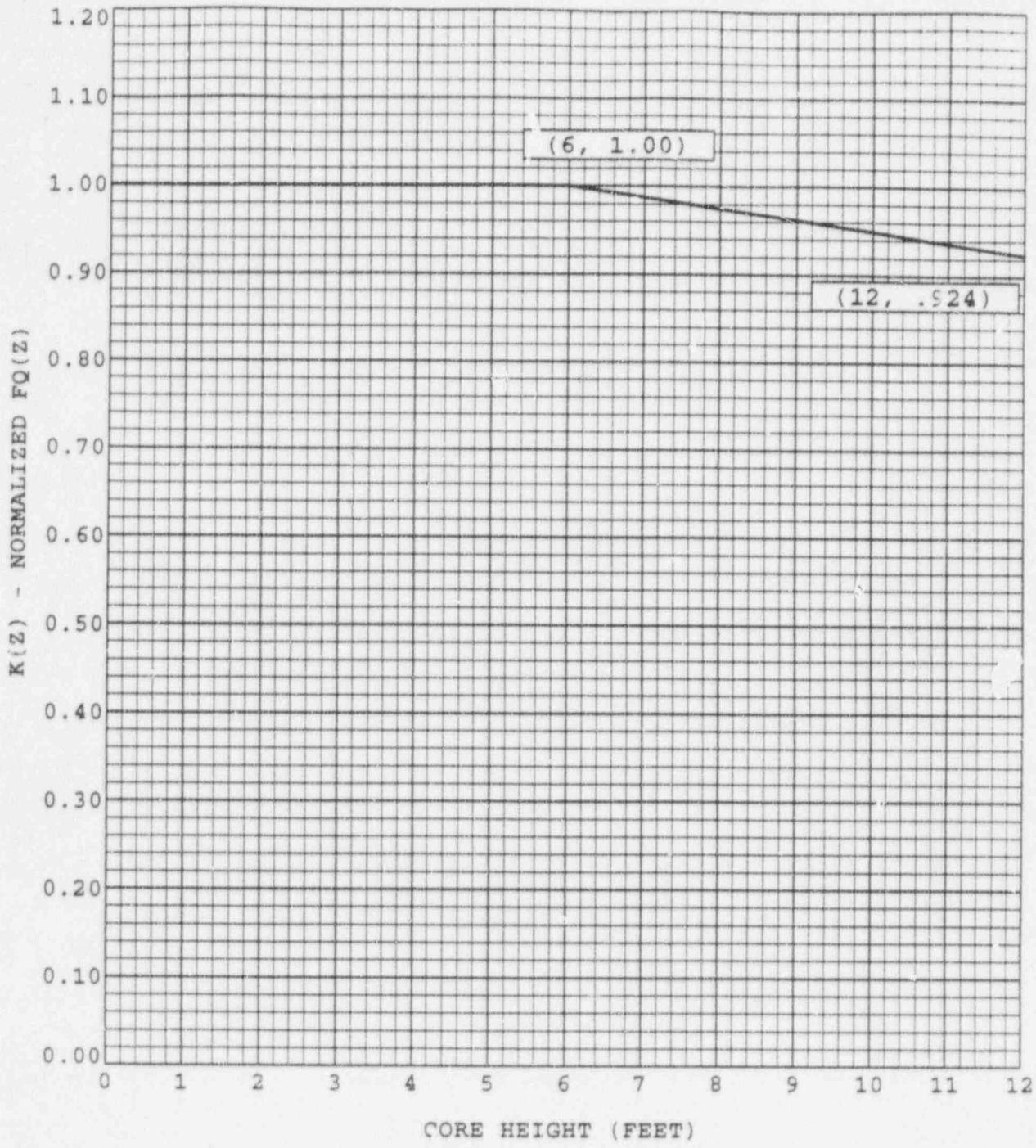
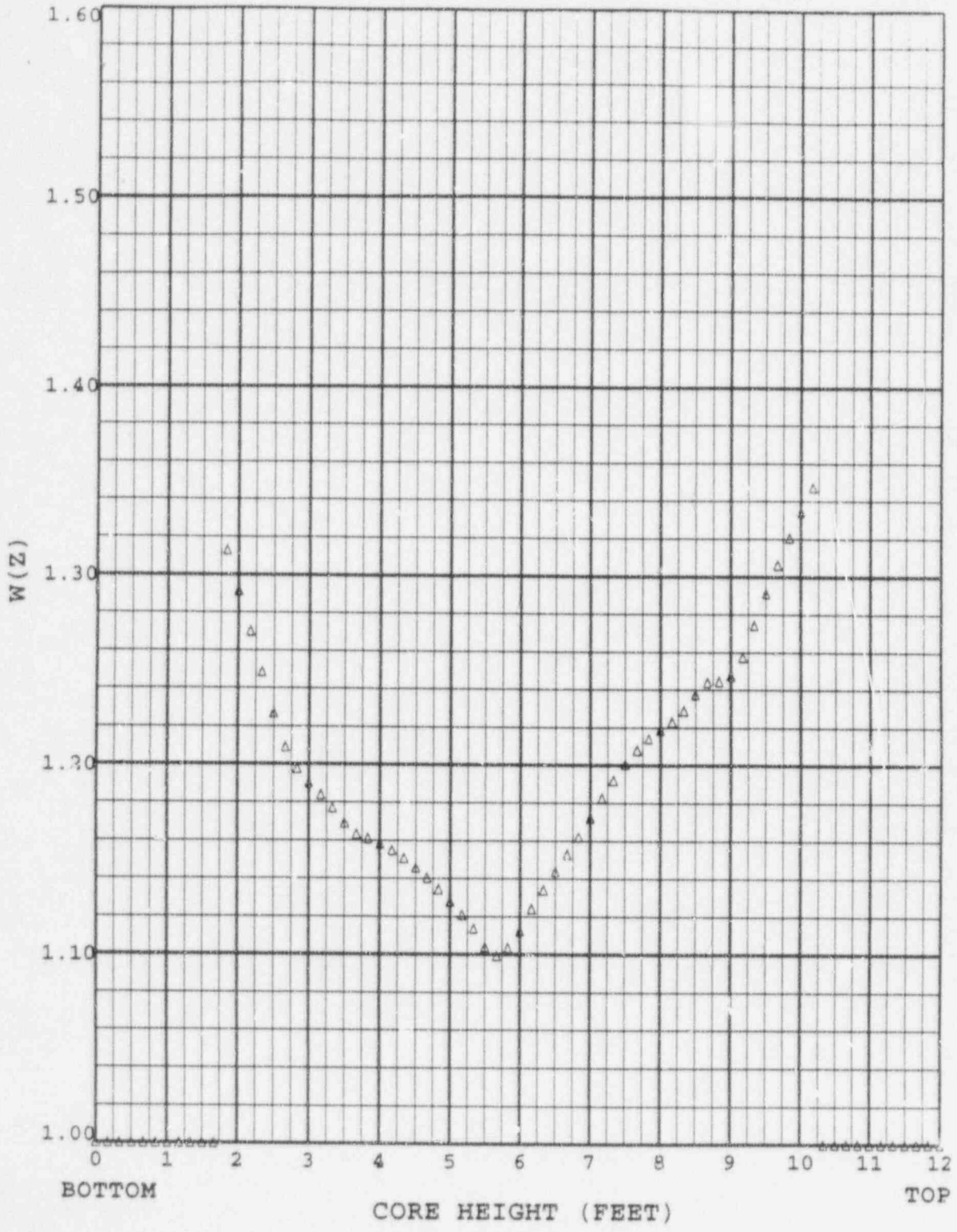



