INDIANA MICHIGAN POWER
A unit of American Electric Power

Indiana Michigan Power
Cook Nuclear Plant
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U.S. Nuclear Regulatory Commission
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Donald C. Cook Nuclear Plant Unit 1 and Unit 2
CORE OPERATING LIMITS REPORTS

Indiana Michigan Power Company, the licensee for Donald C. Cook Nuclear Plant Unit 1 and Unit 2, is submitting Revision 3 to the Core Operating Limits Report (COLR) for Unit 1 Cycle 20 and Revision 0 to the COLR for Unit 2 Cycle 16 in accordance with Technical Specification 5.6.5. Revision 3 to the COLR for Unit 1 Cycle 20 is being made to correct the Overtemperature Delta T equation, add revision numbers and dates to the analytical methodology, and to provide consistent wording with the Unit 2 Cycle 16 COLR.

Revision 3 of the Unit 1 Cycle 20 COLR is provided as Attachment 1. Revision 0 of the Unit 2 Cycle 16 COLR is provided as Attachment 2.

There are no new commitments in this submittal. Should you have any questions, please contact Mr. Michael K. Scarpello, Regulatory Affairs Supervisor, at (269) 466-2649.

Sincerely,

Joseph N. Jensen
Site Vice President

JEN/rdw

Attachments

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A001

ATTACHMENT 1 TO AEP:NRC:6565

Unit 1 Cycle 20 Core Operating Limits Report
Revision 3

Donald C. Cook Nuclear Plant
Unit 1 Cycle 20

Core Operating Limits Report
Revision 3

1.0 CORE OPERATING LIMITS REPORT

This Core Operating Limits Report (COLR) for Donald C. Cook Nuclear Plant Unit 1 Cycle 20 design has been prepared in accordance with the requirements of Technical Specification 5.6.5.

The analytical methods used to determine the core operating limits shall be those previously reviewed and approved by the NRC in:

a. WCAP-9272-P-A, Westinghouse Reload Safety Evaluation Methodology, July 1985

b. WCAP-8385, Power Distribution Control and Load Following Procedures – Topical Report, September 1974

c. WCAP-10216-P-A, Rev. 1A, Relaxation of Constant Axial Offset Control/F_Q Surveillance Technical Specification, February 1994

d. WCAP-10266-P-A, Rev. 2, The 1981 Version of the Westinghouse ECCS Evaluation Model Using the BASH Code, March 1987

e. WCAP-12610-P-A, VANTAGE+ Fuel Assembly Reference Core Report, April 1995

f. WCAP-8745-P-A, Design Bases for the Thermal Overpower ΔT and Thermal Overtemperature ΔT Trip Functions, September 1986

g. WCAP-13749-P-A, Safety Evaluation Supporting the Conditional Exemption of the Most Negative EOL Moderator Temperature Coefficient Measurement, March 1997

The Technical Specifications affected by this report are listed below:

2.1.1	Reactor Core Safety Limits
3.1.1	SHUTDOWN MARGIN (SDM)
3.1.3	Moderator Temperature Coefficient (MTC)
3.1.5	Shutdown Bank Insertion Limits
3.1.6	Control Bank Insertion Limits
3.2.1	Heat Flux Hot Channel Factor ($F_Q(Z)$)
3.2.2	Nuclear Enthalpy Rise Hot Channel Factor ($F^N_{\Delta H}$)
3.2.3	AXIAL FLUX DIFFERENCE (AFD)
3.3.1	Reactor Trip System (RTS) Instrumentation
3.4.1	RCS Pressure, Temperature, and Flow Departure from Nucleate Boiling (DNB) Limits
3.9.1	Boron Concentration

2.0 OPERATING LIMITS

The cycle-specific parameter limits for the specifications listed in Section 1.0 are presented in the following subsections. These limits have been developed using the NRC-approved methodologies specified in Technical Specifications 5.6.5.

2.1 SAFETY LIMITS

2.1.1 Reactor Core Safety Limits (Specification 2.1.1)

In Modes 1 and 2, the combination of thermal power, pressurizer pressure, and the highest loop average temperature (T_{avg}) shall not exceed the limits as shown in Figure 6 for 4 loop operation.

2.2 REACTIVITY CONTROL

2.2.1 SHUTDOWN MARGIN (SDM) (Specification 3.1.1)

Shutdown margin shall be greater than or equal to 1.3% $\Delta k/k$ for $T_{avg} > 200°F$
Shutdown margin shall be greater than or equal to 1.0% $\Delta k/k$ for $T_{avg} \leq 200°F$

2.2.2 Moderator Temperature Coefficient (MTC) (Specification 3.1.3)

a. The Moderator Temperature Coefficient (MTC) limits are:

The BOL/ARO-MTC shall be less positive or equal to the value given in Figure 1.

The EOL/ARO/RTP-MTC shall be less negative or equal to –4.54E-4 $\Delta k/k/°F$.

This limit is based on a T_{avg} program with HFP vessel T_{avg} of 554.0 to 558.0 °F.

Where: ARO stands for All Rods Out
BOL stands for Beginning of Cycle Life
EOL stands for End of Cycle Life
RTP stands for Rated Thermal Power
HFP stands for Hot Full Thermal Power

b. The MTC Surveillance limit is:
The 300 ppm/ARO/RTP-MTC should be less negative or equal to
–3.84E-4 Δk/k/°F at a HFP vessel T_{avg} of 554.0 to 558.0 °F.

c. The Revised Predicted near-EOL 300 ppm MTC shall be calculated using Figure 7 and the following algorithm:

Revised Predicted MTC = Predicted MTC + AFD Correction + Predicted Correction*

* Predicted Correction is -0.30E-4 Δk/k/°F.

If the Revised Predicted MTC is less negative than the SR 3.1.3.2 limit (COLR 2.2.2.b) and all of the benchmark data contained in the surveillance procedure are met, then a MTC measurement in accordance with SR 3.1.3.2 is not required.

d. The MTC Surveillance limit is:
The 60 ppm/ARO/RTP-MTC should be less negative or equal to -4.41E-4 Δk/k/°F at a HFP vessel T_{avg} of 554.0 to 558.0 °F

2.2.3 Shutdown Bank Insertion Limits (Specification 3.1.5)

The shutdown rods shall be withdrawn to at least 228 steps.

2.2.4 Control Bank Insertion Limits (Specifications 3.1.6)

a. The control rod banks shall be limited in physical insertion as shown in Figure 2.

b. Successive Control Banks shall overlap by 100 steps. The sequence for Control Bank withdrawal shall be Control Bank A, Control Bank B, Control Bank C and Control Bank D.

2.3 POWER DISTRIBUTION LIMITS

2.3.1 AXIAL FLUX DIFFERENCE (AFD) (Specification 3.2.3)

a. The Allowable Operation Limits are provided in Figure 3.

b. The AFD target band is ±5% for a cycle average accumulated burnup ≥0.0 MWD/MTU.

2.3.2 Heat Flux Hot Channel Factor ($F_Q(Z)$) (Specification 3.2.1)

$$F_Q^C(Z) \le \frac{CF_Q}{P} * K(Z) \qquad for\ P > 0.5$$

$$F_Q^C(Z) \le 2 * CF_Q * K(Z) \qquad for\ P \le 0.5$$

$$F_Q^W(Z) \le \frac{CF_Q}{P} * K(Z) \qquad for\ P > 0.5$$

$$F_Q^W(Z) \le 2 * CF_Q * K(Z) \qquad for\ P \le 0.5$$

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

a. $CF_Q = 2.15$

b. K(Z) is provided in Figure 4.

c. $F_Q^C(Z)$ is the measured hot channel factor including a 3% manufacturing tolerance uncertainty and a 5% measurement uncertainty.

d. W(Z) is provided in Table 1 for ±5% AFD target band.

e. $F_Q^W(Z) = F_Q^C(Z) \times W(Z) \times F_P$

f. For Cycle 20, F_P = 1.02 for all burnups associated with Note 2.a of SR 3.2.1.2. When no penalty is required, F_P = 1.00.

2.3.3 Nuclear Enthalpy Rise Hot Channel Factor ($F^N_{\Delta H}$) (Specification 3.2.2)

$$F^N_{\Delta H} \le CF_{\Delta H} * (1 + PF_{\Delta H} * (1-P))$$

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

a. $CF_{\Delta H} = 1.49$

b. $PF_{\Delta H} = 0.3$

2.4 INSTRUMENTATION

2.4.1 Reactor Trip System (RTS) Instrumentation (Specification 3.3.1)

The Overtemperature ΔT and Overpower ΔT setpoints are as shown in Figure 5.

2.5 REACTOR COOLANT SYSTEM

2.5.1 RCS Pressure, Temperature, and Flow Departure from Nucleate Boiling (DNB) Limits (Specification 3.4.1)

a. Pressurizer Pressure shall be $\geq$ 2018 psig [+]

b. Reactor Coolant System T_{AVG} shall be $\leq$ 581.4°F [+]

c. Reactor Coolant System Total Flow Rate shall be $\geq$ 341,100 gpm

2.6 REFUELING OPERATIONS

2.6.1 Boron Concentration (Specification 3.9.1)

The boron concentration of all filled portions of the Reactor Coolant System, the refueling canal and the refueling cavity shall be greater than or equal to 2400 ppm[++].

[+] These are Safety Analysis values. With readability allowance, the corresponding values are 579.1°F for T_{avg}, and 2050 psig for Pressurizer Pressure.

[++] This concentration bounds the condition of $K_{eff} \leq 0.95$ which includes a 1% $\Delta k/k$ conservative allowance for uncertainties. The boron concentration of 2400 ppm includes a 50 ppm conservative allowance for uncertainties.

