FRAMATOME ANP

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FRAMATOME ANP, Inc.

February 20, 2004
NRC:04:007

Document Control Desk
ATTN: Chief, Planning, Program and Management Support Branch
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Publication of BAW-10242(NP)(A), Revision 0, "Zero Power Physics Testing for B&W Reactors"

Ref.: 1. Letter, Herbert N. Berkow (NRC) to James F. Mallay (Framatome ANP), "Safety Evaluation for Framatome ANP Topical Report BAW-10242 (NP), Revision 0, 'Zero Power Physics Testing for B&W Reactors' (TAC No. MB 9977)," November 6, 2003.

In Reference 1, the NRC accepted topical report BAW-10242(NP), Revision 0, "Zero Power Physics Testing for B&W Reactors," for referencing in license applications and requested that Framatome ANP publish an accepted version of the report. The "A" version of the report is enclosed.

The published report is constructed in accordance with procedures established in NUREG-0390.

Very truly yours,

James F. Mallay /sm

James F. Mallay, Director
Regulatory Affairs

Enclosure

cc: D. G. Holland
Project 728

T010
4601

FRAMATOME ANP

BAW-10242(NP)-A
Revision 0

ZPPT Modifications for B&W Designed Reactors

November 2003

Framatome ANP, Inc.

Non-Proprietary

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

November 6, 2003

Mr. James F. Mallay
Director, Regulatory Affairs
Framatome ANP
3815 Old Forest Road
Lynchburg, VA 24501

SUBJECT: SAFETY EVALUATION FOR FRAMATOME ANP TOPICAL REPORT BAW-10242(NP), REVISION 0, "ZERO POWER PHYSICS TESTING FOR B&W REACTORS" (TAC NO. MB9977)

Dear Mr. Mallay:

By letter dated July 11, 2003, Framatome ANP submitted Topical Report (TR) BAW-10242(NP), Revision 0, "Zero Power Physics Testing for B&W Reactors," to the NRC staff for review and approval. The staff has completed its review of the subject TR. A draft safety evaluation (SE) was issued for your factual verification on November 4, 2003. By e-mail dated November 4, 2003, you provided comments to the NRC staff. However, because these comments were not based on factual errors, the staff did not incorporate them into the enclosed SE.

The TR is acceptable for referencing in licensing applications for B&W-designed reactors to the extent specified and under the limitations delineated in the TR and in the associated NRC SE. The SE defines the basis for acceptance of the report.

We do not intend to repeat our review of the matters described in the subject TR and found acceptable, when the report appears as a reference in license applications, except to ensure that the material presented applies to the specific plant involved. Our acceptance applies only to matters approved in the subject TR. License amendment requests that deviate from this TR will be subject to a plant-specific review in accordance with applicable review standards.

In accordance with the guidance provided on the NRC website, we request that Framatome ANP publish an accepted version of this TR within three months of receipt of this letter. The accepted version shall incorporate (1) this letter and the enclosed SE between the title page and the abstract, (2) all requests for additional information from the staff and all associated responses, and (3) a "-A" (designated accepted) following the report identification symbol.

Should our criteria or regulations change so that our conclusions as to the acceptability of the TR are invalidated, Framatome ANP and/or the applicant referencing the TR will be expected to revise and resubmit its respective documentation, or submit justification for the continued applicability of the TR without revision of their respective documentation.

Sincerely,

Herbert N. Berkow

Herbert N. Berkow, Director
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Project No. 728

Enclosure: Safety Evaluation

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

BAW-10242(NP), REVISION 0, "ZERO POWER PHYSICS TESTING FOR B&W REACTORS"

FRAMATOME ANP

PROJECT NO. 728

1.0 INTRODUCTION

By letter dated July 11, 2003, Framatome ANP (FANP) submitted Topical Report (TR) BAW-10242(NP), Revision 0, "Zero Power Physics Testing for B&W Reactors," and requested staff review of modified zero power physics testing at cycle startup (Reference 1). Supplemental information was also submitted on September 23, 2003 (Reference 2).

Zero power physics testing (ZPPT) is required for PWRs following completion of a refueling outage. The required testing involves a number of tests performed at zero (very low) power prior to power escalation. The purpose of the testing is to determine that the operating characteristics of the core are consistent with the design predictions and to assure that the core can operate as designed. Successful completion of the testing is demonstrated when measured key physics parameters are within predetermined uncertainties.