Figure 4

Callaway Cycle 9
K(z) - Normalized $F_Q(z)$
As a Function of Core Height

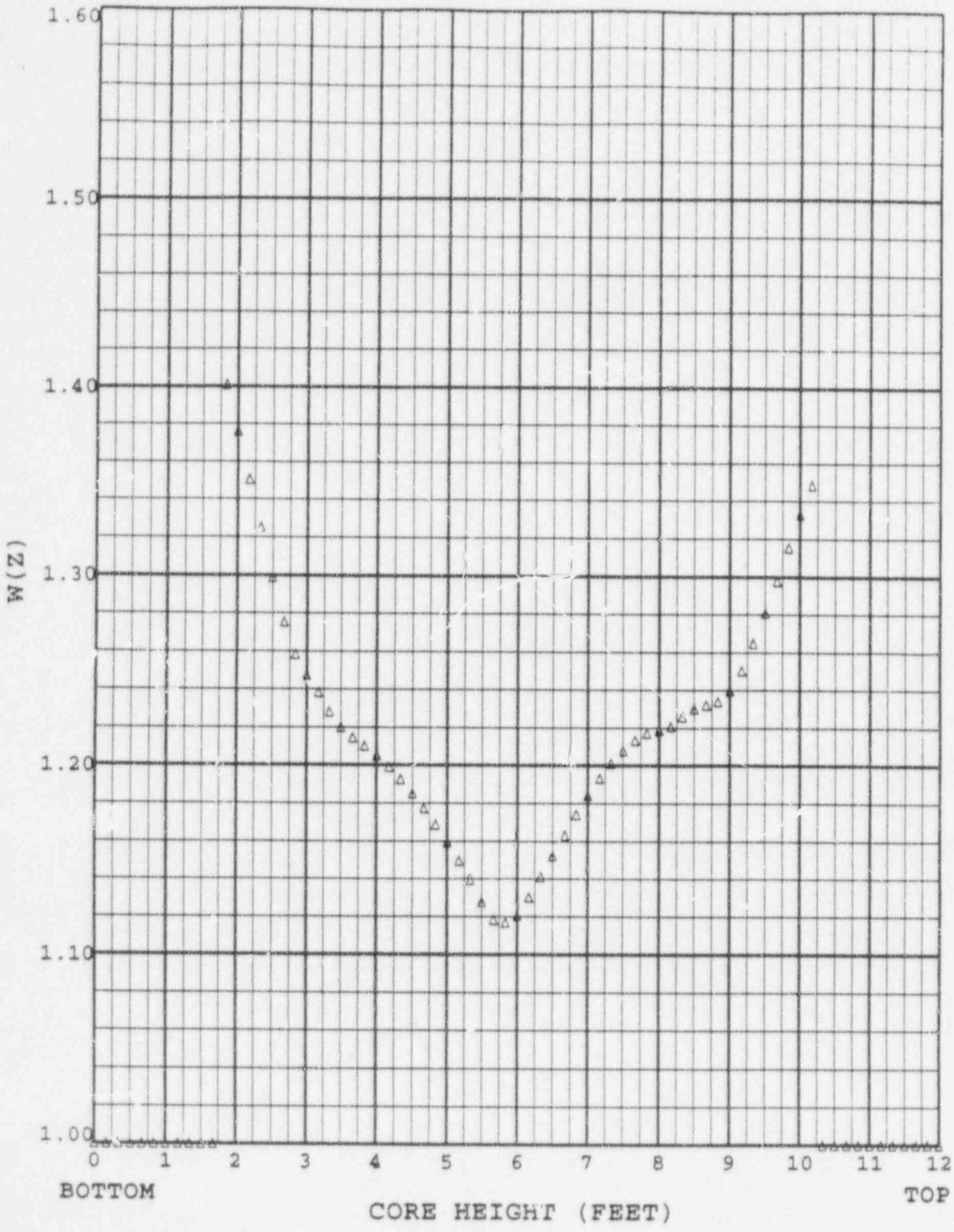



| | HEIGHT FEET | W(Z) |
|---|---|---|
| * | 0.000 | 1.0000 |
| * | 0.167 | 1.0000 |
| * | 0.333 | 1.0000 |
| * | 0.500 | 1.0000 |
| * | 0.667 | 1.0000 |
| * | 0.833 | 1.0000 |
| * | 1.000 | 1.0000 |
| * | 1.167 | 1.0000 |
| * | 1.333 | 1.0000 |
| * | 1.500 | 1.0000 |
| * | 1.667 | 1.0000 |
| | 1.833 | 1.3130 |
| | 2.000 | 1.2917 |
| | 2.167 | 1.2701 |
| | 2.333 | 1.2485 |
| | 2.500 | 1.2271 |
| | 2.667 | 1.2092 |
| | 2.833 | 1.1976 |
| | 3.000 | 1.1902 |
| | 3.167 | 1.1840 |
| | 3.333 | 1.1770 |
| | 3.500 | 1.1692 |
| | 3.667 | 1.1633 |
| | 3.833 | 1.1611 |
| | 4.000 | 1.1584 |
| | 4.167 | 1.1547 |
| | 4.333 | 1.1506 |
| | 4.500 | 1.1458 |
| | 4.667 | 1.1405 |
| | 4.833 | 1.1345 |
| | 5.000 | 1.1279 |
| | 5.167 | 1.1210 |
| | 5.333 | 1.1136 |
| | 5.500 | 1.1039 |
| | 5.667 | 1.0992 |
| | 5.833 | 1.1036 |
| | 6.000 | 1.1125 |
| | 6.167 | 1.1241 |
| | 6.333 | 1.1343 |
| | 6.500 | 1.1439 |
| | 6.667 | 1.1530 |
| | 6.833 | 1.1621 |
| | 7.000 | 1.1723 |
| | 7.167 | 1.1828 |
| | 7.333 | 1.1922 |
| | 7.500 | 1.2006 |
| | 7.667 | 1.2081 |
| | 7.833 | 1.2143 |
| | 8.000 | 1.2190 |
| | 8.167 | 1.2232 |
| | 8.333 | 1.2291 |
| | 8.500 | 1.2376 |
| | 8.667 | 1.2440 |
| | 8.833 | 1.2447 |
| | 9.000 | 1.2475 |
| | 9.167 | 1.2575 |
| | 9.333 | 1.2744 |
| | 9.500 | 1.2913 |
| | 9.667 | 1.3063 |
| | 9.833 | 1.3205 |
| | 10.000 | 1.3345 |
| | 10.167 | 1.3475 |
| * | 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 Cycle 9
## $W(z)_{no}$ at 150 MWD/MTU

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

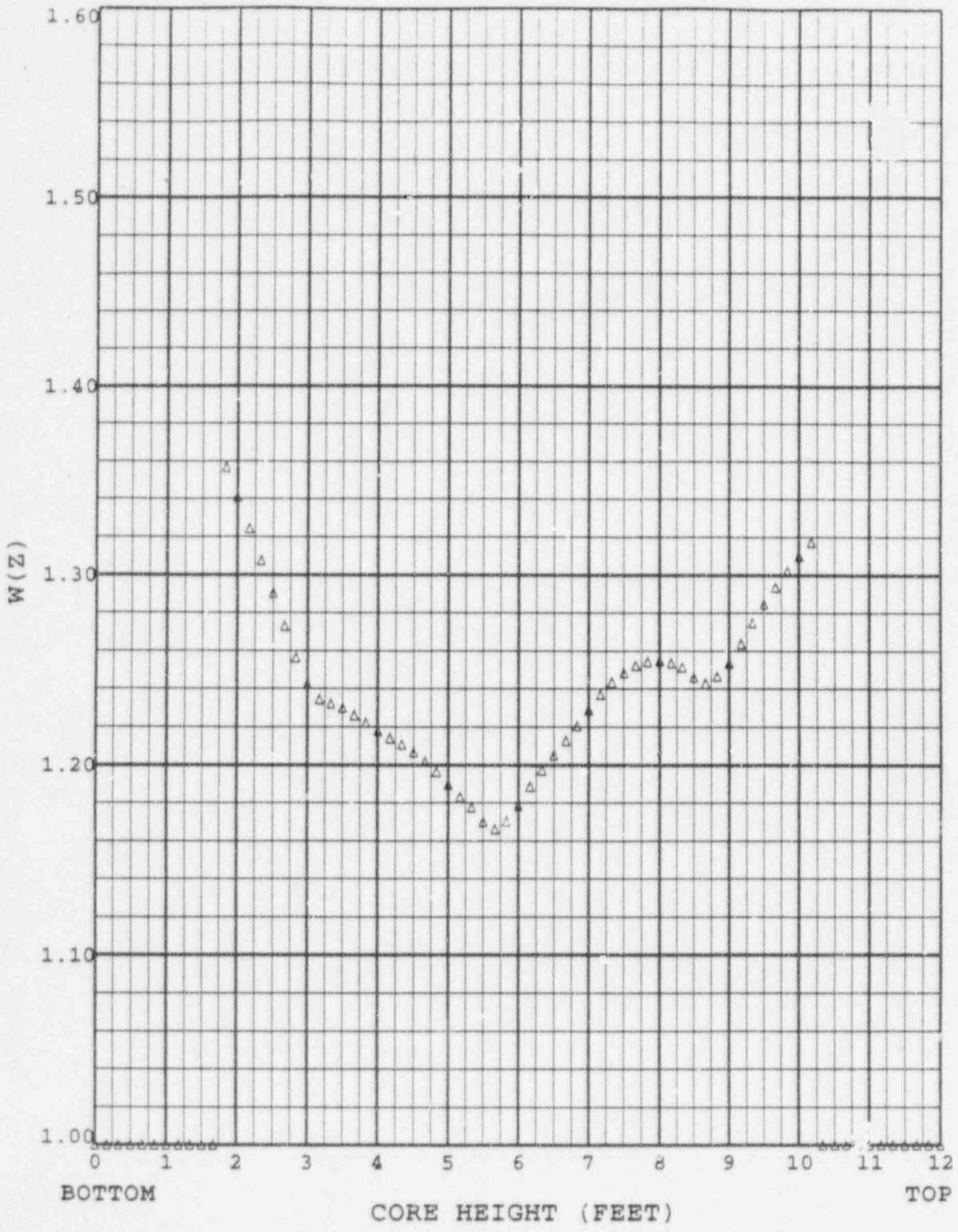



| | HEIGHT FEET | W Z |
|---|---|---|
| * | 0.000 | 1.0000 |
| * | 0.167 | 1.0000 |
| * | 0.333 | 1.0000 |
| * | 0.500 | 1.0000 |
| * | 0.667 | 1.0000 |
| * | 0.833 | 1.0000 |
| * | 1.000 | 1.0000 |
| * | 1.167 | 1.0000 |
| * | 1.333 | 1.0000 |
| * | 1.500 | 1.0000 |
| * | 1.667 | 1.0000 |
| | 1.833 | 1.4009 |
| | 2.000 | 1.3760 |
| | 2.167 | 1.3507 |
| | 2.333 | 1.3253 |
| | 2.500 | 1.2990 |
| | 2.667 | 1.2754 |
| | 2.833 | 1.2584 |
| | 3.000 | 1.2475 |
| | 3.167 | 1.2385 |
| | 3.333 | 1.2282 |
| | 3.500 | 1.2202 |
| | 3.667 | 1.2147 |
| | 3.833 | 1.2102 |
| | 4.000 | 1.2051 |
| | 4.167 | 1.1991 |
| | 4.333 | 1.1926 |
| | 4.500 | 1.1853 |
| | 4.667 | 1.1773 |
| | 4.833 | 1.1688 |
| | 5.000 | 1.1595 |
| | 5.167 | 1.1498 |
| | 5.333 | 1.1396 |
| | 5.500 | 1.1279 |
| | 5.667 | 1.1184 |
| | 5.833 | 1.1170 |
| | 6.000 | 1.1205 |
| | 6.167 | 1.1303 |
| | 6.333 | 1.1412 |
| | 6.500 | 1.1523 |
| | 6.667 | 1.1633 |
| | 6.833 | 1.1741 |
| | 7.000 | 1.1843 |
| | 7.167 | 1.1934 |
| | 7.333 | 1.2013 |
| | 7.500 | 1.2080 |
| | 7.667 | 1.2134 |
| | 7.833 | 1.2173 |
| | 8.000 | 1.2198 |
| | 8.167 | 1.2208 |
| | 8.333 | 1.2261 |
| | 8.500 | 1.2304 |
| | 8.667 | 1.2323 |
| | 8.833 | 1.2341 |
| | 9.000 | 1.2398 |
| | 9.167 | 1.2505 |
| | 9.333 | 1.2650 |
| | 9.500 | 1.2809 |
| | 9.667 | 1.2978 |
| | 9.833 | 1.3155 |
| | 10.000 | 1.3331 |
| | 10.167 | 1.3488 |
| * | 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 Cycle 9
## $W(z)_{no}$ at 3000 MWD/MTU