FIGURE 1

MODERATOR TEMPERATURE COEFFICIENT (MTC) LIMITS

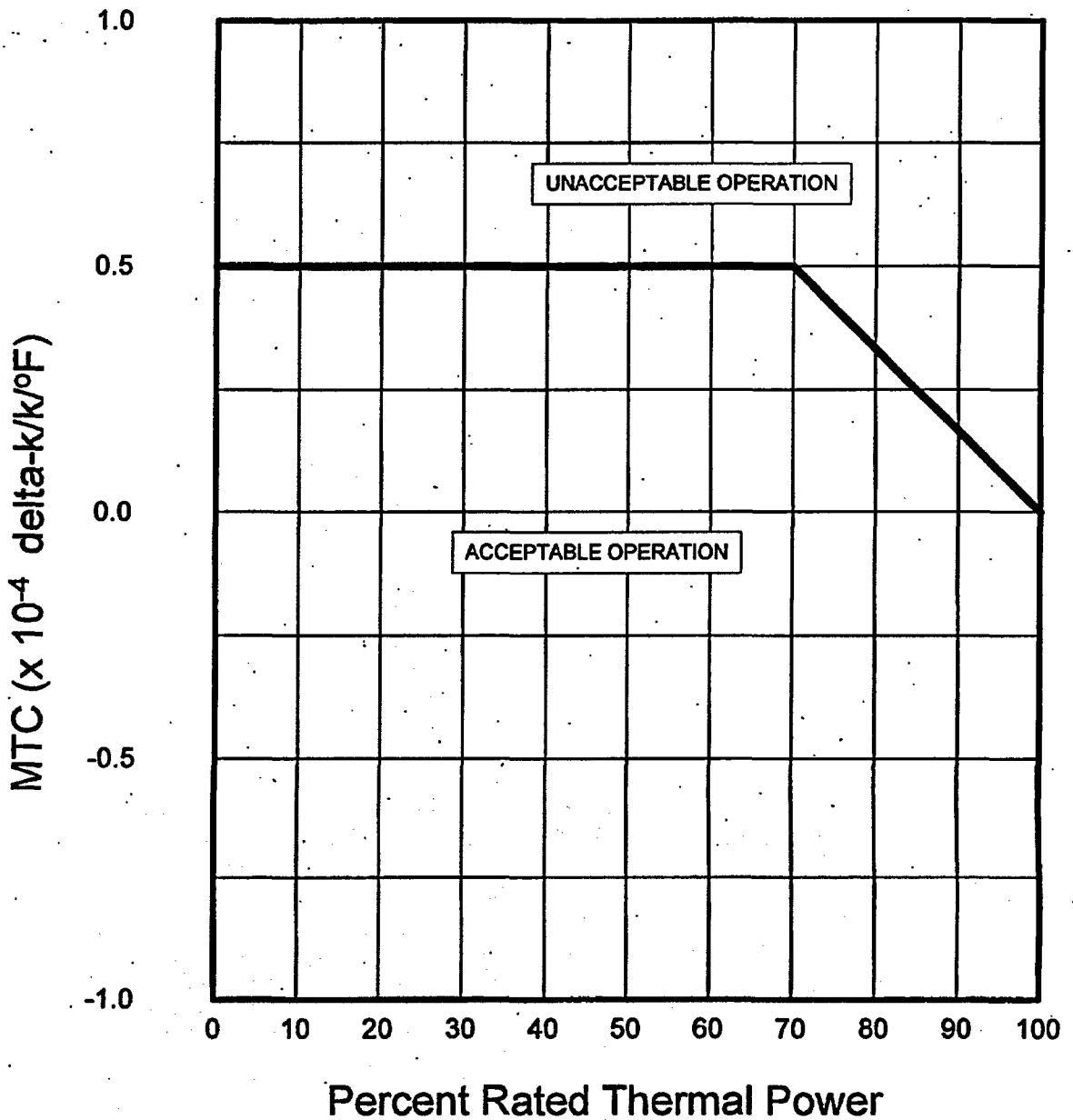


FIGURE 2

ROD BANK INSERTION LIMITS VERSUS THERMAL POWER

(FOUR-LOOP OPERATION)

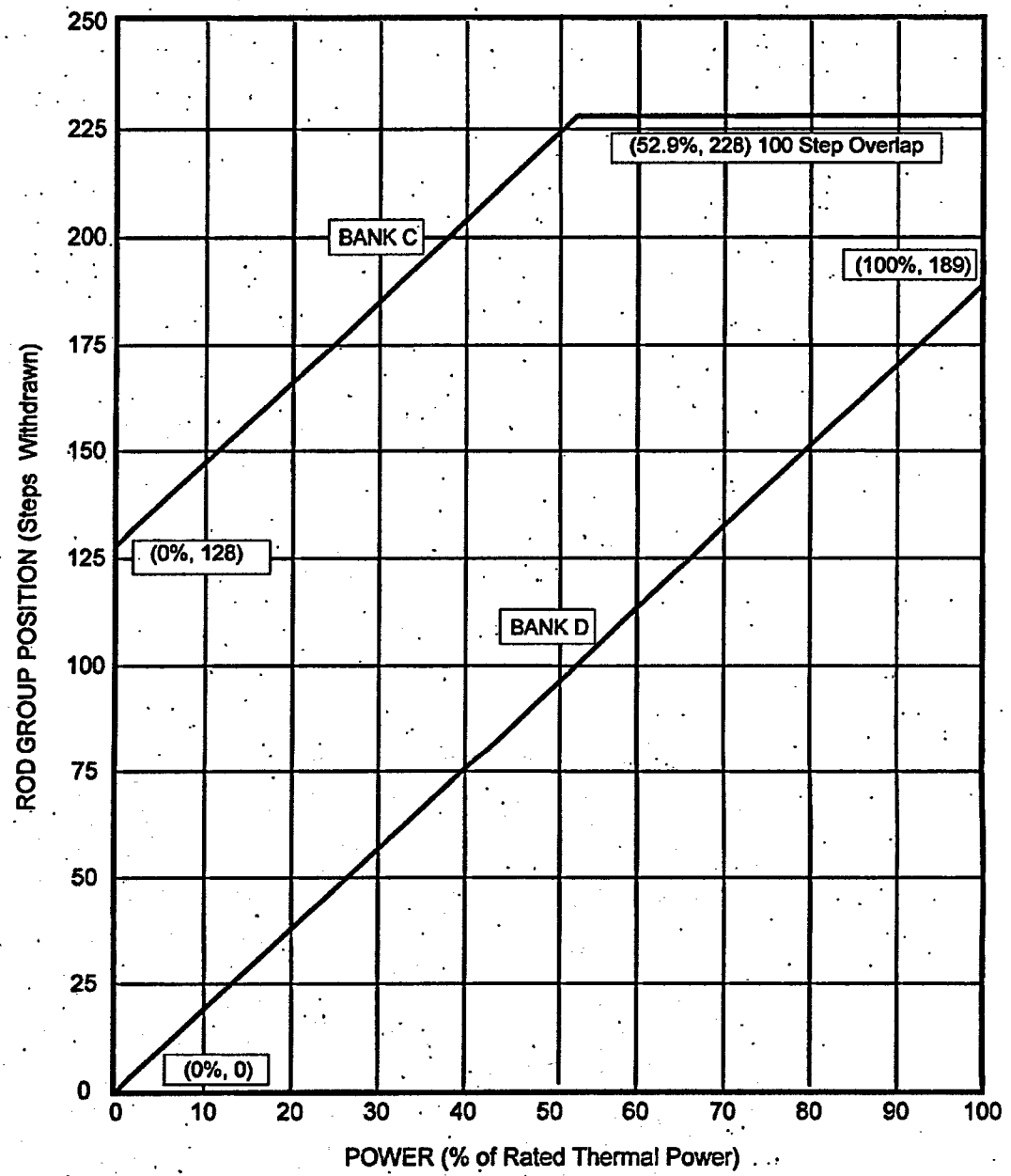


FIGURE 3

AXIAL FLUX DIFFERENCE LIMITS AS A FUNCTION OF RATED THERMAL POWER (RTP)