Part of the ZPPT requires the measurement of "control" rod reactivity worth. Babcock & Wilcox (B&W) reactors have three "control" rod groups (CRGs): 5, 6 and 7, which are used to maintain reactivity control and core flux shaping. Rod groups 1-4 are considered "shutdown" rod groups, as they are fully withdrawn during normal operation and are used for negative reactivity insertion.

Licensees are currently measuring the reactivity worth of CRGs (5-7) using the boron dilution method as described in Regulatory Guide (RG) 1.68, "Initial Test Programs for Water-Cooled Nuclear Power Plants." In the TR, FANP proposes to modify the ZPPT program for B&W reactors by forgoing the testing (reactivity worth measurement) of CRG 5, so that testing is only required for CRGs 6 and 7. Other changes are also listed in the TR, but those are all variations of existing test programs, and therefore, do not require NRC approval. This safety evaluation (SE) is limited to only assessing the safety significance and justification of removing CRG 5 from the boron dilution test.

2.0 REGULATORY EVALUATION

There are no specific regulatory requirements for conducting startup physics tests. However, the staff adopted the scope and objectives of the ANS/ANSI-19.6.1 Standard, "Reload Startup Physics Tests for Pressurized Water Reactors," which defines the acceptance criteria for CRG worth measurement (Reference 3). This standard specifies the content of the minimum acceptable startup physics test program for commercial pressurized water reactors and describes acceptable methods for performing individual tests. (Note: RG 1.68 provides guidance for initial plant startup, but not during reload. Also, General Design Criterion 1 requires testing, but is not specific on the method).

3.0 TECHNICAL EVALUATION

In B&W reactors, the core distribution of the "control" rod groups (located mainly in the peripheral assemblies) suggests their low reactivity worth, which suits their role for reactivity control and core flux shaping. "Shutdown" rod groups on the other hand, are high in reactivity worth and their distribution is mainly towards the center part of the core. CRG 5 for the B&W reactors is located at the core's outer periphery, and consists of 12 control rods (versus 8 for CRGs 6 and 7). Because of its high reactivity worth, however, FANP states that CRG 5 has rarely been used for "control" in B&W reactors, and in actual practice, has been used essentially as a "shutdown" rod group. For this reason, the applicant requests to discontinue the reactivity worth measurement of CRG 5, as doing so would reduce the ZPPT time and increase the efficiency of post-refueling activities.

ANSI-19.6.1 Standard states: "Prior to return to normal operation, successful execution of a physics test program is required to determine . . . that the core can be operated as designed." The measurement of "control" rod worth is an important verification of shutdown margin and overall power distribution; it is also a check of the computer code results for predicted rod worth. In recent reload history, reload errors for B&W reactors have decreased overall. Reload errors basically distort flux (and power) distribution, and in turn affect the CRG worth. The ANSI Standard lists 15 percent ((Calculated-Measured)/Measured)x100 as the test acceptance criterion for the allowable percent deviation of an individual CRG's worth measurement. In the TR, FANP provided 3-5 cycles of data for each B&W plant and their CRG deviations, demonstrating that the predicted worth is within a few percent of the calculated value. The largest deviations were listed for CRG 5, but individual CRG deviations and the mean values are within the ANSI Standard test criterion of 15 percent. In addition, FANP demonstrated in this data analysis that total CRG worth percent deviations would be nearly identical if only CRGs 6 and 7 are measured versus the current practice of measuring CRGs 5, 6, and 7. FANP also stated that the current practice at B&W plants is to keep CRG 5 fully withdrawn during operation, essentially making it a "shutdown" rod group by use. The staff concludes from the results above that CRG 5 can be used as either a "control" or "shutdown" rod group in B&W reactors.

In addition, FANP suggests that flux distribution anomalies and reload errors can be better monitored and accounted for at power using core power distribution testing rather than during the ZPPT. This point was illustrated by FANP in Reference 2 for the case of an uncoupled (unlatched) rod in CRG 5, where the ZPPT program did not reveal an uncoupled rod through measuring CRG 5 worth. Instead of having to rely on reactivity measurements during the ZPPT, B&W reactors are equipped with fixed incore detectors and associated on-line computing software to measure and record core power distribution (and perform flux symmetry evaluations) at five power levels during power ascent. In the case highlighted by FANP, an unlatched assembly in CRG 5 was not detected during zero power measurement because the differential worth was within uncertainty limits; the anomaly was eventually revealed during the power escalation sequence through power distribution monitoring instead. From the analysis above, the staff concludes that the verification of shutdown margin and overall power distribution can be accomplished in B&W reactors through core power distribution testing at power just as reliably as through boron dilution reactivity measurements.