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

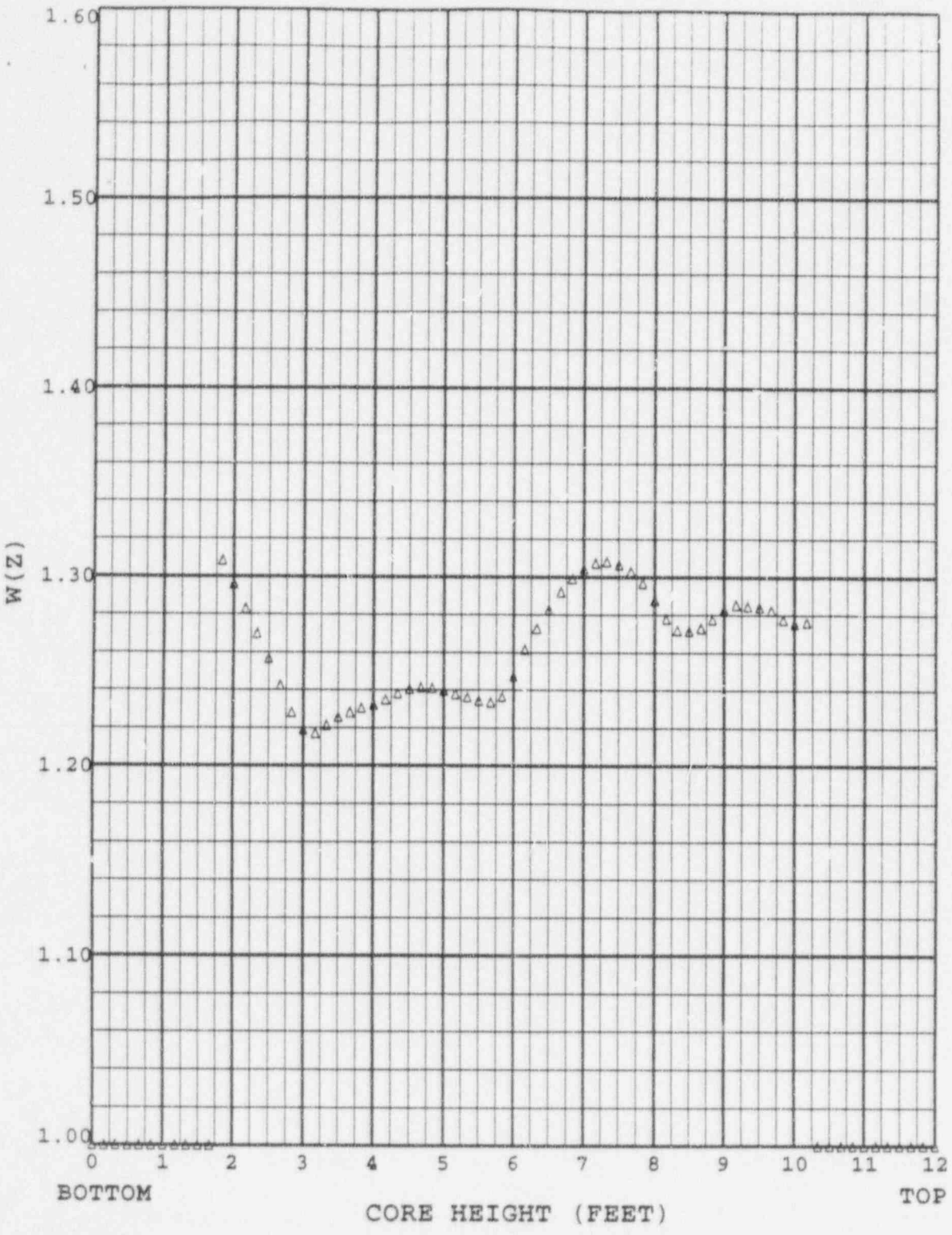



| | HEIGHT FEET | W Z |
|---|---|---|
| * | 0.000 | 1.0000 |
| * | 0.167 | 1.0000 |
| * | 0.333 | 1.0000 |
| * | 0.500 | 1.0000 |
| * | 0.667 | 1.0000 |
| * | 0.833 | 1.0000 |
| * | 1.000 | 1.0000 |
| * | 1.167 | 1.0000 |
| * | 1.333 | 1.0000 |
| * | 1.500 | 1.0000 |
| * | 1.667 | 1.0000 |
| | 1.833 | 1.3569 |
| | 2.000 | 1.3409 |
| | 2.167 | 1.3244 |
| | 2.333 | 1.3076 |
| | 2.500 | 1.2905 |
| | 2.667 | 1.2732 |
| | 2.833 | 1.2564 |
| | 3.000 | 1.2425 |
| | 3.167 | 1.2344 |
| | 3.333 | 1.2323 |
| | 3.500 | 1.2300 |
| | 3.667 | 1.2262 |
| | 3.833 | 1.2221 |
| | 4.000 | 1.2179 |
| | 4.167 | 1.2142 |
| | 4.333 | 1.2108 |
| | 4.500 | 1.2067 |
| | 4.667 | 1.2018 |
| | 4.833 | 1.1963 |
| | 5.000 | 1.1895 |
| | 5.167 | 1.1831 |
| | 5.333 | 1.1777 |
| | 5.500 | 1.1700 |
| | 5.667 | 1.1662 |
| | 5.833 | 1.1706 |
| | 6.000 | 1.1785 |
| | 6.167 | 1.1887 |
| | 6.333 | 1.1972 |
| | 6.500 | 1.2051 |
| | 6.667 | 1.2128 |
| | 6.833 | 1.2205 |
| | 7.000 | 1.2289 |
| | 7.167 | 1.2371 |
| | 7.333 | 1.2435 |
| | 7.500 | 1.2486 |
| | 7.667 | 1.2523 |
| | 7.833 | 1.2546 |
| | 8.000 | 1.2548 |
| | 8.167 | 1.2539 |
| | 8.333 | 1.2515 |
| | 8.500 | 1.2461 |
| | 8.667 | 1.2430 |
| | 8.833 | 1.2466 |
| | 9.000 | 1.2535 |
| | 9.167 | 1.2639 |
| | 9.333 | 1.2749 |
| | 9.500 | 1.2848 |
| | 9.667 | 1.2936 |
| | 9.833 | 1.3021 |
| | 10.000 | 1.3102 |
| | 10.167 | 1.3173 |
| * | 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 7

## Callaway Cycle 9
## $W(z)_{nc}$ at 10000 MWD/MTU

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

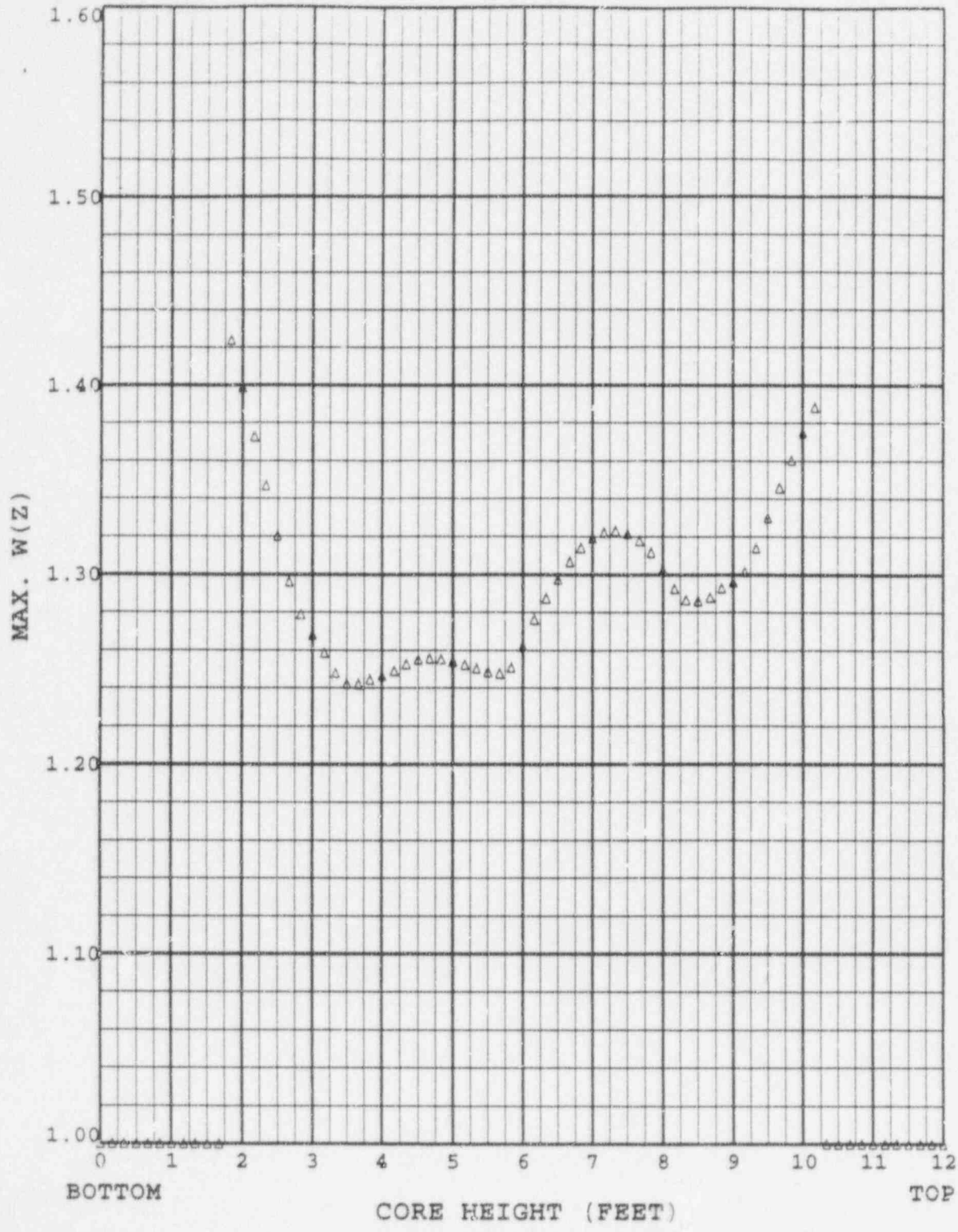



| | HEIGHT (FEET) | 18000 W(Z) |
|---|---|---|
| * | 0.000 | 1.0000 |
| * | 0.167 | 1.0000 |
| * | 0.333 | 1.0000 |
| * | 0.500 | 1.0000 |
| * | 0.667 | 1.0000 |
| * | 0.833 | 1.0000 |
| * | 1.000 | 1.0000 |
| * | 1.167 | 1.0000 |
| * | 1.333 | 1.0000 |
| * | 1.500 | 1.0000 |
| * | 1.667 | 1.0000 |
| | 1.833 | 1.3086 |
| | 2.000 | 1.2961 |
| | 2.167 | 1.2831 |
| | 2.333 | 1.2699 |
| | 2.500 | 1.2567 |
| | 2.667 | 1.2425 |
| | 2.833 | 1.2282 |
| | 3.000 | 1.2190 |
| | 3.167 | 1.2171 |
| | 3.333 | 1.2215 |
| | 3.500 | 1.2257 |
| | 3.667 | 1.2283 |
| | 3.833 | 1.2305 |
| | 4.000 | 1.2324 |
| | 4.167 | 1.2349 |
| | 4.333 | 1.2383 |
| | 4.500 | 1.2407 |
| | 4.667 | 1.2415 |
| | 4.833 | 1.2411 |
| | 5.000 | 1.2390 |
| | 5.167 | 1.2380 |
| | 5.333 | 1.2363 |
| | 5.500 | 1.2344 |
| | 5.667 | 1.2337 |
| | 5.833 | 1.2367 |
| | 6.000 | 1.2477 |
| | 6.167 | 1.2618 |
| | 6.333 | 1.2728 |
| | 6.500 | 1.2828 |
| | 6.667 | 1.2921 |
| | 6.833 | 1.2992 |
| | 7.000 | 1.3043 |
| | 7.167 | 1.3074 |
| | 7.333 | 1.3081 |
| | 7.500 | 1.3066 |
| | 7.667 | 1.3029 |
| | 7.833 | 1.2968 |
| | 8.000 | 1.2876 |
| | 8.167 | 1.2780 |
| | 8.333 | 1.2719 |
| | 8.500 | 1.2716 |
| | 8.667 | 1.2731 |
| | 8.833 | 1.2770 |
| | 9.000 | 1.2828 |
| | 9.167 | 1.2854 |
| | 9.333 | 1.2847 |
| | 9.500 | 1.2841 |
| | 9.667 | 1.2825 |
| | 9.833 | 1.2777 |
| | 10.000 | 1.2757 |
| | 10.167 | 1.2763 |
| * | 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 8