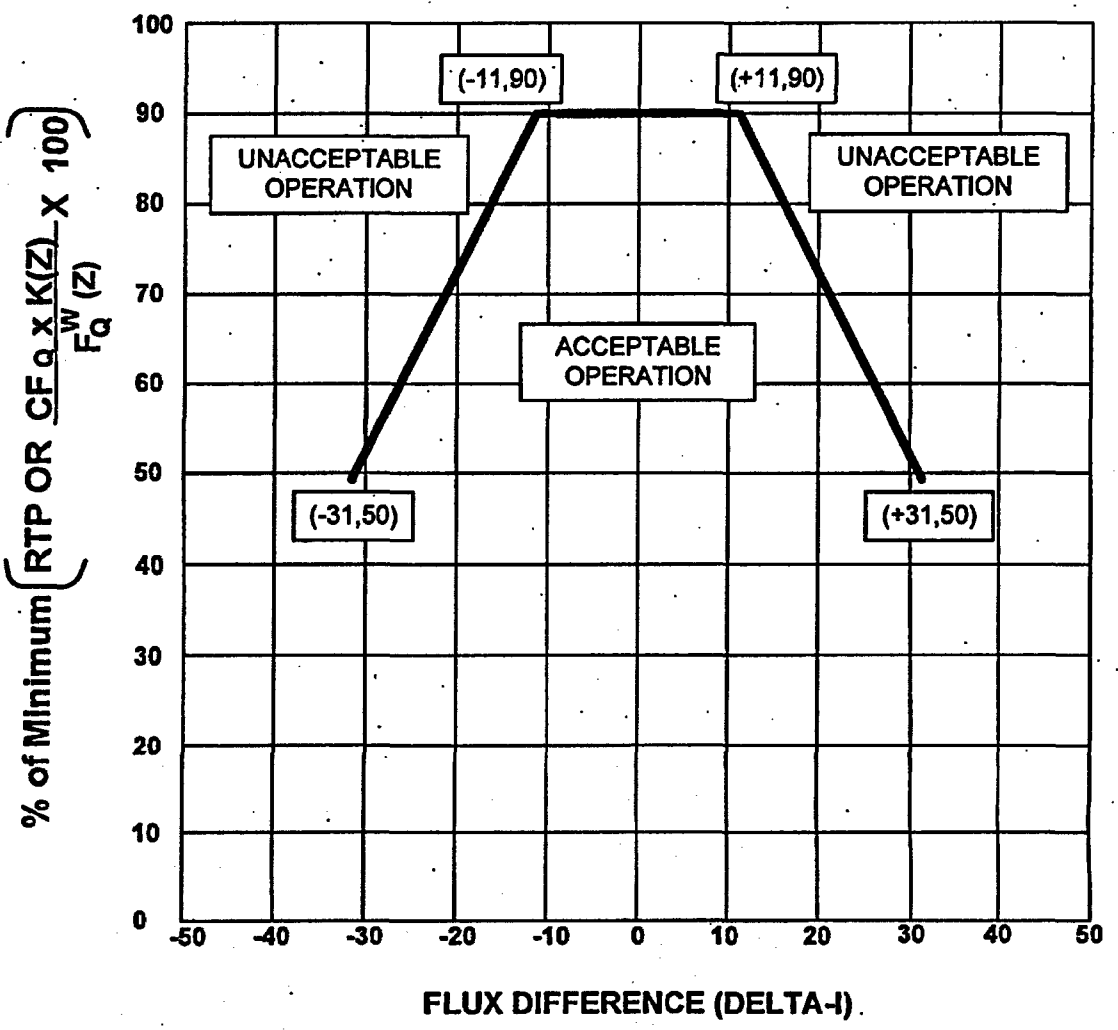


FIGURE 4

K(Z) – NORMALIZED $F_Q(Z)$ AS A FUNCTION OF CORE HEIGHT

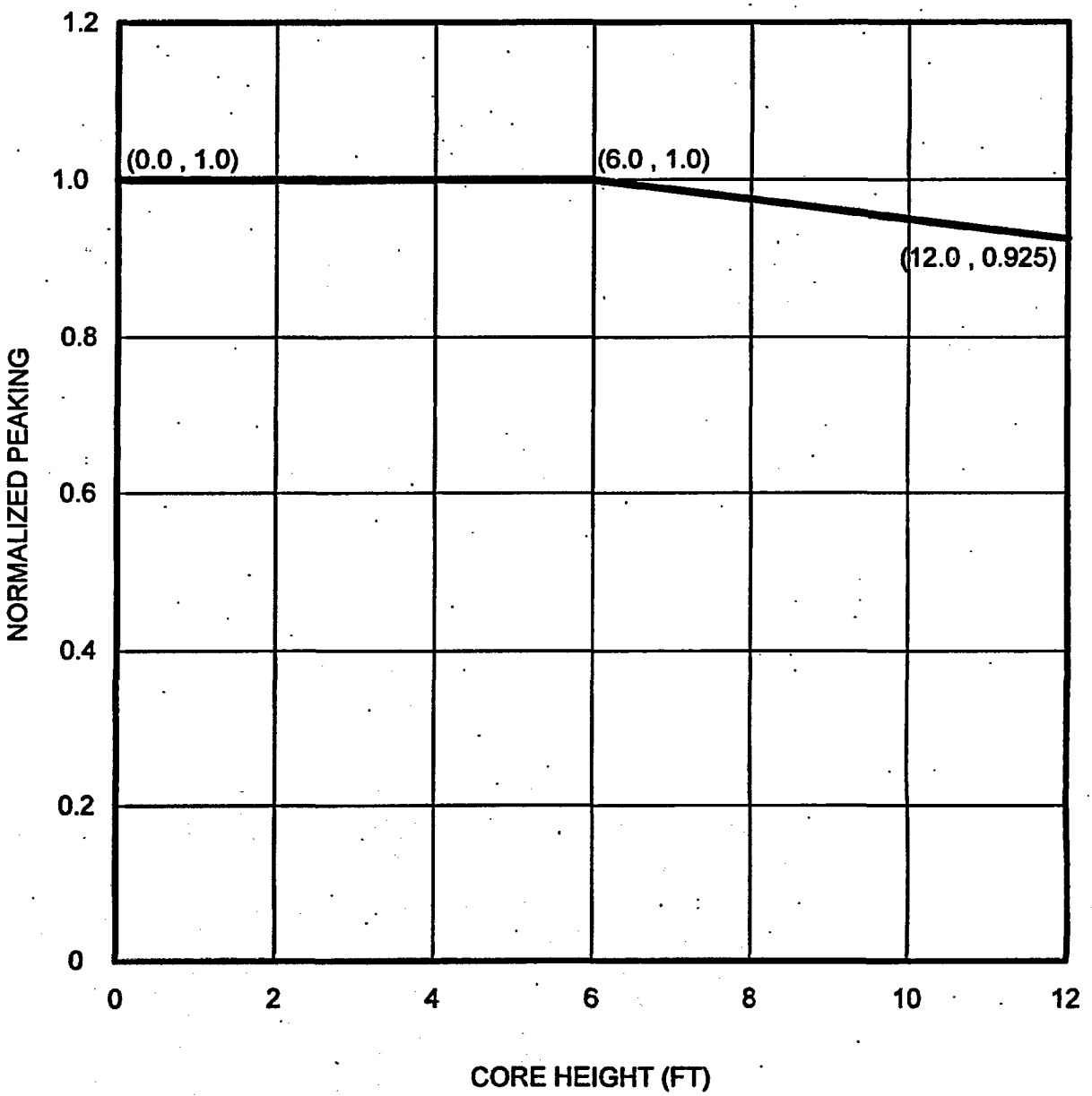


FIGURE 5
(Page 1 of 2)
Reactor Trip System Instrumentation Trip Setpoints
Overtemperature ΔT Trip Setpoint

$$\text{Overtemperature } \Delta T \le \Delta T_o \left[K_1 - K_2 \left[\frac{1+\tau_1 S}{1+\tau_2 S}\right](T-T') + K_3 (P-P') - f_1(\Delta I)\right]$$

Where:

ΔT	=	Measured RCS ΔT, °F
ΔT_o	=	Indicated ΔT at RATED THERMAL POWER °F
T	=	Average temperature, °F
T'	=	Nominal T_{avg} at RATED THERMAL POWER (≤ 574.0 °F)
P	=	Pressurizer pressure, psig
P'	=	Nominal RCS operating pressure (2085 psig)
$\frac{1+\tau_1 S}{1+\tau_2 S}$	=	The function generated by the lead-lag controller for T_{avg} dynamic compensation
τ_1, τ_2	=	Time constants utilized in the lead-lag controller for T_{avg} $\tau_1 \ge 22$ secs. $\tau_2 \le 4$ secs.
S	=	Laplace transform operator, sec^{-1}
K_1	≤	1.35 *
K_2	≥	0.0230/°F
K_3	≥	0.00110/psig
$f_1(\Delta I)$	=	$-0.33\{37\% + (q_t - q_b)\}$ when $q_t - q_b \le -37\%$ RTP 0% of RTP when -37% RTP $< q_t - q_b \le 3\%$ RTP $+2.34\{(q_t - q_b) - 3\%\}$ when $q_t - q_b > 3\%$ RTP

where q_t and q_b are percent RATED THERMAL POWER in the upper and lower halves of the core respectively, and $q_t + q_b$ is total THERMAL POWER in percent RATED THERMAL POWER.

* This is a Safety Analysis value. Refer to Technical Requirements Manual for nominal value of this coefficient used in programming the trip setpoint.

FIGURE 5
(Page 2 of 2)
Overpower ΔT Trip Setpoint

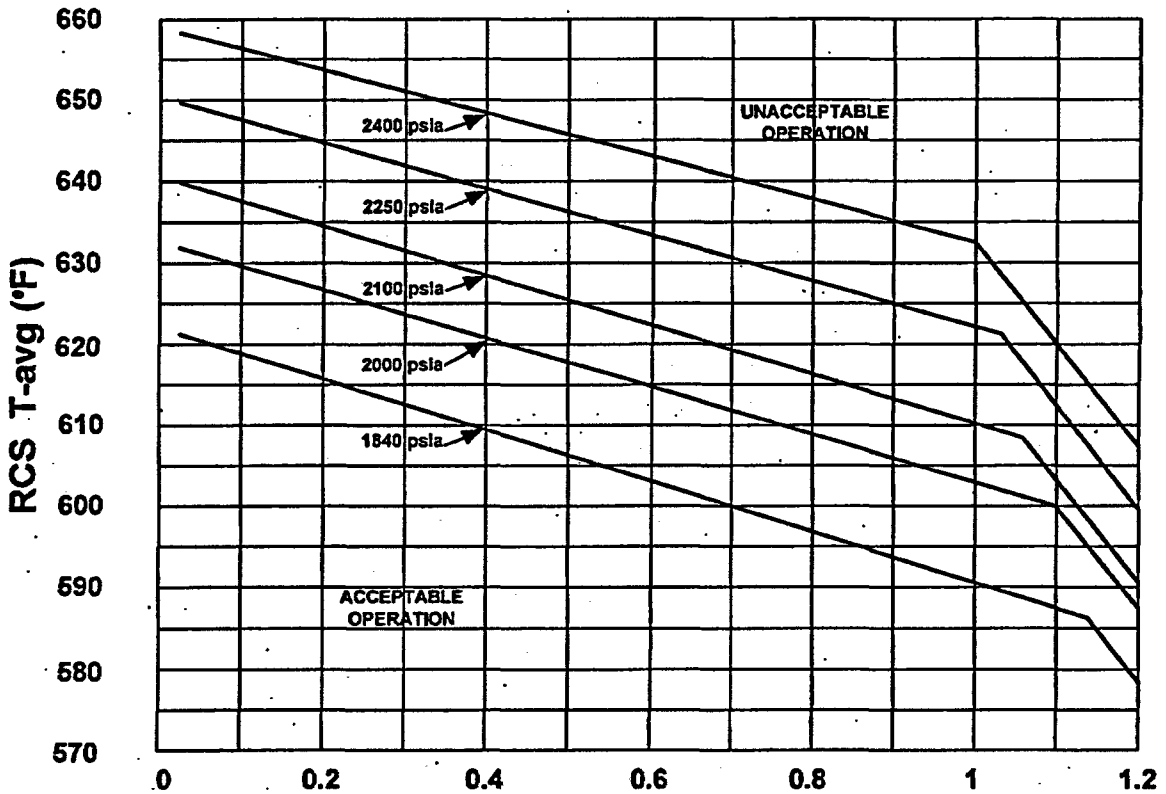
$$\text{Overpower } \Delta T \le \Delta T_o \left[K_4 - K_5 \left[\frac{\tau_3 S}{1+\tau_3 S}\right] T - K_6 (T - T'') - f_2(\Delta I)\right]$$

Where:	ΔT	=	Measured RCS ΔT, °F
	ΔT_o	=	Indicated ΔT at RATED THERMAL POWER, °F
	T	=	Average temperature, °F
	T''	=	Nominal T_{avg} at RATED THERMAL POWER (≤ 562.1 °F)
	K_4	≤	1.172 *
	K_5	≥	0.0177/°F for increasing average temperature ; K_5 = 0 for decreasing average temperature
	K_6	≥	0.0015/°F for T greater than T'' ; K_6 = 0 for T less than or equal to T''
	$\frac{\tau_3 S}{1+\tau_3 S}$	=	The function generated by the rate lag controller for T_{avg} dynamic compensation
	τ_3	=	Time constant utilized in the rate lag controller for T_{avg} $\tau_3 \ge$ 10 secs.
	S	=	Laplace transform operator, sec^{-1}
	$f_2(\Delta I)$	=	0.0

* This is a Safety Analysis value. Refer to Technical Requirements Manual for nominal value of this coefficient used in programming the trip setpoint.

FIGURE 6

Reactor Core Safety Limits



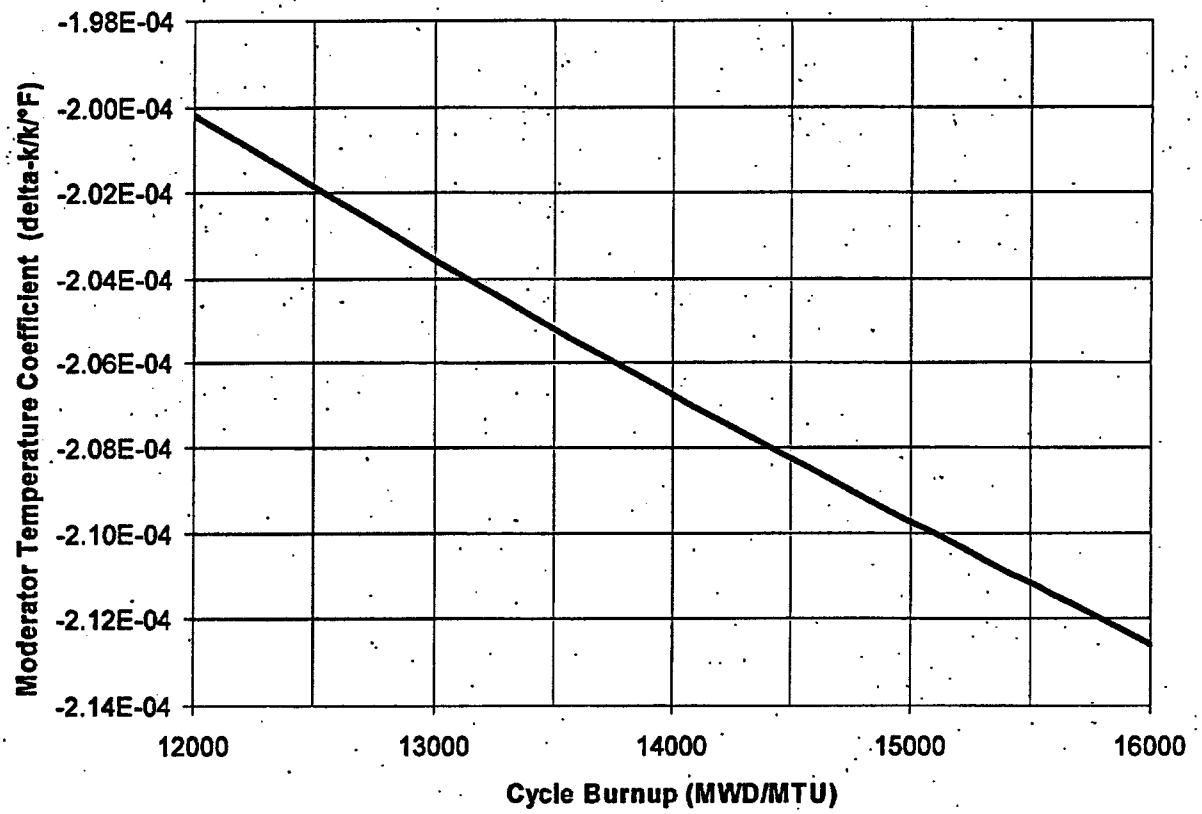
Power (fraction of rated thermal power)