Finally, although FANP requested to eliminate CRG 5 from startup testing, it is seeking to retain measurements following the introduction of new control rod assemblies and during reload startup tests where any rod worth acceptance criteria has failed. This is a conservative and prudent provision and is acceptable.

The discussion presented by FANP indicates that the scope and objectives of the ZPPT program's CRG reactivity worth measurements (as presented in the ANSI 19.6.1 Standard) will be fulfilled for B&W reactors through FANP's proposal. The reactivity measurement of CRGs 6 and 7, using boron dilution, will suffice instead of measuring all CRGs 5, 6 and 7, as FANP has demonstrated that the elimination of CRG 5 from the boron reactivity measurements does not diminish the effectiveness of the ZPPTs.

4.0 CONCLUSION

The staff has reviewed BAW-10242(NP), Revision 0, "Zero Power Physics Testing for B&W Reactors," and the supplemental information provided in Reference 2. The objective of the review was to establish that the scope and objectives of the ANSI 19.6.1 Standard for the ZPPT are not compromised with the proposed change to eliminate CRG 5 from the required reactivity worth measurement. The staff's conclusion, based on the reasoning above, is that CRG 5 is effectively a "shutdown" rod group in B&W reactors, and is not required to be measured for reactivity worth during ZPPT.

REFERENCES

1 Letter from J. F. Mallay, Framatome ANP to US Nuclear Regulatory Commission, "Request for Approval of BAW-10242(NP) Revision 0, 'Zero Power Physics Testing for B&W Reactors'," July 11, 2003.

2 Letter from J. F. Mallay, Framatome ANP to US Nuclear Regulatory Commission, "Response to Request for Additional Information - BAW-10242(NP), 'Zero Power Physics Testing for B&W Reactors'," September 23, 2003.

3 ANSI/ANS-19.6.1, American National Standard, "Reload Startup Physics Tests for Pressurized Water Reactors," 2002.

Principle Contributor: L. Lois

November 6, 2003

Nature of Changes

Item	Section(s) or Page(s)	Description and Justification
Rev. 0		Initial issue.

I. PURPOSE

The purpose of this report is twofold: (1) to describe the evaluations performed by Framatome ANP to justify a revised zero power physics testing program for Babcock & Wilcox (B&W) designed reactors, and (2) to gain NRC acceptance for the revised program.

Zero power physics testing (ZPPT) is required for PWRs following completion of a refueling outage. The required testing involves a number of tests performed at zero (very low) power prior to power escalation. Significantly reducing the time required to perform these tests will increase the efficiency of post-refueling activities, since ZPPT is performed on the critical path.

The ZPPT program and the reload physics startup program (including power escalation testing) are discussed herein. Framatome-ANP (FANP) specifically seeks approval for the change to the control rod worth testing (item (1) in Section II below). The remaining items are modifications to FANP's testing program which are already in practice at other operating U.S. PWRs and for which NRC approval is not required. These modifications are included herein for information only.

II. SUMMARY

Most of the modifications to the ZPPT program for B&W-designed reactors outlined herein are minor changes to the current scope of testing. These changes consist of modifications to test techniques and approaches that result in gathering the same data as the previous ZPPT program. NRC approval is sought for item (1) below. The remaining items are modifications to FANP's testing program which are included herein for information only. The changes are as follows:

1) The measurement of Control Rod Groups (CRGs) 5, 6, and 7 to determine worth has been changed to measure only CRGs 6 and 7. This change is discussed in Section III. A. NRC approval is sought for this modification.

2) The all rods out critical boron concentration (AROCBC) test has been changed from 100 percent withdrawal of CRG 7 to a minimum of 80 percent withdrawal. This change is discussed in Section III. B.

3) The test for determining the all rods out temperature coefficient (α_T) has been changed to perform two reactor coolant system temperature changes. This change is discussed in Section III. C.

4) The differential boron worth (DBW) test has been changed as follows:

   - Boron equilibrium (between the RCS and pressurizer and between the RCS and the makeup tank) is no longer required following the completion of rod worth measurements.

- A measured DBW will be obtained by taking the ratio of the reactivity rate of change (from the reactivity computer) to the boron rate of change from measured boron samples at specific time intervals.

- The measured DBW results will be considered information only.

These changes are discussed in Section III. D.

III. DETAILED TEST DESCRIPTIONS AND JUSTIFICATION FOR REVISED TESTING PROCEDURE

The purpose of this section is to describe the evaluations performed by FANP to justify a revised ZPPT Program for B&W-designed Reactors.

A. CRG Worths

FANP proposes that only CRGs 6 and 7 be measured for worth rather than CRGs 5, 6, and 7.