## Callaway Cycle 9
## $W(z)_{no}$ at 18000 MWD/MTU

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

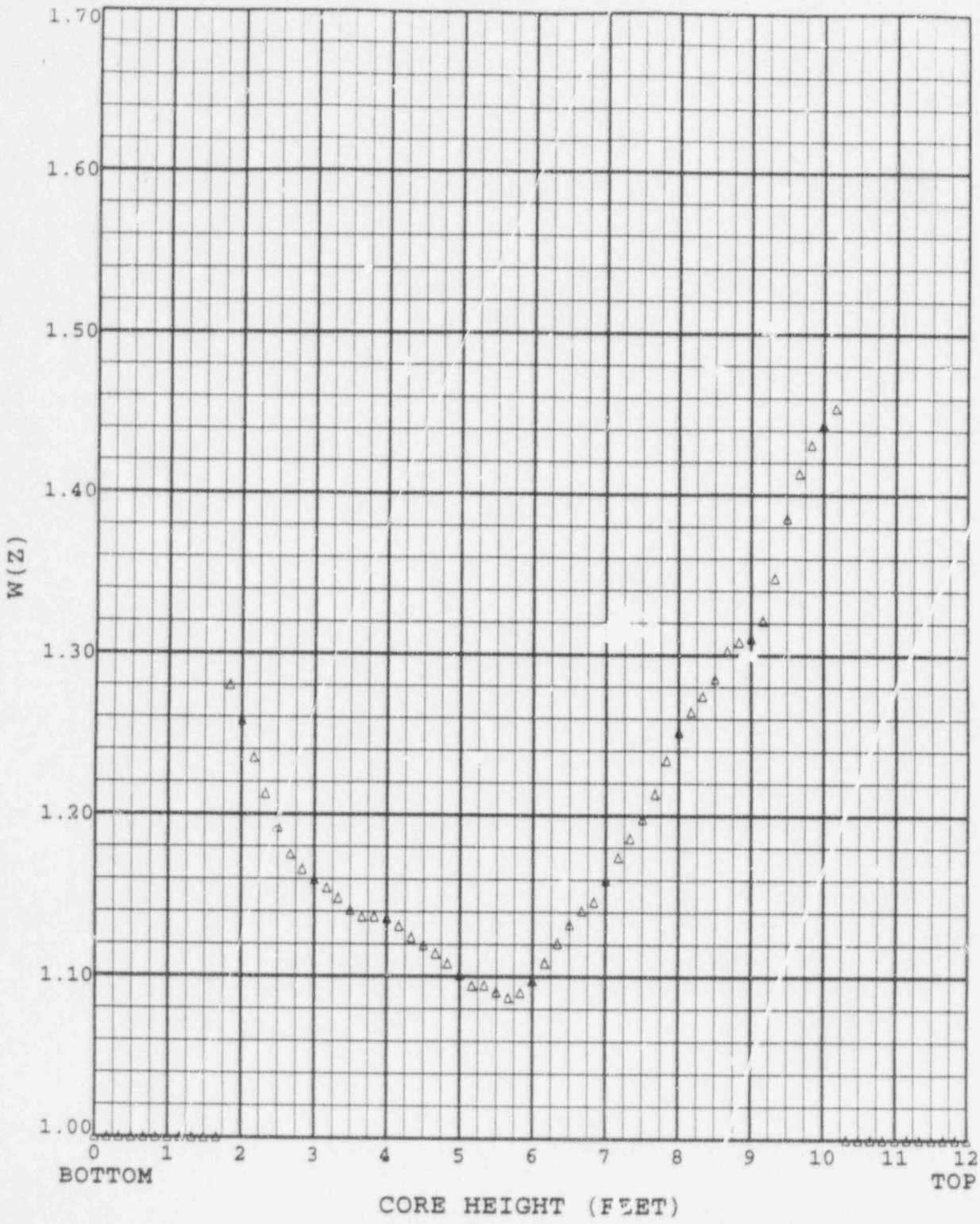



| | HEIGHT FEET | MAX W Z |
|---|---|---|
| * | 0.000 | 1.0000 |
| * | 0.167 | 1.0000 |
| * | 0.333 | 1.0000 |
| * | 0.500 | 1.0000 |
| * | 0.667 | 1.0000 |
| * | 0.833 | 1.0000 |
| * | 1.000 | 1.0000 |
| * | 1.167 | 1.0000 |
| * | 1.333 | 1.0000 |
| * | 1.500 | 1.0000 |
| * | 1.667 | 1.0000 |
| | 1.833 | 1.4239 |
| | 2.000 | 1.3986 |
| | 2.167 | 1.3728 |
| | 2.333 | 1.3471 |
| | 2.500 | 1.3204 |
| | 2.667 | 1.2963 |
| | 2.833 | 1.2790 |
| | 3.000 | 1.2681 |
| | 3.167 | 1.2597 |
| | 3.333 | 1.2480 |
| | 3.500 | 1.2426 |
| | 3.667 | 1.2422 |
| | 3.833 | 1.2446 |
| | 4.000 | 1.2467 |
| | 4.167 | 1.2492 |
| | 4.333 | 1.2526 |
| | 4.500 | 1.2550 |
| | 4.667 | 1.2558 |
| | 4.833 | 1.2556 |
| | 5.000 | 1.2541 |
| | 5.167 | 1.2523 |
| | 5.333 | 1.2505 |
| | 5.500 | 1.2487 |
| | 5.667 | 1.2479 |
| | 5.833 | 1.2510 |
| | 6.000 | 1.2621 |
| | 6.167 | 1.2764 |
| | 6.333 | 1.2875 |
| | 6.500 | 1.2976 |
| | 6.667 | 1.3069 |
| | 6.833 | 1.3142 |
| | 7.000 | 1.3194 |
| | 7.167 | 1.3224 |
| | 7.333 | 1.3232 |
| | 7.500 | 1.3217 |
| | 7.667 | 1.3179 |
| | 7.833 | 1.3118 |
| | 8.000 | 1.3025 |
| | 8.167 | 1.2927 |
| | 8.333 | 1.2866 |
| | 8.500 | 1.2862 |
| | 8.667 | 1.2879 |
| | 8.833 | 1.2929 |
| | 9.000 | 1.2962 |
| | 9.167 | 1.3015 |
| | 9.333 | 1.3140 |
| | 9.500 | 1.3300 |
| | 9.667 | 1.3460 |
| | 9.833 | 1.3606 |
| | 10.000 | 1.3750 |
| | 10.167 | 1.3886 |
| * | 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 9