DESCRIPTION OF SAFETY LIMITS

PRESSURE (PSIA)	Power (frac)	Tavg (°F)	Power (frac)	Tavg (°F)	Power (frac)	Tavg (°F)
1840	0.02	620.86	1.136	586.17	1.2	577.94
2000	0.02	632.79	1.094	600.31	1.2	586.52
2100	0.02	639.85	1.068	608.72	1.2	591.77
2250	0.02	649.96	1.031	620.83	1.2	599.40
2400	0.02	659.52	0.996	632.42	1.2	606.63

UNIT 1 **Reactor Core Safety Limits**

FIGURE 7
Unit 1 Cycle 20 Predicted HFP ARO 300 PPM MTC Versus Burnup



Burnup (MWD/MTU)	MTC (Δk/k/°F)
12000	-2.0020E-4
13320	-2.0458E-4
14320	-2.0770E-4
15320	-2.1064E-4
16000	-2.1256E-4

TABLE 1
DONALD C. COOK UNIT 1 CYCLE 20
W(Z) FUNCTION

Node	Height	Burnup (MWD/MTU)										
No.	(feet)	150	1000	2000	4000	6000	8000	10000	12000	14000	16000	17970
1	0.0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	0.2	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
3	0.4	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
4	0.6	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
5	0.8	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
6	1.0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
7	1.2	1.0985	1.0993	1.1003	1.1026	1.1052	1.1081	1.1114	1.1151	1.1191	1.1231	1.1268
8	1.4	1.0987	1.0994	1.1004	1.1025	1.1050	1.1078	1.1109	1.1143	1.1181	1.1219	1.1254
9	1.6	1.0986	1.0993	1.1002	1.1022	1.1045	1.1071	1.1100	1.1132	1.1167	1.1202	1.1235
10	1.8	1.0983	1.0989	1.0997	1.1016	1.1037	1.1060	1.1087	1.1116	1.1147	1.1179	1.1209
11	2.0	1.0977	1.0983	1.0990	1.1006	1.1025	1.1046	1.1069	1.1094	1.1122	1.1151	1.1177
12	2.2	1.0969	1.0974	1.0980	1.0994	1.1010	1.1027	1.1047	1.1069	1.1093	1.1117	1.1139
13	2.4	1.0959	1.0963	1.0968	1.0978	1.0991	1.1006	1.1022	1.1040	1.1060	1.1080	1.1099
14	2.6	1.0947	1.0949	1.0952	1.0960	1.0969	1.0980	1.0993	1.1008	1.1025	1.1042	1.1057
15	2.8	1.0932	1.0933	1.0934	1.0938	1.0944	1.0951	1.0961	1.0973	1.0986	1.1000	1.1011
16	3.0	1.0916	1.0915	1.0915	1.0915	1.0917	1.0921	1.0926	1.0934	1.0943	1.0952	1.0960
17	3.2	1.0901	1.0899	1.0897	1.0894	1.0892	1.0892	1.0893	1.0895	1.0899	1.0903	1.0906
18	3.4	1.0888	1.0885	1.0882	1.0876	1.0871	1.0868	1.0865	1.0864	1.0864	1.0865	1.0864
19	3.6	1.0880	1.0875	1.0870	1.0862	1.0856	1.0852	1.0849	1.0849	1.0851	1.0853	1.0853
20	3.8	1.0875	1.0867	1.0860	1.0848	1.0840	1.0837	1.0839	1.0845	1.0855	1.0866	1.0874
21	4.0	1.0869	1.0859	1.0849	1.0835	1.0828	1.0828	1.0836	1.0851	1.0874	1.0899	1.0917
22	4.2	1.0862	1.0851	1.0841	1.0828	1.0824	1.0828	1.0842	1.0864	1.0896	1.0930	1.0955
23	4.4	1.0854	1.0844	1.0835	1.0825	1.0824	1.0832	1.0851	1.0880	1.0918	1.0958	1.0989
24	4.6	1.0845	1.0836	1.0828	1.0820	1.0822	1.0835	1.0858	1.0893	1.0937	1.0984	1.1021
25	4.8	1.0833	1.0825	1.0818	1.0813	1.0819	1.0836	1.0864	1.0903	1.0953	1.1006	1.1048
26	5.0	1.0823	1.0816	1.0810	1.0807	1.0815	1.0835	1.0867	1.0911	1.0966	1.1025	1.1071
27	5.2	1.0818	1.0810	1.0804	1.0800	1.0809	1.0830	1.0866	1.0914	1.0974	1.1038	1.1090
28	5.4	1.0813	1.0804	1.0797	1.0792	1.0801	1.0824	1.0862	1.0913	1.0978	1.1047	1.1102
29	5.6	1.0805	1.0798	1.0793	1.0791	1.0803	1.0827	1.0865	1.0916	1.0981	1.1049	1.1103
30	5.8	1.0795	1.0791	1.0789	1.0793	1.0807	1.0833	1.0871	1.0920	1.0980	1.1043	1.1095
31	6.0	1.0782	1.0781	1.0782	1.0791	1.0809	1.0836	1.0873	1.0919	1.0974	1.1031	1.1079
32	6.2	1.0766	1.0768	1.0772	1.0786	1.0807	1.0835	1.0870	1.0912	1.0961	1.1012	1.1056
33	6.4	1.0746	1.0751	1.0759	1.0777	1.0800	1.0828	1.0861	1.0899	1.0941	1.0986	1.1025
34	6.6	1.0722	1.0730	1.0740	1.0763	1.0788	1.0815	1.0846	1.0879	1.0915	1.0951	1.0985
35	6.8	1.0696	1.0706	1.0718	1.0743	1.0768	1.0795	1.0823	1.0852	1.0883	1.0913	1.0942
36	7.0	1.0671	1.0682	1.0695	1.0721	1.0747	1.0775	1.0803	1.0831	1.0861	1.0890	1.0919
37	7.2	1.0646	1.0660	1.0678	1.0711	1.0743	1.0775	1.0805	1.0833	1.0861	1.0889	1.0917
38	7.4	1.0630	1.0655	1.0682	1.0731	1.0773	1.0809	1.0837	1.0859	1.0874	1.0887	1.0906
39	7.6	1.0654	1.0681	1.0711	1.0763	1.0806	1.0840	1.0863	1.0876	1.0879	1.0880	1.0890
40	7.8	1.0702	1.0727	1.0755	1.0801	1.0838	1.0864	1.0879	1.0883	1.0877	1.0868	1.0869
41	8.0	1.0750	1.0773	1.0798	1.0838	1.0868	1.0886	1.0891	1.0885	1.0867	1.0846	1.0837
42	8.2	1.0796	1.0816	1.0837	1.0871	1.0892	1.0902	1.0899	1.0884	1.0858	1.0828	1.0809
43	8.4	1.0840	1.0855	1.0871	1.0895	1.0909	1.0914	1.0909	1.0895	1.0870	1.0844	1.0826
44	8.6	1.0881	1.0891	1.0900	1.0914	1.0921	1.0921	1.0914	1.0900	1.0879	1.0856	1.0840
45	8.8	1.0921	1.0923	1.0926	1.0928	1.0928	1.0924	1.0917	1.0907	1.0894	1.0879	1.0868
46	9.0	1.0957	1.0952	1.0947	1.0939	1.0932	1.0927	1.0924	1.0923	1.0924	1.0926	1.0925
47	9.2	1.0990	1.0978	1.0966	1.0946	1.0934	1.0929	1.0933	1.0943	1.0961	1.0981	1.0994
48	9.4	1.1020	1.1000	1.0980	1.0950	1.0932	1.0928	1.0937	1.0959	1.0994	1.1033	1.1059
49	9.6	1.1045	1.1021	1.0997	1.0961	1.0942	1.0938	1.0952	1.0983	1.1029	1.1081	1.1116
50	9.8	1.1069	1.1043	1.1017	1.0978	1.0958	1.0956	1.0973	1.1009	1.1064	1.1124	1.1165
51	10.0	1.1093	1.1065	1.1036	1.0994	1.0972	1.0971	1.0991	1.1033	1.1094	1.1162	1.1209
52	10.2	1.1112	1.1083	1.1054	1.1012	1.0990	1.0991	1.1013	1.1057	1.1122	1.1194	1.1244
53	10.4	1.1125	1.1099	1.1072	1.1034	1.1016	1.1018	1.1042	1.1086	1.1150	1.1219	1.1269
54	10.6	1.1136	1.1111	1.1087	1.1053	1.1037	1.1041	1.1065	1.1108	1.1170	1.1238	1.1286
55	10.8	1.1150	1.1126	1.1103	1.1070	1.1056	1.1060	1.1083	1.1125	1.1185	1.1251	1.1298
56	11.0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
57	11.2	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
58	11.4	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
59	11.6	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
60	11.8	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
61	12.0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Top and bottom 10% of core excluded.

ATTACHMENT 2 TO AEP:NRC:6565

Unit 2 Cycle 16 Core Operating Limits Report
Revision 0

Donald C. Cook Nuclear Plant
Unit 2 Cycle 16

Core Operating Limits Report
Revision 0

1.0 CORE OPERATING LIMITS REPORT

This Core Operating Limits Report (COLR) for the Donald C. Cook Nuclear Plant Unit 2 Cycle 16 has been prepared in accordance with the requirements of Technical Specification 5.6.5.