The primary reason for discontinuing the measurement of CRG 5 is that present-day physics codes for predicted CRG worth have demonstrated the ability to calculate individual CRG worth. Table 1 contains comparisons of measured CRG worths to predicted values for recent startups for B&W-designed reactors. The measured worths are determined using the boron swap (boron dilution) method. The acceptance criterion for the allowable % deviation ({Pred – Meas} / Pred * 100 %) for an individual CRG is $\pm$15%. Table 1 demonstrates the accuracy of the CRG worth calculations.

Table 2 shows that "total" CRG worth % deviations (the differences compared to predicted for the sum of all measured CRGs) would be nearly identical if only CRGS 6 and 7 are measured versus the current practice of measuring CRGs 5, 6, and 7.

Below are additional justifications for this change:

1) The ANS 19.6.1 Standard distinguishes between "control rod groups" and "safety groups" based on normal practice. While CRG 5 is still considered a control rod group, CRG 5 is very rarely inserted during normal power operations, such that it is essentially a safety group.

2) Control rod worth testing is performed to assess whether or not the core is operating as designed – not to measure the worth of every control rod. The assessment that the core is operating as designed (and that shutdown margin-related acceptance criteria can be met) can be accomplished by measuring CRGs 6 and 7 as accurately as the determination can be made by measuring CRGs 5, 6, and 7.

3) The presence of the fixed incore detector system at the B&W-designed reactors and associated on-line computing software determines the presence of unlatched control rods (or other potential core anomalies) at low power levels. The measured power distribution is provided as low as 8 %FP at six-minute intervals at B&W-designed reactors. These power distribution measurements are continuously available at a low power level for the B&W-designed reactors.

4) The ANS 19.6.1 Standard states that the rods measured should be "radially representative" of the core. CRG 5 locations are in close enough proximity to the CRG 6 and 7 locations such that significant additional information relative to the zero-power power distribution is not acquired by measuring CRG 5 worth, as illustrated by Figures 1 and 2.

5) From a shutdown margin perspective, measuring just two groups by dilution is consistent with how the rods are inserted during normal plant operation Measuring control rod worth for each reload is to verify the uncertainty used in the cycle-specific shutdown margin analyses, it follows that a more direct verification of this uncertainty is obtained by measuring rod worth by dilution – even if only two CRGs are measured.

6) Also, from a shutdown margin and operations perspective, measuring CRG 5 worth by dilution usually means that Technical Specification MODE 2 Physics Test Exceptions are declared to allow for CRG 4 (safety group) insertion to account for possible over-dilution. Additionally, having the reactor critical with all the CRGs (CRGs 5-7) inserted, places the core in a configuration where the maximum ejected rod worth exists. Therefore, eliminating the CRG 5 worth measurement will result in the operational convenience of not declaring a MODE 2 Physics Test Exception and will result in less probability for a limiting reactivity insertion accident.

7) Since the test criteria are not altered to reflect the smaller sample size, measuring fewer control rods provides a more severe test of neutronics models underlying the predictive and engineering analysis of the core.

NOTE 1:

Reference 2 documents the NRC acceptance of as low as a 5% uncertainty when using the approved NEMO code (Reference 3) to calculate the total rod worth. Testing during the startup of each reload cycle confirms the validity of this uncertainty. Measuring one less CRG does not impact the conclusions reached in that document.

NOTE 2:

The rod worth evaluations herein were performed using predicted data from both the NEMO and SIMULATE-3 nodal codes. Both codes have been approved for reload licensing calculations. They utilize similar advanced nodal methods to determine the core reactivity and power distribution. Differences in cross section treatment have been verified to be accurate for each code system. Some examples of equivalent rod worth results are provided in Table 4. The results of this analysis are valid for predicted data calculated from either the NEMO or SIMULATE-3 nodal code, or any other code used in the future that has been adequately benchmarked (to the level demonstrated herein) and approved for use in the reload design process by the NRC.