## Callaway Cycle 9
## Bounding $W(z)_{no}$

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

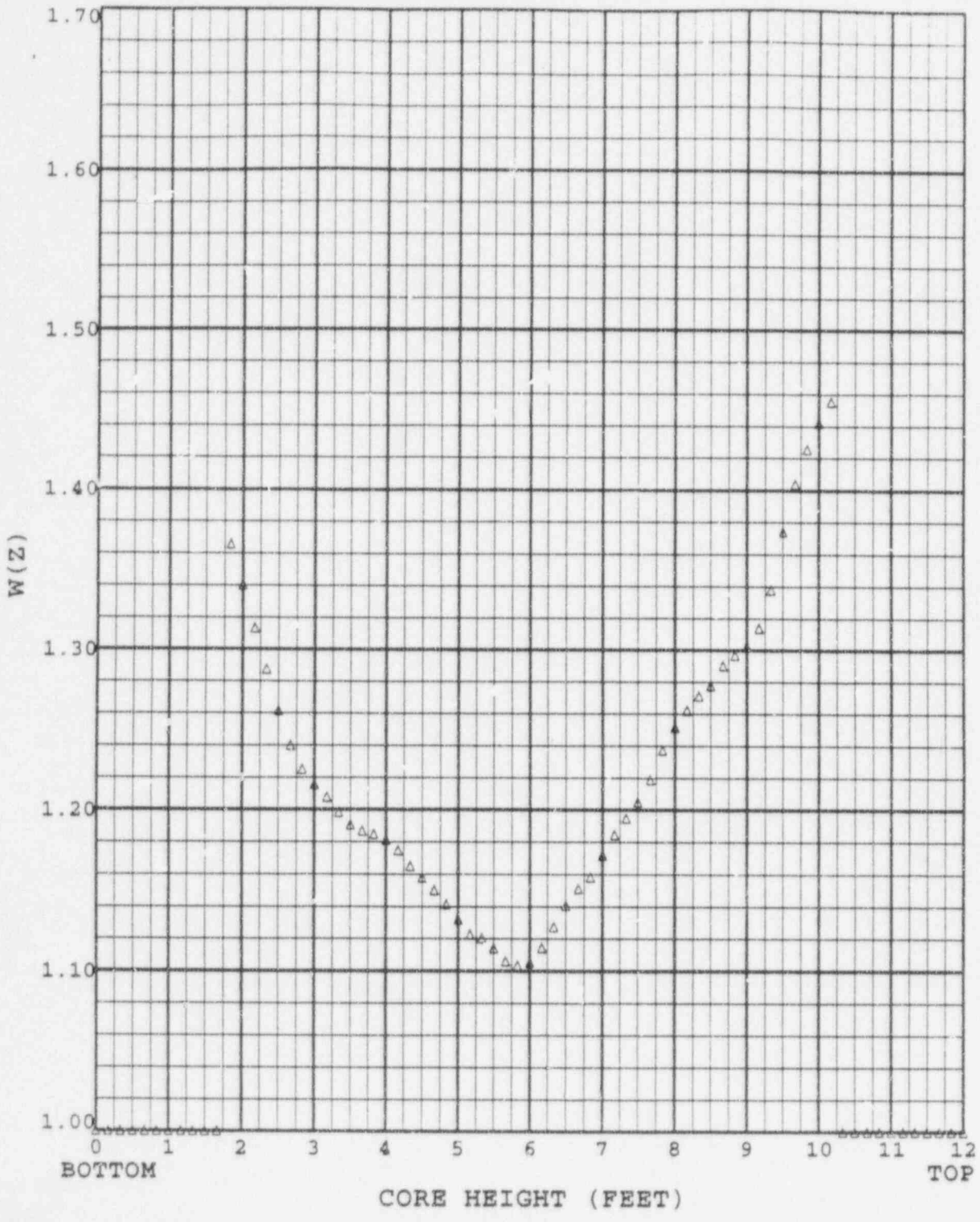



| | HEIGHT FEET | Z(Z) X Y |
|---|---|---|
| * | 0.000 | 1.0000 |
| * | 0.167 | 1.0000 |
| * | 0.333 | 1.0000 |
| * | 0.500 | 1.0000 |
| * | 0.667 | 1.0000 |
| * | 0.833 | 1.0000 |
| * | 1.000 | 1.0000 |
| * | 1.167 | 1.0000 |
| * | 1.333 | 1.0000 |
| * | 1.500 | 1.0000 |
| * | 1.667 | 1.0000 |
| | 1.833 | 1.2802 |
| | 2.000 | 1.2581 |
| | 2.167 | 1.2350 |
| | 2.333 | 1.2127 |
| | 2.500 | 1.1919 |
| | 2.667 | 1.1755 |
| | 2.833 | 1.1659 |
| | 3.000 | 1.1599 |
| | 3.167 | 1.1546 |
| | 3.333 | 1.1484 |
| | 3.500 | 1.1409 |
| | 3.667 | 1.1368 |
| | 3.833 | 1.1369 |
| | 4.000 | 1.1358 |
| | 4.167 | 1.1312 |
| | 4.333 | 1.1243 |
| | 4.500 | 1.1195 |
| | 4.667 | 1.1144 |
| | 4.833 | 1.1080 |
| | 5.000 | 1.1013 |
| | 5.167 | 1.0945 |
| | 5.333 | 1.0948 |
| | 5.500 | 1.0906 |
| | 5.667 | 1.0872 |
| | 5.833 | 1.0904 |
| | 6.000 | 1.0975 |
| | 6.167 | 1.1086 |
| | 6.333 | 1.1207 |
| | 6.500 | 1.1326 |
| | 6.667 | 1.1409 |
| | 6.833 | 1.1465 |
| | 7.000 | 1.1601 |
| | 7.167 | 1.1740 |
| | 7.333 | 1.1859 |
| | 7.500 | 1.1977 |
| | 7.667 | 1.2134 |
| | 7.833 | 1.2362 |
| | 8.000 | 1.2518 |
| | 8.167 | 1.2646 |
| | 8.333 | 1.2744 |
| | 8.500 | 1.2853 |
| | 8.667 | 1.3026 |
| | 8.833 | 1.3081 |
| | 9.000 | 1.3104 |
| | 9.167 | 1.3214 |
| | 9.333 | 1.3401 |
| | 9.500 | 1.3854 |
| | 9.667 | 1.4132 |
| | 9.833 | 1.4311 |
| | 10.000 | 1.4436 |
| | 10.167 | 1.4540 |
| * | 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 10**

**Callaway Cycle 9**
**$W(z)_{no}$ at 150 MWD/MTU**
**Measured-Predicted Axial Offset = -2.7%**

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

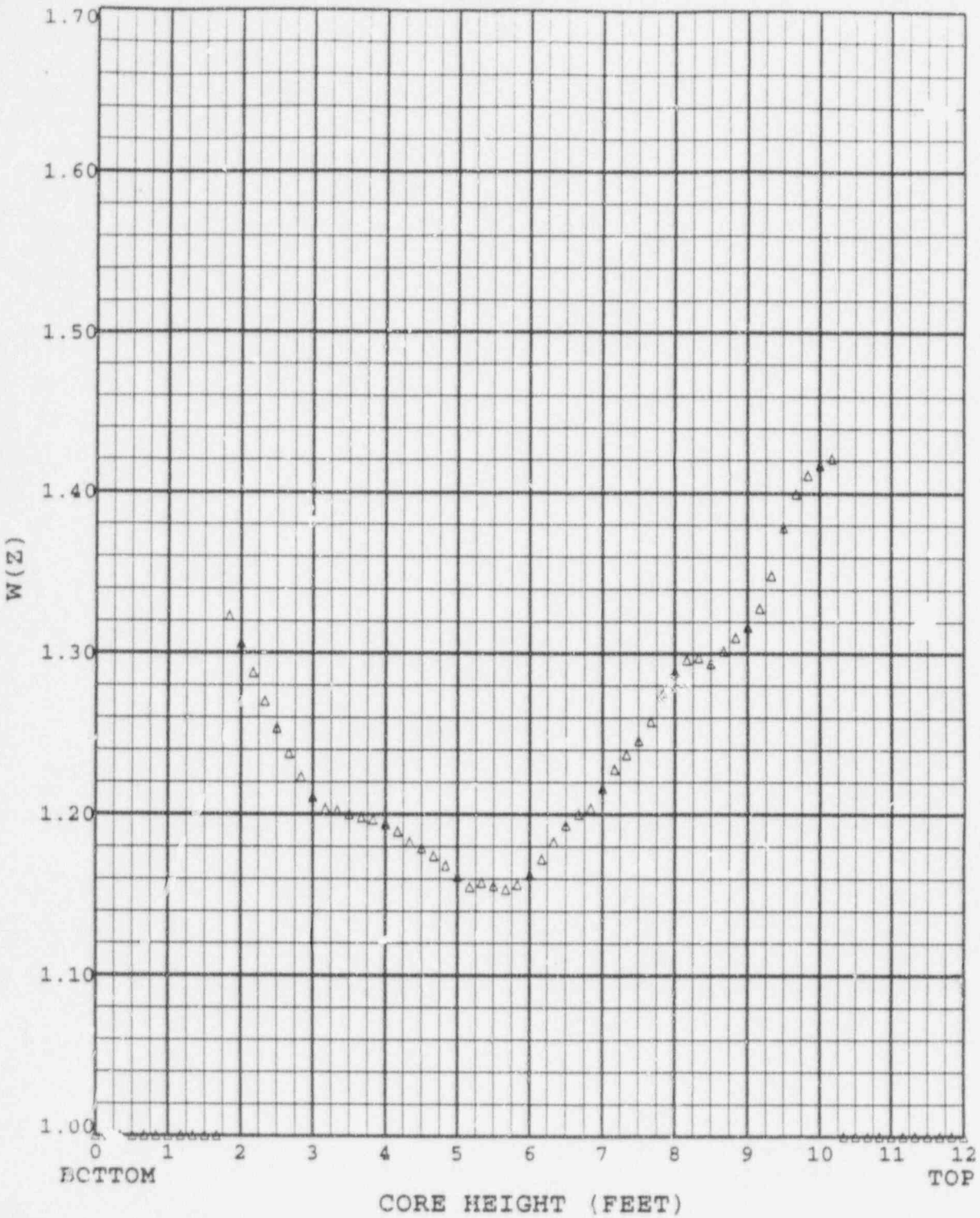



| | HEIGHT FEET | W(z) |
|---|---|---|
| * | 0.000 | 1.0000 |
| * | 0.167 | 1.0000 |
| * | 0.333 | 1.0000 |
| * | 0.500 | 1.0000 |
| * | 0.667 | 1.0000 |
| * | 0.833 | 1.0000 |
| * | 1.000 | 1.0000 |
| * | 1.167 | 1.0000 |
| * | 1.333 | 1.0000 |
| * | 1.500 | 1.0000 |
| * | 1.667 | 1.0000 |
| | 1.833 | 1.3659 |
| | 2.000 | 1.3402 |
| | 2.167 | 1.3134 |
| | 2.333 | 1.2873 |
| | 2.500 | 1.2617 |
| | 2.667 | 1.2398 |
| | 2.833 | 1.2251 |
| | 3.000 | 1.2157 |
| | 3.167 | 1.2078 |
| | 3.333 | 1.1983 |
| | 3.500 | 1.1907 |
| | 3.667 | 1.1870 |
| | 3.833 | 1.1850 |
| | 4.000 | 1.1815 |
| | 4.167 | 1.1747 |
| | 4.333 | 1.1653 |
| | 4.500 | 1.1581 |
| | 4.667 | 1.1503 |
| | 4.833 | 1.1415 |
| | 5.000 | 1.1322 |
| | 5.167 | 1.1226 |
| | 5.333 | 1.1204 |
| | 5.500 | 1.1143 |
| | 5.667 | 1.1061 |
| | 5.833 | 1.1036 |
| | 6.000 | 1.1054 |
| | 6.167 | 1.1147 |
| | 6.333 | 1.1276 |
| | 6.500 | 1.1409 |
| | 6.667 | 1.1511 |
| | 6.833 | 1.1584 |
| | 7.000 | 1.1720 |
| | 7.167 | 1.1845 |
| | 7.333 | 1.1949 |
| | 7.500 | 1.2051 |
| | 7.667 | 1.2188 |
| | 7.833 | 1.2373 |
| | 8.000 | 1.2516 |
| | 8.167 | 1.2621 |
| | 8.333 | 1.2713 |
| | 8.500 | 1.2778 |
| | 8.667 | 1.2904 |
| | 8.833 | 1.2970 |
| | 9.000 | 1.3023 |
| | 9.167 | 1.3141 |
| | 9.333 | 1.3381 |
| | 9.500 | 1.3742 |
| | 9.667 | 1.4040 |
| | 9.833 | 1.4256 |
| | 10.000 | 1.4421 |
| | 10.167 | 1.4554 |
| * | 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 Cycle 9
## $W(z)_{no}$ at 3000 MWD/MTU
## Measured - Predicted Axial Offset = -2.7%