The analytical methods used to determine the core operating limits shall be those previously reviewed and approved by the NRC in:

a. WCAP-9272-P-A, Westinghouse Reload Safety Evaluation Methodology, July 1985

b. WCAP-8385, Power Distribution Control and Load Following Procedures – Topical Report, September 1974

c. WCAP-10216-P-A, Rev. 1A, Relaxation of Constant Axial Offset Control/F_Q Surveillance Technical Specification, February 1994

d. WCAP-10266-P-A, Rev. 2, The 1981 Version of the Westinghouse ECCS Evaluation Model Using the BASH Code, March 1987

e. WCAP-12610-P-A, VANTAGE+ Fuel Assembly Reference Core Report, April 1995

f. WCAP-8745-P-A, Design Bases for the Thermal Overpower ΔT and Thermal Overtemperature ΔT Trip Functions, September 1986

g. WCAP-13749-P-A, Safety Evaluation Supporting the Conditional Exemption of the Most Negative EOL Moderator Temperature Coefficient Measurement, March 1997

The Technical Specifications affected by this report are listed below:

2.1.1	Reactor Core Safety Limits
3.1.1	SHUTDOWN MARGIN (SDM)
3.1.3	Moderator Temperature Coefficient (MTC)
3.1.5	Shutdown Bank Insertion Limits
3.1.6	Control Bank Insertion Limits
3.2.1	Heat Flux Hot Channel Factor ($F_Q(Z)$)
3.2.2	Nuclear Enthalpy Rise Hot Channel Factor ($F^N_{\Delta H}$)
3.2.3	AXIAL FLUX DIFFERENCE (AFD)
3.3.1	Reactor Trip System (RTS) Instrumentation
3.4.1	RCS Pressure, Temperature, and Flow Departure from Nucleate Boiling (DNB) Limits
3.9.1	Boron Concentration

2.0 OPERATING LIMITS

The cycle-specific parameter limits listed in Section 1.0 are presented in the following subsections. These limits have been developed using the NRC-approved methodologies specified in Technical Specification 5.6.5.

2.1 SAFETY LIMITS

2.1.1 Reactor Core Safety Limits (Specification 2.1.1)

In Modes 1 and 2, the combination of thermal power, pressurizer pressure, and the highest loop average temperature (T_{avg}) shall not exceed the limits as shown in Figure 6 for 4 loop operation.

2.2 REACTIVITY CONTROL

2.2.1 SHUTDOWN MARGIN (SDM) (Specification 3.1.1)

Shutdown margin shall be greater than or equal to 1.3% Δk/k for $T_{avg} > 200°F$
Shutdown margin shall be greater than or equal to 1.0% Δk/k for $T_{avg} \leq 200°F$

2.2.2 Moderator Temperature Coefficient (MTC) (Specification 3.1.3)

a. The Moderator Temperature Coefficient (MTC) limits are:

The BOL/ARO-MTC shall be less positive or equal to the value given in Figure 1.

The EOL/ARO/RTP-MTC shall be less negative or equal to -4.10E-4 Δk/k/°F.

This limit is based on a T_{avg} program with HFP vessel T_{avg} of 571.0 to 576.0 °F

Where: ARO stands for All Rods Out
BOL stands for Beginning of Cycle Life
EOL stands for End of Cycle Life
RTP stands for Rated Thermal Power
HFP stands for Hot Full Thermal Power

b. The MTC Surveillance limit is:
The 300 ppm/ARO/RTP-MTC should be less negative or equal to -3.20E-4 Δk/k/°F at a HFP vessel T_{avg} of 571.0 to 576.0 °F

c. The Revised Predicted near-EOL 300 ppm MTC shall be calculated using Figure 7 and the following algorithm:

Revised Predicted MTC = Predicted MTC + AFD Correction + Predicted Correction*

* Predicted Correction is -0.30E-4 Δk/k/°F.

If the Revised Predicted MTC is less negative than the SR 3.1.3.2 limit (COLR 2.2.2.b) and all of the benchmark data contained in the surveillance procedure are met, then a MTC measurement in accordance with SR 3.1.3.2 is not required.

d. The MTC Surveillance limit is:
The 60 ppm/ARO/RTP-MTC should be less negative or equal to -3.90E-4 Δk/k/°F at a HFP vessel T_{avg} of 571.0 to 576.0 °F

2.2.3 Shutdown Bank Insertion Limits (Specification 3.1.5)

The shutdown rods shall be withdrawn to at least 228 steps.

2.2.4 Control Bank Insertion Limits (Specifications 3.1.6)

a. The control rod banks shall be limited in physical insertion as shown in Figure 2.

b. Successive Control Banks shall overlap by 100 steps. The sequence for Control Bank withdrawal shall be Control Bank A, Control Bank B, Control Bank C, and Control Bank D.

2.3 POWER DISTRIBUTION LIMITS

2.3.1 AXIAL FLUX DIFFERENCE (AFD) (Specification 3.2.3)

a. The Allowable Operation Limits are provided in Figure 3.

b. The AFD target band is ±5% for a cycle average accumulated burnup ≥0.0 MWD/MTU.

2.3.2 Heat Flux Hot Channel Factor ($F_Q(Z)$) (Specification 3.2.1)

$$F_Q^C(Z) \le \frac{CF_Q}{P} * K(Z) \qquad for\ P > 0.5$$

$$F_Q^C(Z) \le 2 * CF_Q * K(Z) \qquad for\ P \le 0.5$$

$$F_Q^W(Z) \le \frac{CF_Q}{P} * K(Z) \qquad for\ P > 0.5$$

$$F_Q^W(Z) \le 2 * CF_Q * K(Z) \qquad for\ P \le 0.5$$

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

a. $CF_Q = 2.335$

b. K(Z) is provided in Figure 4.

c. $F_Q^C(Z)$ is the measured hot channel factor including a 3% manufacturing tolerance uncertainty and a 5% measurement uncertainty.

d. W(Z) is provided in Table 1 for ±5% AFD target band.

e. $F_Q^W(Z) = F_Q^C(Z) \times W(Z) \times F_P$

f. For Cycle 16, $F_P = 1.02$ for all burnups associated with Note 2.a of SR 3.2.1.2, except as shown in the table below. When no penalty is required, $F_P = 1.00$.

Cycle Burnup (MWD/MTU)	F_P Penalty Multiplier
0	1.020
150	1.020
317	1.024
484	1.054
651	1.063
818	1.060
985	1.056
1152	1.052
1319	1.048

1486	1.043
1653	1.038
1820	1.033
1987	1.028
2154	1.024
2322	1.020

The burnup range only covers where F_P exceeds 1.02. Linear interpolation is adequate for intermediate cycle burnups.

2.3.3 Nuclear Enthalpy Rise Hot Channel Factor ($F^N_{\Delta H}$) (Specification 3.2.2)

$$F^N_{\Delta H} \leq CF_{\Delta H} * (1 + PF_{\Delta H} * (1-P))$$

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

a. $CF_{\Delta H} = 1.58$

b. $PF_{\Delta H} = 0.3$

2.4 INSTRUMENTATION

2.4.1 Reactor Trip System (RTS) Instrumentation (Specification 3.3.1)

The Overtemperature ΔT and Overpower ΔT setpoints are as shown in Figure 5.

2.5 REACTOR COOLANT SYSTEM

2.5.1 RCS Pressure, Temperature, and Flow Departure from Nucleate Boiling (DNB) Limits (Specification 3.4.1)

a. Pressurizer Pressure shall be ≥ 2172.4 psig [+]

b. Reactor Coolant System T_{avg} shall be ≤ 580.1 °F [+]

c. Reactor Coolant System Total Flow Rate shall be ≥ 366,400 gpm

2.6 REFUELING OPERATIONS

2.6.1 Boron Concentration (Specification 3.9.1)

The boron concentration of all filled portions of the Reactor Coolant System, the refueling canal and the refueling cavity shall be greater than or equal to 2400 ppm[++].

[+] These are Safety Analysis values. With readability allowance, the corresponding values are 577.8°F for T_{avg}, and 2200 psig for Pressurizer Pressure.

[++] This concentration bounds the condition of $K_{eff} \leq 0.95$ which includes a 1% Δk/k conservative allowance for uncertainties. The boron concentration of 2400 ppm includes a 50 ppm conservative allowance for uncertainties.

FIGURE 1
MODERATOR TEMPERATURE COEFFICIENT (MTC) LIMITS

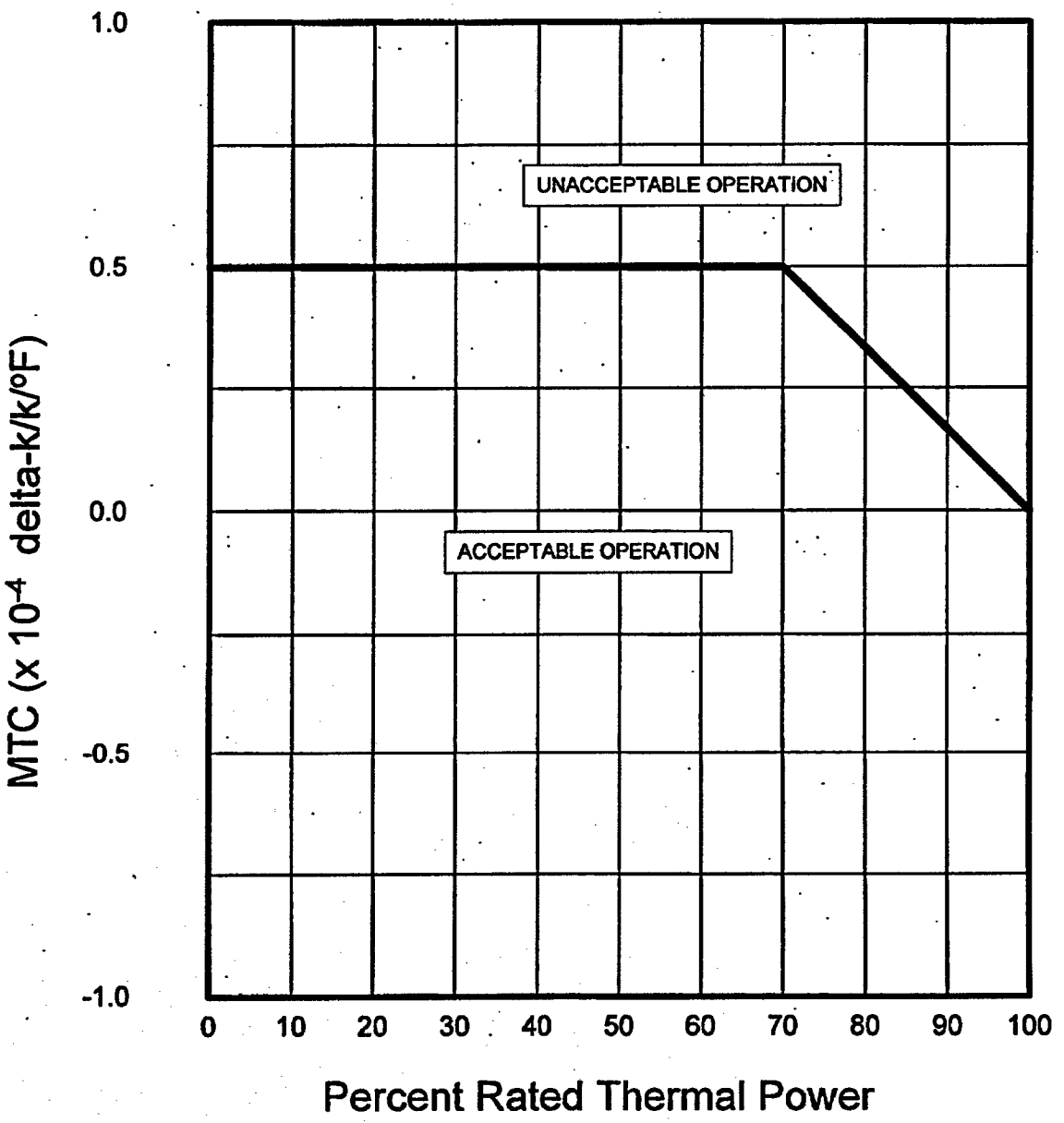


FIGURE 2
ROD BANK INSERTION LIMITS VERSUS THERMAL POWER
(FOUR-LOOP OPERATION)