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

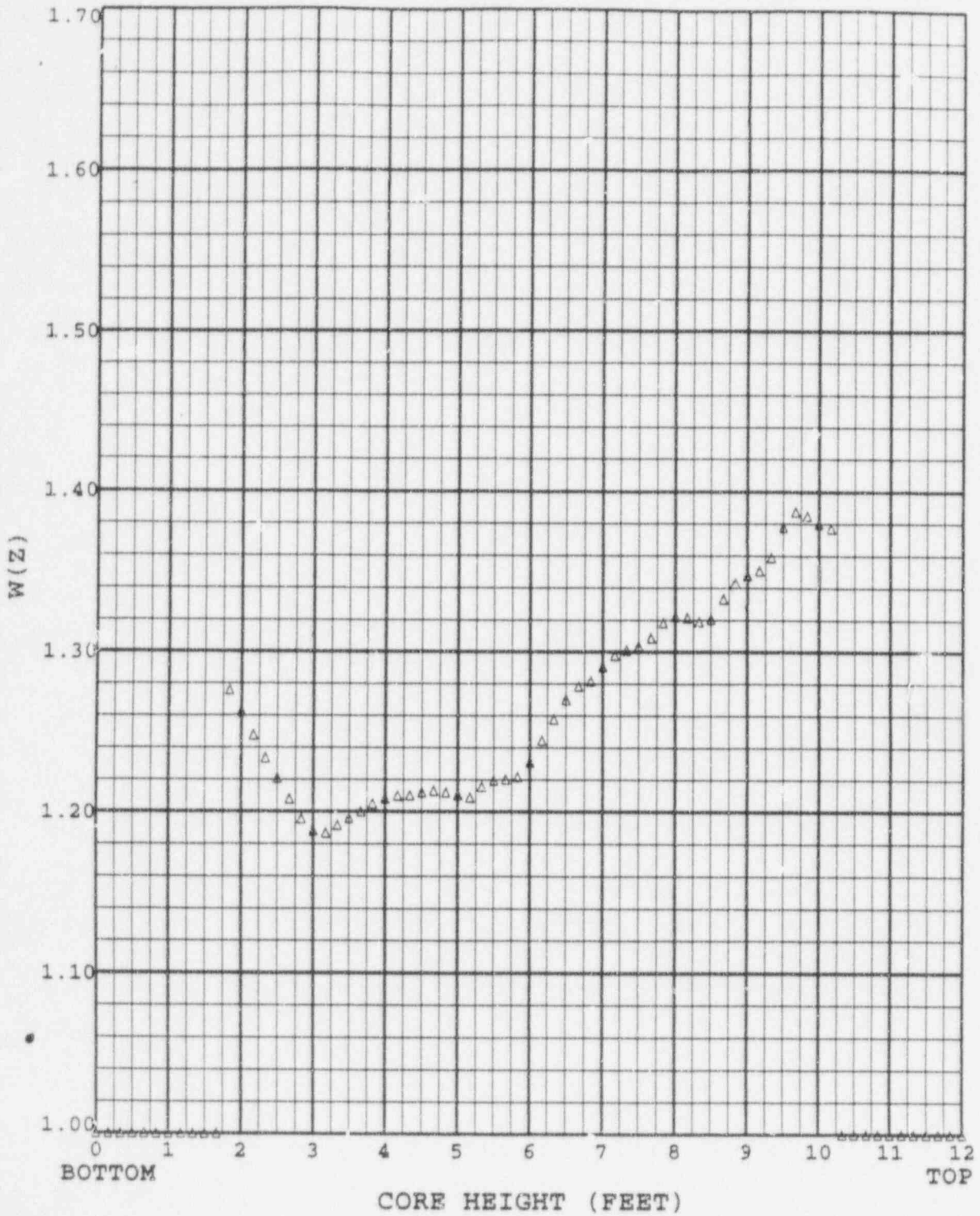



| | HEIGHT FEET | W(Z) |
|---|---|---|
| * | 0.000 | 1.0000 |
| * | 0.167 | 1.0000 |
| * | 0.333 | 1.0000 |
| * | 0.500 | 1.0000 |
| * | 0.667 | 1.0000 |
| * | 0.833 | 1.0000 |
| * | 1.000 | 1.0000 |
| * | 1.167 | 1.0000 |
| * | 1.333 | 1.0000 |
| * | 1.500 | 1.0000 |
| * | 1.667 | 1.0000 |
| | 1.833 | 1.3230 |
| | 2.000 | 1.3060 |
| | 2.167 | 1.2878 |
| | 2.333 | 1.2701 |
| | 2.500 | 1.2534 |
| | 2.667 | 1.2377 |
| | 2.833 | 1.2231 |
| | 3.000 | 1.2109 |
| | 3.167 | 1.2038 |
| | 3.333 | 1.2023 |
| | 3.500 | 1.2002 |
| | 3.667 | 1.1982 |
| | 3.833 | 1.1967 |
| | 4.000 | 1.1941 |
| | 4.167 | 1.1895 |
| | 4.333 | 1.1831 |
| | 4.500 | 1.1790 |
| | 4.667 | 1.1742 |
| | 4.833 | 1.1684 |
| | 5.000 | 1.1614 |
| | 5.167 | 1.1551 |
| | 5.333 | 1.1570 |
| | 5.500 | 1.1559 |
| | 5.667 | 1.1536 |
| | 5.833 | 1.1564 |
| | 6.000 | 1.1626 |
| | 6.167 | 1.1723 |
| | 6.333 | 1.1829 |
| | 6.500 | 1.1932 |
| | 6.667 | 1.2000 |
| | 6.833 | 1.2041 |
| | 7.000 | 1.2161 |
| | 7.167 | 1.2279 |
| | 7.333 | 1.2369 |
| | 7.500 | 1.2456 |
| | 7.667 | 1.2578 |
| | 7.833 | 1.2750 |
| | 8.000 | 1.2886 |
| | 8.167 | 1.2964 |
| | 8.333 | 1.2976 |
| | 8.500 | 1.2941 |
| | 8.667 | 1.3016 |
| | 8.833 | 1.3101 |
| | 9.000 | 1.3167 |
| | 9.167 | 1.3281 |
| | 9.333 | 1.3486 |
| | 9.500 | 1.3784 |
| | 9.667 | 1.3995 |
| | 9.833 | 1.4111 |
| | 10.000 | 1.4173 |
| | 10.167 | 1.4214 |
| * | 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 12

## Callaway Cycle 9
## $W(z)_{no}$ at 10000 MWD/MTU
## Measured - Predicted Axial Offset = -2.7%

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

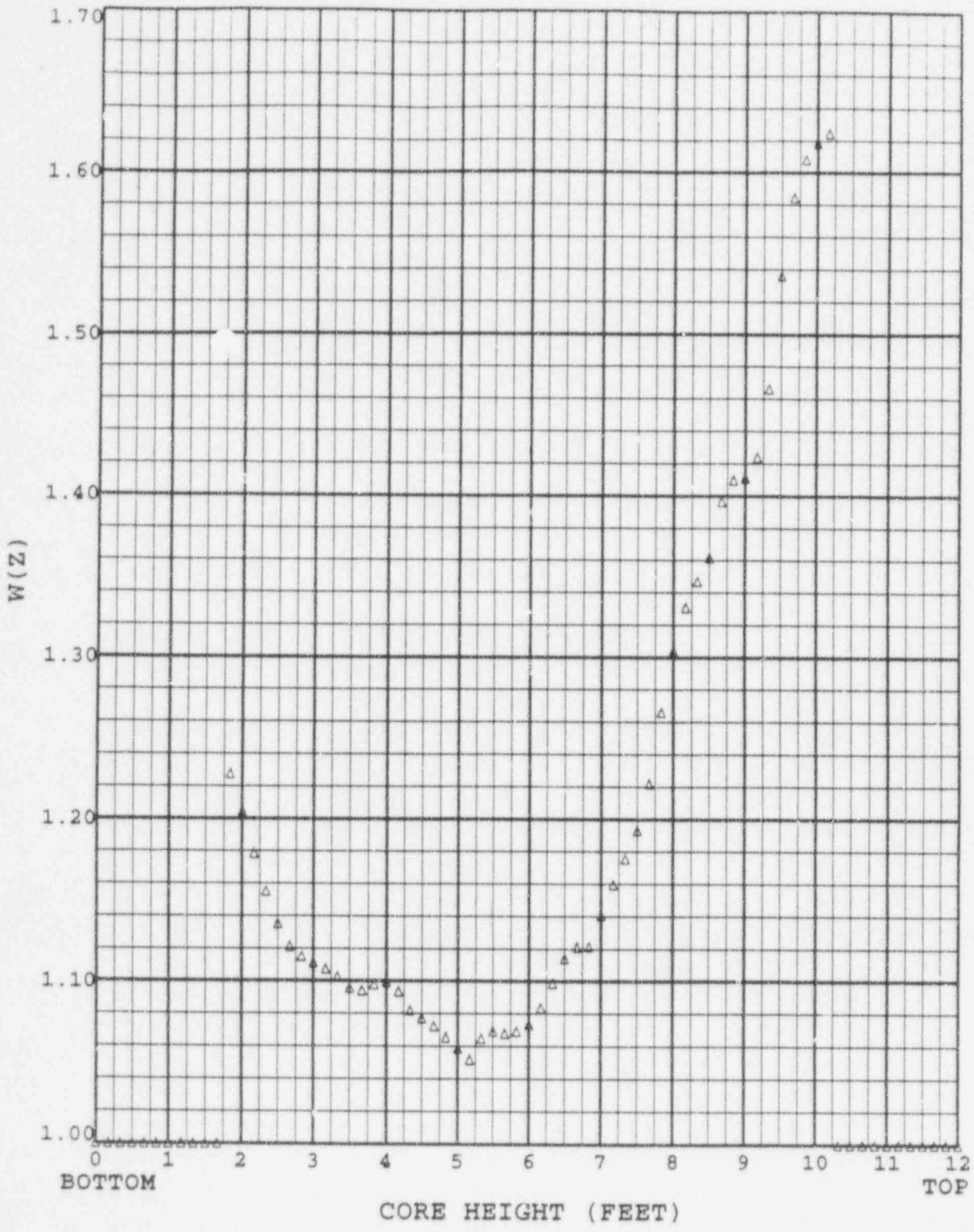



| | HEIGHT (FEET) | 18000 W(z) |
|---|---|---|
| * | 0.000 | 1.0000 |
| * | 0.167 | 1.0000 |
| * | 0.333 | 1.0000 |
| * | 0.500 | 1.0000 |
| * | 0.667 | 1.0000 |
| * | 0.833 | 1.0000 |
| * | 1.000 | 1.0000 |
| * | 1.167 | 1.0000 |
| * | 1.333 | 1.0000 |
| * | 1.500 | 1.0000 |
| * | 1.667 | 1.0000 |
| | 1.833 | 1.2759 |
| | 2.000 | 1.2624 |
| | 2.167 | 1.2476 |
| | 2.333 | 1.2335 |
| | 2.500 | 1.2206 |
| | 2.667 | 1.2078 |
| | 2.833 | 1.1957 |
| | 3.000 | 1.1880 |
| | 3.167 | 1.1870 |
| | 3.333 | 1.1918 |
| | 3.500 | 1.1960 |
| | 3.667 | 1.2003 |
| | 3.833 | 1.2049 |
| | 4.000 | 1.2083 |
| | 4.167 | 1.2098 |
| | 4.333 | 1.2100 |
| | 4.500 | 1.2122 |
| | 4.667 | 1.2130 |
| | 4.833 | 1.2121 |
| | 5.000 | 1.2106 |
| | 5.167 | 1.2087 |
| | 5.333 | 1.2155 |
| | 5.500 | 1.2195 |
| | 5.667 | 1.2202 |
| | 5.833 | 1.2219 |
| | 6.000 | 1.2309 |
| | 6.167 | 1.2444 |
| | 6.333 | 1.2576 |
| | 6.500 | 1.2701 |
| | 6.667 | 1.2785 |
| | 6.833 | 1.2818 |
| | 7.000 | 1.2907 |
| | 7.167 | 1.2977 |
| | 7.333 | 1.3011 |
| | 7.500 | 1.3035 |
| | 7.667 | 1.3087 |
| | 7.833 | 1.3181 |
| | 8.000 | 1.3222 |
| | 8.167 | 1.3213 |
| | 8.333 | 1.3188 |
| | 8.500 | 1.3206 |
| | 8.667 | 1.3331 |
| | 8.833 | 1.3429 |
| | 9.000 | 1.3475 |
| | 9.167 | 1.3507 |
| | 9.333 | 1.3590 |
| | 9.500 | 1.3776 |
| | 9.667 | 1.3875 |
| | 9.833 | 1.3947 |
| * | 10.000 | 1.3800 |
| * | 10.167 | 1.3772 |
| * | 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 13

## Callaway Cycle 9
## $W(z)_{no}$ at 18000 MWD/MTU
## Measured - Predicted Axial Offset = -2.7%

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

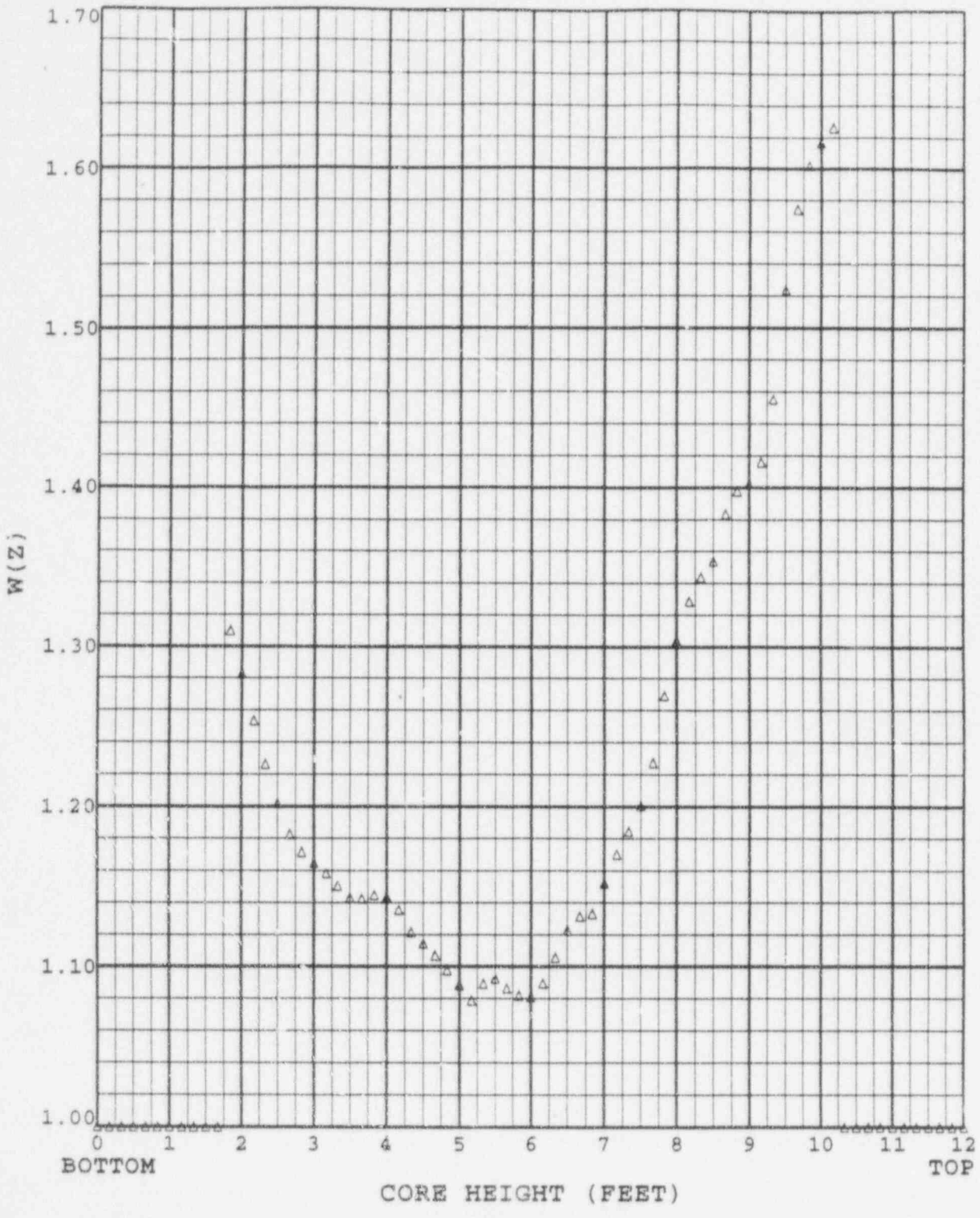



| | HEIGHT FEET | 150 W(z) |
|---|---|---|
| * | 0.000 | 1.0000 |
| * | 0.167 | 1.0000 |
| * | 0.333 | 1.0000 |
| * | 0.500 | 1.0000 |
| * | 0.667 | 1.0000 |
| * | 0.833 | 1.0000 |
| * | 1.000 | 1.0000 |
| * | 1.167 | 1.0000 |
| * | 1.333 | 1.0000 |
| * | 1.500 | 1.0000 |
| * | 1.667 | 1.0000 |
| | 1.833 | 1.2275 |
| | 2.000 | 1.2042 |
| | 2.167 | 1.1787 |
| | 2.333 | 1.1553 |
| | 2.500 | 1.1354 |
| | 2.667 | 1.1214 |
| | 2.833 | 1.1151 |
| | 3.000 | 1.1114 |
| | 3.167 | 1.1076 |
| | 3.333 | 1.1026 |
| | 3.500 | 1.0956 |
| | 3.667 | 1.0943 |
| | 3.833 | 1.0982 |
| | 4.000 | 1.0995 |
| | 4.167 | 1.0936 |
| | 4.333 | 1.0821 |
| | 4.500 | 1.0778 |
| | 4.667 | 1.0725 |
| | 4.833 | 1.0656 |
| | 5.000 | 1.0587 |
| | 5.167 | 1.0519 |
| | 5.333 | 1.0647 |
| | 5.500 | 1.0693 |
| | 5.667 | 1.0679 |
| | 5.833 | 1.0692 |
| | 6.000 | 1.0735 |
| | 6.167 | 1.0837 |
| | 6.333 | 1.0990 |
| | 6.500 | 1.1144 |
| | 6.667 | 1.1214 |
| | 6.833 | 1.1215 |
| | 7.000 | 1.1406 |
| | 7.167 | 1.1599 |
| | 7.333 | 1.1757 |
| | 7.500 | 1.1931 |
| | 7.667 | 1.2220 |
| | 7.833 | 1.2662 |
| | 8.000 | 1.3043 |
| | 8.167 | 1.3310 |
| | 8.333 | 1.3470 |
| | 8.500 | 1.3617 |
| | 8.667 | 1.3965 |
| | 8.833 | 1.4098 |
| | 9.000 | 1.4111 |
| | 9.167 | 1.4238 |
| | 9.333 | 1.4662 |
| | 9.500 | 1.5361 |
| | 9.667 | 1.5846 |
| | 9.833 | 1.6082 |
| | 10.000 | 1.6184 |
| | 10.167 | 1.6246 |
| * | 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 14