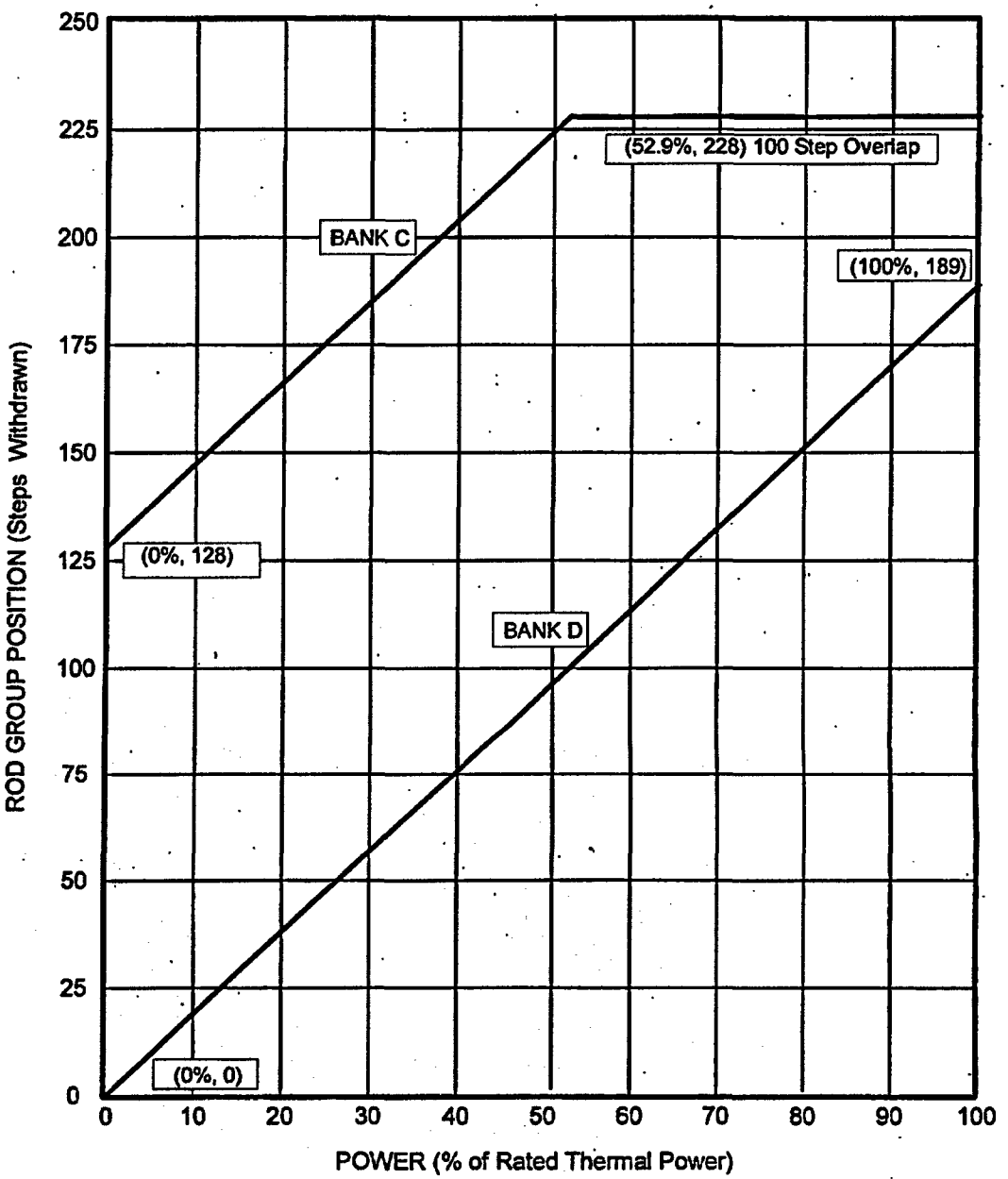


FIGURE 3
AXIAL FLUX DIFFERENCE LIMITS AS A FUNCTION OF RATED THERMAL POWER (RTP)

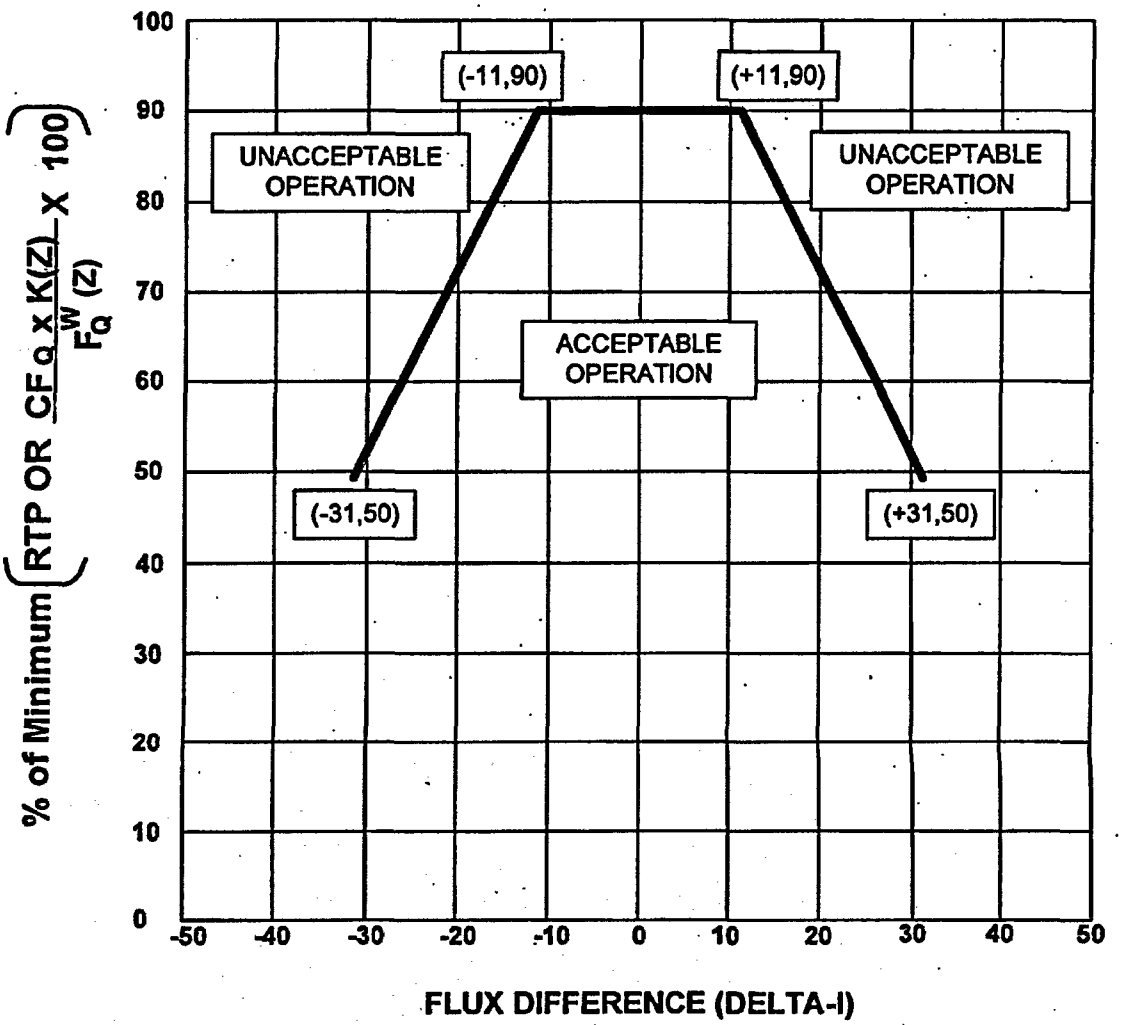


FIGURE 4
K(Z) - NORMALIZED $F_Q(Z)$ AS A FUNCTION OF CORE HEIGHT

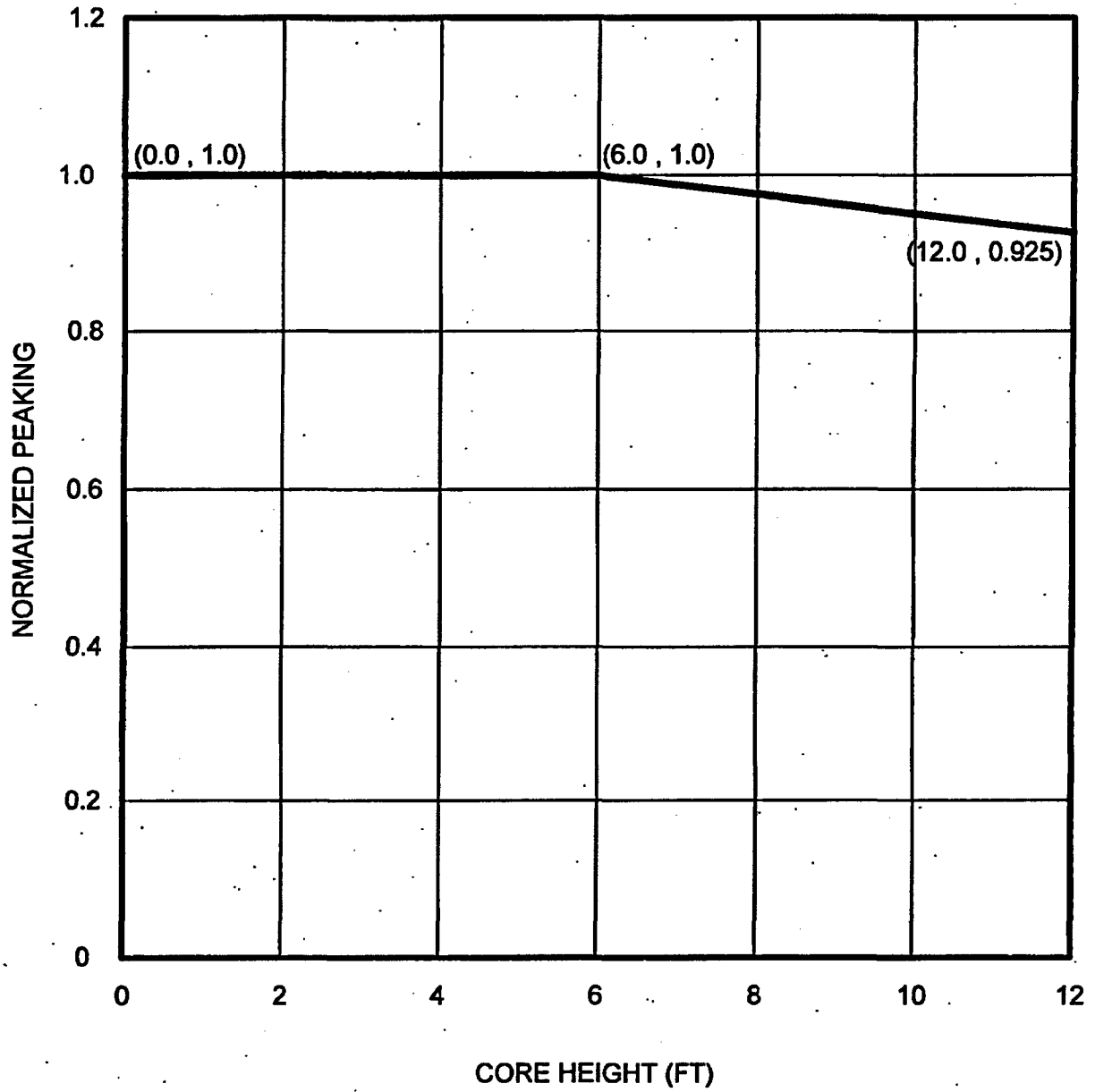


FIGURE 5

(Page 1 of 2)

Reactor Trip System Instrumentation Trip Setpoints

Overtemperature ΔT Trip Setpoint

$$\text{Overtemperature } \Delta T \le \Delta T_o \left[K_1 - K_2 \left[\frac{1+\tau_1 S}{1+\tau_2 S}\right](T-T') + K_3 (P-P') - f_1(\Delta I)\right]$$

Where:

ΔT	=	Measured RCS ΔT, °F
ΔT_o	=	Indicated ΔT at RATED THERMAL POWER, °F
T	=	Average temperature, °F
T'	=	Nominal T_{avg} at RATED THERMAL POWER, (≤ 576.0°F)
P	=	Pressurizer Pressure, psig
P'	=	Nominal RCS operating pressure (2235 psig)
$\frac{1+\tau_1 S}{1+\tau_2 S}$	=	The function generated by the lead-lag controller for T_{avg} dynamic compensation
τ_1, τ_2	=	Time constants utilized in the lead-lag controller for T_{avg} $\tau_1 \ge 28$ secs. $\tau_2 \le 4$ secs.
S	=	Laplace transform operator, sec^{-1}
K_1	≤	1.19 *
K_2	≥	0.01331/°F
K_3	≥	0.00058/psig
$f_1(\Delta I)$	=	$-3.5\{33\% + (q_t - q_b)\}$ when $q_t - q_b \le -33\%$ RTP 0% of RTP when -33% RTP $< q_t - q_b \le 6\%$ RTP $+1.0\{(q_t - q_b) - 6\%\}$ when $q_t - q_b > 6\%$ RTP

where q_t and q_b are percent RATED THERMAL POWER in the upper and lower halves of the core respectively, and $q_t + q_b$ is total THERMAL POWER in percent RATED THERMAL POWER.

* This is a Safety Analysis value. Refer to Technical Requirements Manual for nominal value of this coefficient used in programming the trip setpoint.

FIGURE 5

(Page 2 of 2)

Overpower ΔT Trip Setpoint

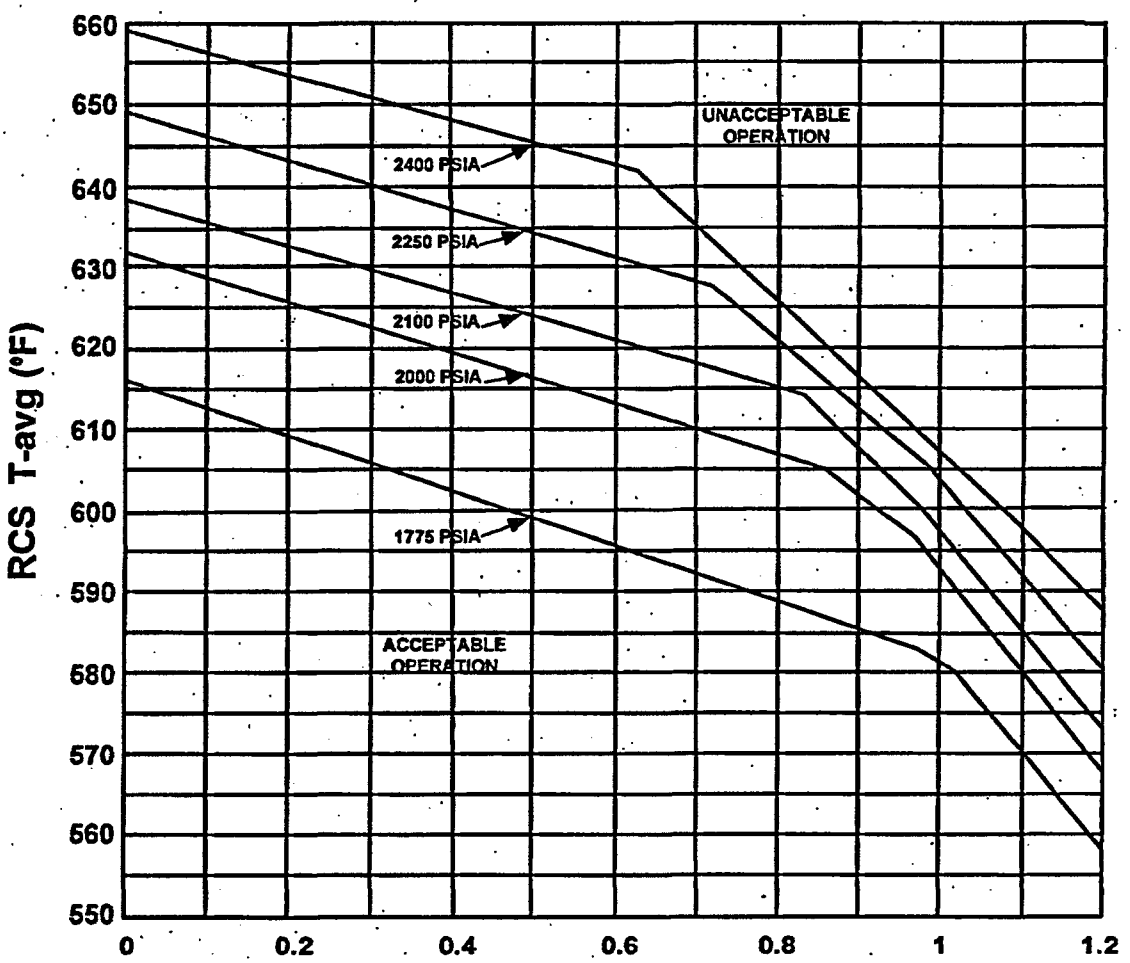
$$\text{Overpower } \Delta T \le \Delta T_o \left[K_4 - K_5 \left[\frac{\tau_3 S}{1+\tau_3 S}\right] T - K_6 (T - T'') - f_2(\Delta I)\right]$$

Where:

ΔT	=	Measured RCS ΔT, °F
ΔT_o	=	Indicated ΔT at RATED THERMAL POWER, °F
T	=	Average temperature, °F
T''	=	Nominal T_{avg} at RATED THERMAL POWER, ($\le$ 576.0 °F)
K_4	$\le$	1.16 *
K_5	$\ge$	0.02/°F for increasing average temperature; $K_5 = 0$ for decreasing average temperature
K_6	$\ge$	0.00197/°F for T greater than T''; K_6=0 for T less than or equal to T''
$\frac{\tau_3 S}{1+\tau_3 S}$	=	The function generated by the rate lag controller for T_{avg} dynamic compensation
τ_3	=	Time constant utilized in the rate lag controller for T_{avg}; $\tau_3 \ge 10$ secs.
S	=	Laplace transform operator, sec^{-1}
$f_2(\Delta I)$	=	0.0

* This is a Safety Analysis value. Refer to Technical Requirements Manual for nominal value of this coefficient used in programming the trip setpoint.

FIGURE 6
Reactor Core Safety Limits

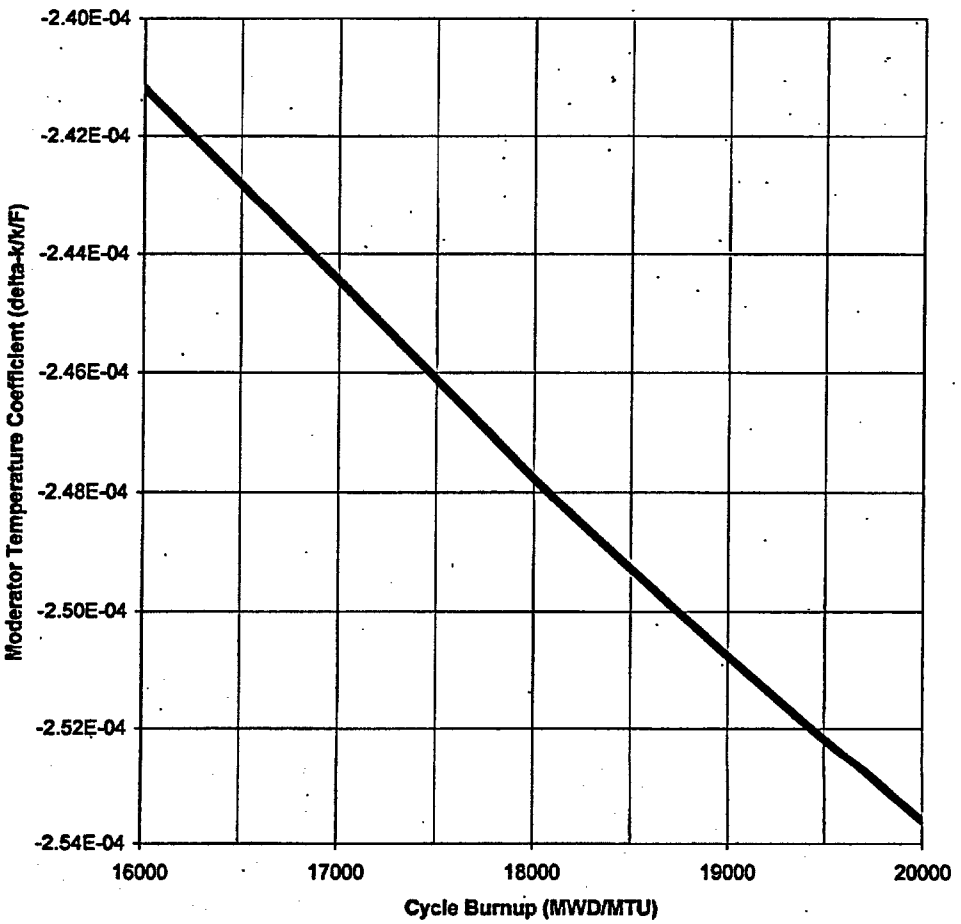


DESCRIPTION OF SAFETY LIMITS

PRESSURE (psia)	Power (frac)	Tavg (°F)	Power (frac)	Tavg (°F)	Power (frac)	Tavg (°F)	Power (frac)	Tavg (°F)
1775	0.00	615.4	0.98	583.8	1.02	580.9	1.2	558.1
2000	0.00	631.8	0.86	605.8	0.96	597.5	1.2	568.5
2100	0.00	639.1	0.82	614.0	0.96	601.6	1.2	573.1
2250	0.00	649.2	0.72	628.6	0.98	605.2	1.2	580.4
2400	0.00	659.0	0.62	642.0	1.1	599.0	1.2	588.1