## Callaway Cycle 9
## $W(z)_{no}$ at 150 MWD/MTU
## Measured - Predicted Axial Offset = -7.0%

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

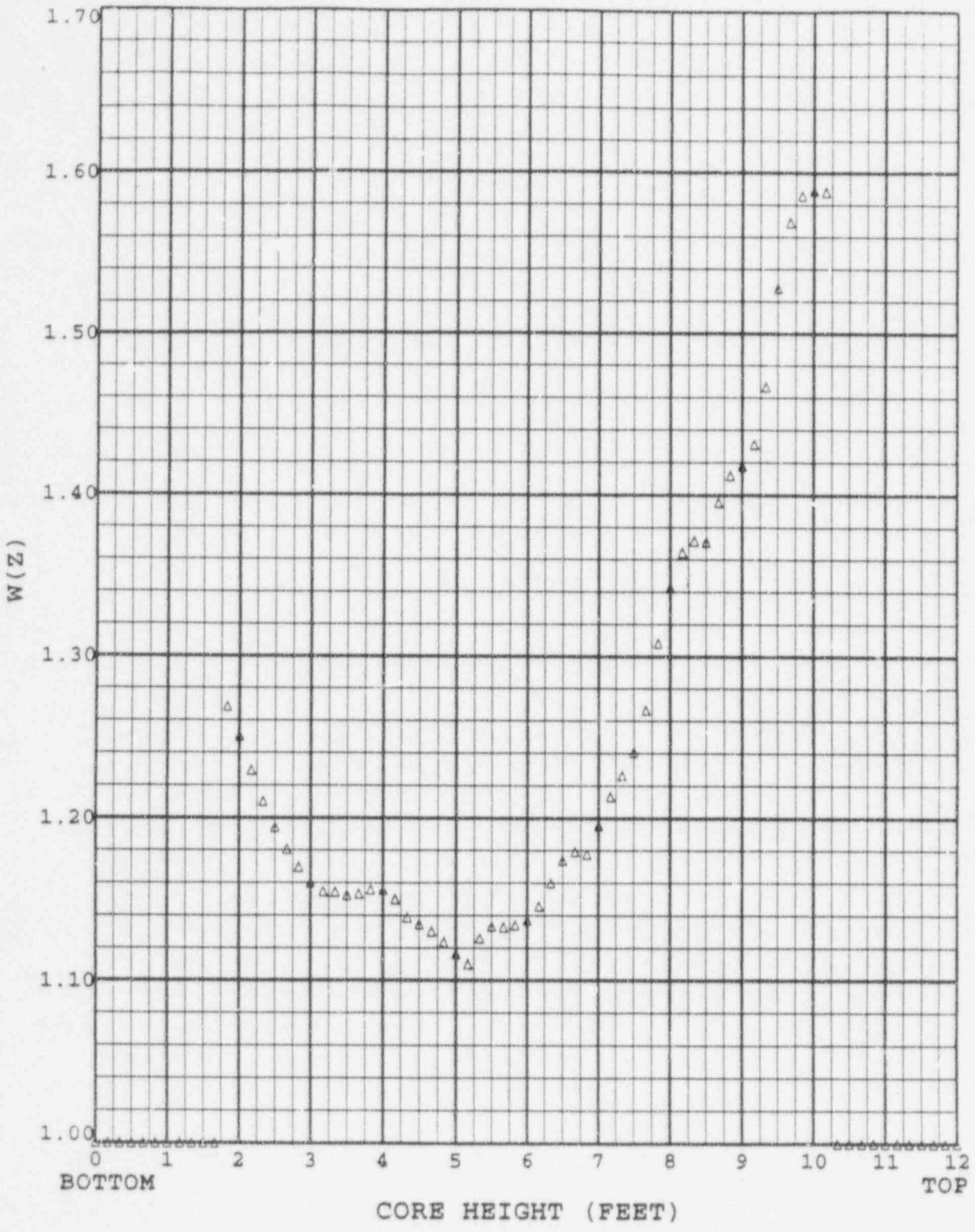



| | HEIGHT FT | 3000 W(Z) |
|---|---|---|
| * | 0.000 | 1.0000 |
| * | 0.167 | 1.0000 |
| * | 0.333 | 1.0000 |
| * | 0.500 | 1.0000 |
| * | 0.667 | 1.0000 |
| * | 0.833 | 1.0000 |
| * | 1.000 | 1.0000 |
| * | 1.167 | 1.0000 |
| * | 1.333 | 1.0000 |
| * | 1.500 | 1.0000 |
| * | 1.667 | 1.0000 |
| | 1.833 | 1.3097 |
| | 2.000 | 1.2828 |
| | 2.167 | 1.2535 |
| | 2.333 | 1.2264 |
| | 2.500 | 1.2019 |
| | 2.667 | 1.1828 |
| | 2.833 | 1.1717 |
| | 3.000 | 1.1649 |
| | 3.167 | 1.1586 |
| | 3.333 | 1.1505 |
| | 3.500 | 1.1434 |
| | 3.667 | 1.1426 |
| | 3.833 | 1.1467 |
| | 4.000 | 1.1438 |
| | 4.167 | 1.1357 |
| | 4.333 | 1.1216 |
| | 4.500 | 1.1146 |
| | 4.667 | 1.1071 |
| | 4.833 | 1.0978 |
| | 5.000 | 1.0883 |
| | 5.167 | 1.0789 |
| | 5.333 | 1.0896 |
| | 5.500 | 1.0925 |
| | 5.667 | 1.0865 |
| | 5.833 | 1.0822 |
| | 6.000 | 1.0812 |
| | 6.167 | 1.0897 |
| | 6.333 | 1.1057 |
| | 6.500 | 1.1226 |
| | 6.667 | 1.1314 |
| | 6.833 | 1.1331 |
| | 7.000 | 1.1522 |
| | 7.167 | 1.1703 |
| | 7.333 | 1.1847 |
| | 7.500 | 1.2005 |
| | 7.667 | 1.2274 |
| | 7.833 | 1.2693 |
| | 8.000 | 1.3041 |
| | 8.167 | 1.3284 |
| | 8.333 | 1.3437 |
| | 8.500 | 1.3538 |
| | 8.667 | 1.3834 |
| | 8.833 | 1.3977 |
| | 9.000 | 1.4024 |
| | 9.167 | 1.4159 |
| | 9.333 | 1.4553 |
| | 9.500 | 1.5237 |
| | 9.667 | 1.5742 |
| | 9.833 | 1.6021 |
| | 10.000 | 1.6167 |
| | 10.167 | 1.6262 |
| * | 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 15

## Callaway Cycle 9
## $(F^N_{\Delta H}(z))_{no}$ at 3000 MWD/MTU
## Measured - Predicted Axial Offset = -7.0%

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

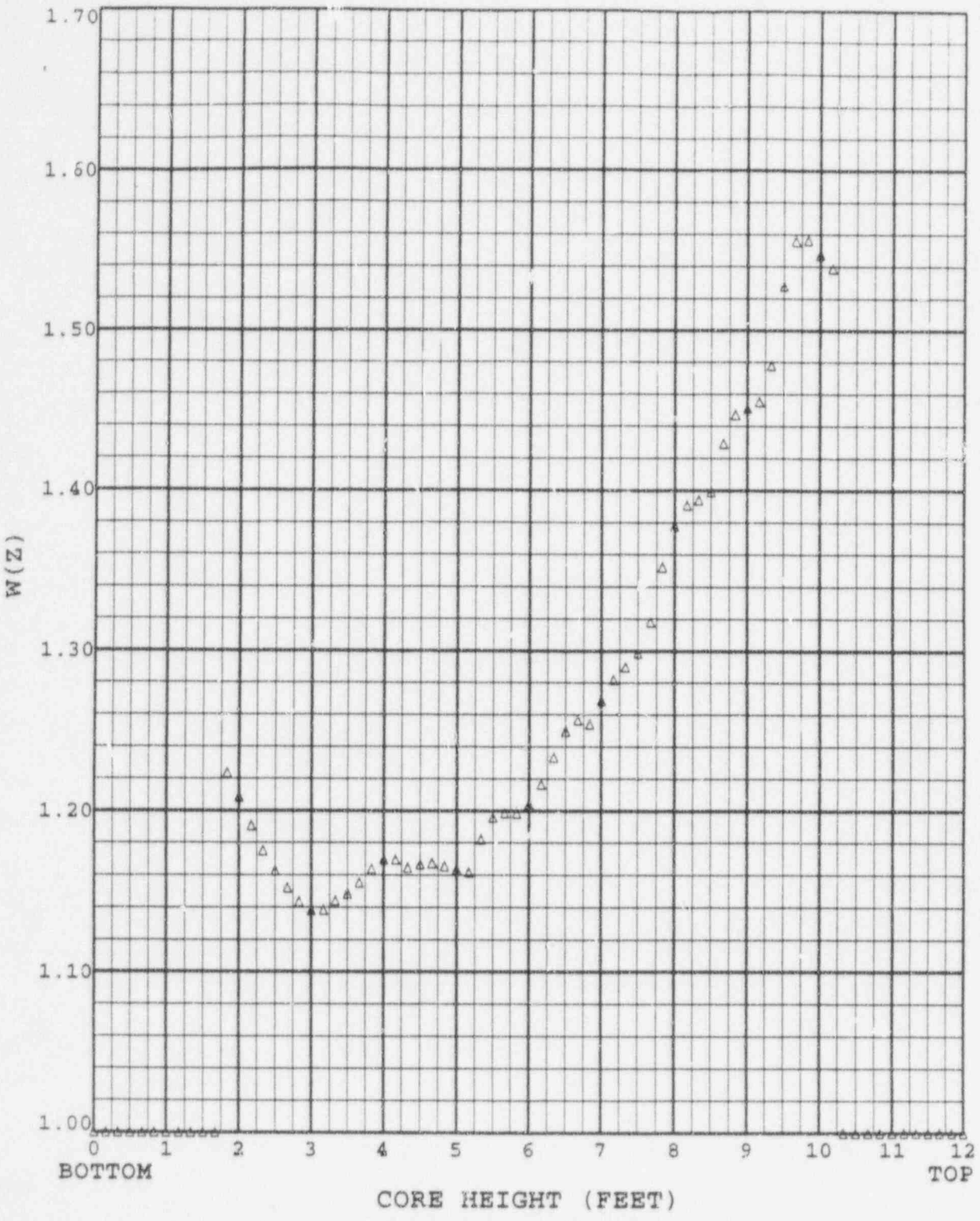



| | HEIGHT | 10000 |
|---|---|---|
| | FEET | W(z) |
| * | 0.000 | 1.0000 |
| * | 0.167 | 1.0000 |
| * | 0.333 | 1.0000 |
| * | 0.500 | 1.0000 |
| * | 0.667 | 1.0000 |
| * | 0.833 | 1.0000 |
| * | 1.000 | 1.0000 |
| * | 1.167 | 1.0000 |
| * | 1.333 | 1.0000 |
| * | 1.500 | 1.0000 |
| * | 1.667 | 1.0000 |
| | 1.833 | 1.2686 |
| | 2.000 | 1.2501 |
| | 2.167 | 1.2291 |
| | 2.333 | 1.2100 |
| | 2.500 | 1.1941 |
| | 2.667 | 1.1807 |
| | 2.833 | 1.1698 |
| | 3.000 | 1.1602 |
| | 3.167 | 1.1547 |
| | 3.333 | 1.1544 |
| | 3.500 | 1.1526 |
| | 3.667 | 1.1534 |
| | 3.833 | 1.1559 |
| | 4.000 | 1.1559 |
| | 4.167 | 1.1500 |
| | 4.333 | 1.1388 |
| | 4.500 | 1.1347 |
| | 4.667 | 1.1301 |
| | 4.833 | 1.1237 |
| | 5.000 | 1.1165 |
| | 5.167 | 1.1102 |
| | 5.333 | 1.1260 |
| | 5.500 | 1.1333 |
| | 5.667 | 1.1329 |
| | 5.833 | 1.1339 |
| | 6.000 | 1.1372 |
| | 6.167 | 1.1459 |
| | 6.333 | 1.1600 |
| | 6.500 | 1.1740 |
| | 6.667 | 1.1796 |
| | 6.833 | 1.1779 |
| | 7.000 | 1.1956 |
| | 7.167 | 1.2132 |
| | 7.333 | 1.2263 |
| | 7.500 | 1.2408 |
| | 7.667 | 1.2667 |
| | 7.833 | 1.3080 |
| | 8.000 | 1.3426 |
| | 8.167 | 1.3644 |
| | 8.333 | 1.3716 |
| | 8.500 | 1.3711 |
| | 8.667 | 1.3954 |
| | 8.833 | 1.4119 |
| | 9.000 | 1.4179 |
| | 9.167 | 1.4311 |
| | 9.333 | 1.4667 |
| | 9.500 | 1.5283 |
| | 9.667 | 1.5691 |
| | 9.833 | 1.5858 |
| | 10.000 | 1.5889 |
| | 10.167 | 1.5882 |
| * | 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 16

## Callaway Cycle 9
## $W(z)_{no}$ at 10000 MWD/MTU
## Measured - Predicted Axial Offset = -7.0%

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




| | HEIGHT FEET | 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 | 1.2234 |
| | 2.000 | 1.2084 |
| | 2.167 | 1.1908 |
| | 2.333 | 1.1751 |
| | 2.500 | 1.1628 |
| | 2.667 | 1.1523 |
| | 2.833 | 1.1436 |
| | 3.000 | 1.1383 |
| | 3.167 | 1.1386 |
| | 3.333 | 1.1442 |
| | 3.500 | 1.1485 |
| | 3.667 | 1.1554 |
| | 3.833 | 1.1639 |
| | 4.000 | 1.1597 |
| | 4.167 | 1.1696 |
| | 4.333 | 1.1646 |
| | 4.500 | 1.1667 |
| | 4.667 | 1.1674 |
| | 4.833 | 1.1657 |
| | 5.000 | 1.1637 |
| | 5.167 | 1.1617 |
| | 5.333 | 1.1821 |
| | 5.500 | 1.1957 |
| | 5.667 | 1.1985 |
| | 5.833 | 1.1982 |
| | 6.000 | 1.2040 |
| | 6.167 | 1.2164 |
| | 6.333 | 1.2332 |
| | 6.500 | 1.2497 |
| | 6.667 | 1.2567 |
| | 6.833 | 1.2539 |
| | 7.000 | 1.2690 |
| | 7.167 | 1.2821 |
| | 7.333 | 1.2900 |
| | 7.500 | 1.2985 |
| | 7.667 | 1.3179 |
| | 7.833 | 1.3522 |
| | 8.000 | 1.3777 |
| | 8.167 | 1.3906 |
| | 8.333 | 1.3939 |
| | 8.500 | 1.3991 |
| | 8.667 | 1.4292 |
| | 8.833 | 1.4472 |
| | 9.000 | 1.4511 |
| | 9.167 | 1.4554 |
| | 9.333 | 1.4780 |
| | 9.500 | 1.5275 |
| | 9.667 | 1.5557 |
| | 9.833 | 1.5561 |
| | 10.000 | 1.5471 |
| | 10.167 | 1.5388 |
| * | 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 17

## Callaway Cycle 9
## $W(z)_{no}$ at 18000 MWD/MTU
## Measured - Predicted Axial Offset = -7.0%

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