UNIT 2 Reactor Core Safety Limits

FIGURE 7
Unit 2 Cycle 16 Predicted HFP ARO 300 PPM MTC Versus Burnup



Burnup (MWD/MTU)	MTC (Δk/k/°F)
16000	-2.4118E-4
17000	-2.4444E-4
18000	-2.4777E-4
19000	-2.5075E-4
20000	-2.5360E-4

TABLE 1
D. C. Cook Unit 2 Cycle 16
W(Z) Function

Node	Height	Burnup (MWD/MTU)													
PT	(Ft.)	150	1000	2000	4000	5000	6000	8000	10000	12000	14000	16000	18000	20000	20910
1	0.00	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	0.20	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
3	0.40	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
4	0.60	1.1207	1.1151	1.1095	1.1024	1.1011	1.1016	1.1061	1.1130	1.1200	1.1271	1.1348	1.1433	1.1509	1.1543
5	0.80	1.1208	1.1141	1.1075	1.0994	1.0982	1.0991	1.1053	1.1140	1.1219	1.1289	1.1358	1.1433	1.1506	1.1539
6	1.00	1.1199	1.1133	1.1069	1.0990	1.0979	1.0990	1.1056	1.1144	1.1222	1.1290	1.1355	1.1424	1.1494	1.1526
7	1.20	1.1188	1.1126	1.1067	1.0995	1.0986	1.0997	1.1060	1.1144	1.1218	1.1282	1.1343	1.1407	1.1472	1.1502
8	1.40	1.1171	1.1116	1.1062	1.0998	1.0991	1.1002	1.1061	1.1140	1.1209	1.1268	1.1323	1.1381	1.1442	1.1469
9	1.60	1.1151	1.1102	1.1055	1.0999	1.0993	1.1004	1.1060	1.1132	1.1195	1.1249	1.1298	1.1350	1.1404	1.1429
10	1.80	1.1126	1.1084	1.1044	1.0997	1.0993	1.1003	1.1054	1.1120	1.1176	1.1223	1.1267	1.1312	1.1360	1.1381
11	2.00	1.1097	1.1062	1.1029	1.0992	1.0989	1.1000	1.1045	1.1102	1.1151	1.1192	1.1229	1.1267	1.1308	1.1327
12	2.20	1.1064	1.1037	1.1012	1.0984	1.0984	1.0993	1.1033	1.1081	1.1122	1.1156	1.1186	1.1216	1.1250	1.1265
13	2.40	1.1028	1.1009	1.0991	1.0973	1.0975	1.0983	1.1016	1.1055	1.1088	1.1114	1.1137	1.1159	1.1185	1.1196
14	2.60	1.0988	1.0977	1.0968	1.0960	1.0963	1.0971	1.0997	1.1026	1.1049	1.1067	1.1082	1.1095	1.1113	1.1121
15	2.80	1.0945	1.0943	1.0941	1.0944	1.0948	1.0955	1.0973	1.0992	1.1006	1.1016	1.1022	1.1027	1.1036	1.1040
16	3.00	1.0901	1.0906	1.0912	1.0924	1.0930	1.0936	1.0947	1.0956	1.0960	1.0961	1.0958	1.0953	1.0952	1.0951
17	3.20	1.0862	1.0873	1.0885	1.0903	1.0910	1.0915	1.0919	1.0919	1.0915	1.0908	1.0897	1.0883	1.0874	1.0870
18	3.40	1.0841	1.0854	1.0868	1.0887	1.0893	1.0895	1.0892	1.0886	1.0879	1.0874	1.0868	1.0861	1.0854	1.0852
19	3.60	1.0852	1.0862	1.0872	1.0884	1.0886	1.0883	1.0873	1.0864	1.0867	1.0879	1.0900	1.0925	1.0941	1.0948
20	3.80	1.0877	1.0880	1.0883	1.0883	1.0880	1.0874	1.0858	1.0851	1.0864	1.0894	1.0941	1.0998	1.1035	1.1052
21	4.00	1.0907	1.0900	1.0893	1.0879	1.0872	1.0864	1.0851	1.0852	1.0876	1.0920	1.0984	1.1062	1.1114	1.1138
22	4.20	1.0934	1.0916	1.0898	1.0871	1.0862	1.0856	1.0854	1.0869	1.0905	1.0961	1.1035	1.1124	1.1187	1.1216
23	4.40	1.0959	1.0930	1.0901	1.0861	1.0851	1.0849	1.0861	1.0893	1.0942	1.1006	1.1086	1.1180	1.1252	1.1284
24	4.60	1.0982	1.0941	1.0901	1.0849	1.0839	1.0839	1.0865	1.0915	1.0976	1.1048	1.1133	1.1230	1.1309	1.1345
25	4.80	1.1001	1.0952	1.0904	1.0842	1.0831	1.0834	1.0871	1.0934	1.1005	1.1083	1.1173	1.1274	1.1359	1.1398
26	5.00	1.1017	1.0961	1.0907	1.0839	1.0827	1.0832	1.0878	1.0950	1.1029	1.1112	1.1205	1.1310	1.1400	1.1441
27	5.20	1.1029	1.0968	1.0908	1.0834	1.0822	1.0829	1.0882	1.0963	1.1048	1.1135	1.1231	1.1337	1.1431	1.1473
28	5.40	1.1036	1.0970	1.0906	1.0827	1.0815	1.0823	1.0883	1.0971	1.1061	1.1151	1.1248	1.1355	1.1451	1.1495
29	5.60	1.1038	1.0968	1.0901	1.0817	1.0805	1.0814	1.0880	1.0975	1.1069	1.1160	1.1257	1.1363	1.1460	1.1504
30	5.80	1.1035	1.0962	1.0891	1.0804	1.0791	1.0802	1.0873	1.0973	1.1069	1.1161	1.1256	1.1360	1.1456	1.1500
31	6.00	1.1026	1.0950	1.0877	1.0787	1.0775	1.0787	1.0861	1.0965	1.1063	1.1154	1.1246	1.1346	1.1441	1.1484
32	6.20	1.1011	1.0933	1.0858	1.0766	1.0754	1.0767	1.0844	1.0951	1.1048	1.1137	1.1225	1.1320	1.1412	1.1454
33	6.40	1.0989	1.0910	1.0834	1.0741	1.0729	1.0742	1.0822	1.0929	1.1025	1.1111	1.1194	1.1283	1.1371	1.1411
34	6.60	1.0961	1.0884	1.0809	1.0718	1.0706	1.0719	1.0797	1.0901	1.0993	1.1074	1.1152	1.1234	1.1317	1.1355
35	6.80	1.0921	1.0847	1.0776	1.0689	1.0677	1.0689	1.0761	1.0859	1.0946	1.1022	1.1094	1.1171	1.1249	1.1285
36	7.00	1.0888	1.0821	1.0756	1.0676	1.0665	1.0677	1.0745	1.0836	1.0918	1.0990	1.1060	1.1134	1.1208	1.1242
37	7.20	1.0888	1.0823	1.0760	1.0684	1.0673	1.0684	1.0749	1.0837	1.0916	1.0987	1.1056	1.1130	1.1203	1.1237
38	7.40	1.0915	1.0852	1.0790	1.0714	1.0704	1.0715	1.0780	1.0866	1.0939	1.1000	1.1057	1.1115	1.1178	1.1206
39	7.60	1.0938	1.0875	1.0815	1.0741	1.0731	1.0743	1.0807	1.0890	1.0958	1.1011	1.1057	1.1103	1.1157	1.1181
40	7.80	1.0954	1.0894	1.0835	1.0763	1.0754	1.0765	1.0828	1.0908	1.0970	1.1016	1.1052	1.1087	1.1132	1.1153
41	8.00	1.0967	1.0908	1.0851	1.0782	1.0774	1.0785	1.0846	1.0921	1.0977	1.1014	1.1039	1.1062	1.1097	1.1113
42	8.20	1.0974	1.0918	1.0863	1.0797	1.0789	1.0799	1.0858	1.0929	1.0978	1.1006	1.1021	1.1032	1.1058	1.1069
43	8.40	1.0976	1.0922	1.0870	1.0806	1.0799	1.0809	1.0866	1.0932	1.0975	1.0995	1.1000	1.0999	1.1015	1.1023
44	8.60	1.0973	1.0921	1.0870	1.0809	1.0802	1.0813	1.0870	1.0933	1.0969	1.0977	1.0968	1.0949	1.0952	1.0954
45	8.80	1.0964	1.0917	1.0871	1.0815	1.0809	1.0818	1.0869	1.0928	1.0963	1.0975	1.0973	1.0964	1.0973	1.0977
46	9.00	1.0957	1.0917	1.0878	1.0832	1.0827	1.0837	1.0882	1.0937	1.0976	1.0999	1.1012	1.1022	1.1043	1.1053
47	9.20	1.0964	1.0927	1.0892	1.0854	1.0855	1.0871	1.0930	1.0996	1.1038	1.1058	1.1062	1.1060	1.1076	1.1083
48	9.40	1.1020	1.0974	1.0931	1.0883	1.0883	1.0900	1.0969	1.1045	1.1091	1.1109	1.1109	1.1098	1.1112	1.1118
49	9.60	1.1075	1.1025	1.0976	1.0922	1.0921	1.0939	1.1011	1.1090	1.1138	1.1155	1.1151	1.1137	1.1149	1.1154
50	9.80	1.1125	1.1072	1.1021	1.0963	1.0961	1.0979	1.1053	1.1133	1.1181	1.1197	1.1190	1.1173	1.1183	1.1188
51	10.00	1.1173	1.1116	1.1062	1.1000	1.0997	1.1014	1.1089	1.1172	1.1220	1.1235	1.1228	1.1209	1.1218	1.1222
52	10.20	1.1216	1.1157	1.1100	1.1034	1.1030	1.1047	1.1123	1.1206	1.1255	1.1271	1.1264	1.1246	1.1255	1.1260
53	10.40	1.1256	1.1194	1.1135	1.1065	1.1060	1.1076	1.1152	1.1235	1.1284	1.1300	1.1293	1.1275	1.1285	1.1289
54	10.60	1.1288	1.1225	1.1163	1.1090	1.1084	1.1100	1.1174	1.1258	1.1306	1.1322	1.1315	1.1297	1.1306	1.1311
55	10.80	1.1316	1.1251	1.1187	1.1111	1.1103	1.1118	1.1192	1.1275	1.1323	1.1338	1.1331	1.1313	1.1322	1.1326
56	11.00	1.1337	1.1270	1.1205	1.1126	1.1118	1.1132	1.1205	1.1287	1.1335	1.1349	1.1341	1.1322	1.1331	1.1335
57	11.20	1.1352	1.1283	1.1217	1.1136	1.1126	1.1140	1.1212	1.1295	1.1341	1.1354	1.1344	1.1323	1.1330	1.1334
58	11.40	1.1359	1.1289	1.1221	1.1138	1.1128	1.1141	1.1213	1.1295	1.1341	1.1352	1.1340	1.1316	1.1322	1.1324
59	11.60	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
60	11.80	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
61	12.00	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Top and bottom 5% of core excluded.