Table 1
Individual Group Worth Comparisons

Plant	Cycle	Group 7 Worth (pcm)			Group 6 Worth (pcm)			Group 5 Worth (pcm)			Total		
		Predicted	Measured	% Dev	Predicted	Measured	% Dev	Predicted	Measured	% Dev	Predicted	Measured	% Dev
Crystal River 3	10	891	943.5	-5.9	864	832.7	3.6	1399	1522.4	-8.8	3154	3298.5	-4.6
	11	885	907.1	-2.5	845	867.3	-2.6	1309	1338.5	-2.3	3039	3112.9	-2.4
	12	918	958.6	-4.4	843	812.5	3.6	1475	1470.6	0.3	3236	3241.6	-0.2
	13	875	873.1	0.2	976	956.6	2.0	1248	1192.2	4.5	3099	3021.9	2.5
Davis Besse	10	1114	1101.2	1.1	717	719.0	-0.3	1554	1565.2	-0.7	3385	3385.4	0.0
	11	860	894.4	-4.0	768	740.5	3.6	1258	1356.3	-7.8	2886	2991.3	-3.6
	12	830	856.9	-3.2	807	796.8	1.3	1314	1378.8	-4.9	2951	3032.5	-2.8
	13	795	830.3	-4.4	913	921.6	-0.9	1173	1197.8	-2.1	2881	2949.7	-2.4
ANO-1	15	851	869.8	-2.2	894	890.3	0.4	1625	1543.2	5.0	3370	3303.3	2.0
	16	861	875.1	-1.6	881	868.1	1.5	1364	1293.1	5.2	3106	3036.2	2.2
	17	913	935.5	-2.5	825	841.7	-2.0	1409	1351.2	4.1	3147	3128.4	0.6
TMI-1	10	952	956.0	-0.4	735	713.0	3.0	1377	1400.0	-1.7	3064	3069.0	-0.2
	11	1023	1078.5	-5.4	812	807.5	0.6	1188	1219.5	-2.7	3023	3105.5	-2.7
	12	881	909.8	-3.3	754	741.9	1.6	1227	1263.0	-2.9	2862	2914.6	-1.8
	13	901	934.1	-3.7	853	868.2	-1.8	1486	1499.6	-0.9	3240	3301.9	-1.9
	14	951	1000.8	-5.2	870	825.3	5.1	1166	1160.3	0.5	2987	2986.4	0.0
Oconee 1	17	841	868.7	-3.3	932	941.2	-1.0	1139	1192.3	-4.7	2912	3002.2	-3.1
	18	902	933.9	-3.5	950	950.7	-0.1	1093	1173.1	-7.3	2945	3057.7	-3.8
	19	763	819.7	-7.4	905	897.3	0.9	1178	1242.2	-5.4	2846	2959.1	-4.0
	20	808	843.7	-4.4	846	860.7	-1.7	1094	1206.6	-10.3	2748	2910.9	-5.9
Oconee 2	16	871	925.6	-6.3	790	818.0	-3.5	1350	1465.3	-8.5	3011	3208.9	-6.6
	17	797	840.5	-5.5	745	800.2	-7.4	1248	1289.8	-3.3	2790	2930.5	-5.0
	18	776	830.0	-7.0	794	805.9	-1.5	1222	1306.6	-6.9	2792	2942.5	-5.4
	19	859	878.4	-2.3	779	843.1	-8.2	1267	1348.4	-6.4	2905	3069.9	-5.7
Oconee 3	16	800	806.9	-0.9	873	883.3	-1.2	1255	1302.6	-3.8	2928	2992.8	-2.2
	17	881	898.0	-1.9	877	898.0	-2.4	1428	1445.0	-1.2	3186	3241.0	-1.7
	18	896	907.2	-1.2	798	785.9	1.5	1150	1178.3	-2.5	2844	2871.4	-1.0
	19	927	973.4	-5.0	912	936.8	-2.7	1218	1360.6	-11.7	3057	3270.8	-7.0

%Dev = (Pred – Meas) / Pred * 100

Table 2
Groups 6 and 7 Combined Comparisons

Plant	Cycle	Total %Dev	Grp 7 + Grp 6 %Dev
Crystal River 3	10	-4.6	-1.2
	11	-2.4	-2.6
	12	-0.2	-0.6
	13	2.5	1.1
Davis Besse	10	0.0	0.6
	11	-3.6	-0.4
	12	-2.8	-1.0
	13	-2.4	-2.6
ANO-1	15	2.0	-0.9
	16	2.2	-0.1
	17	0.6	-2.3
TMI-1	10	-0.2	1.1
	11	-2.7	-2.8
	12	-1.8	-1.0
	13	-1.9	-2.8
	14	0.0	-0.3
Oconee 1	17	-3.1	-2.1
	18	-3.8	-1.8
	19	-4.0	-2.9
	20	-5.9	-3.0
Oconee 2	16	-6.6	-5.0
	17	-5.0	-6.4
	18	-5.4	-4.2
	19	-5.7	-5.1
Oconee 3	16	-2.2	-1.0
	17	-1.7	-2.2
	18	-1.0	0.1
	19	-7.0	-3.9

Table 3
CRG 7 Worth from 60 to 100 %WD

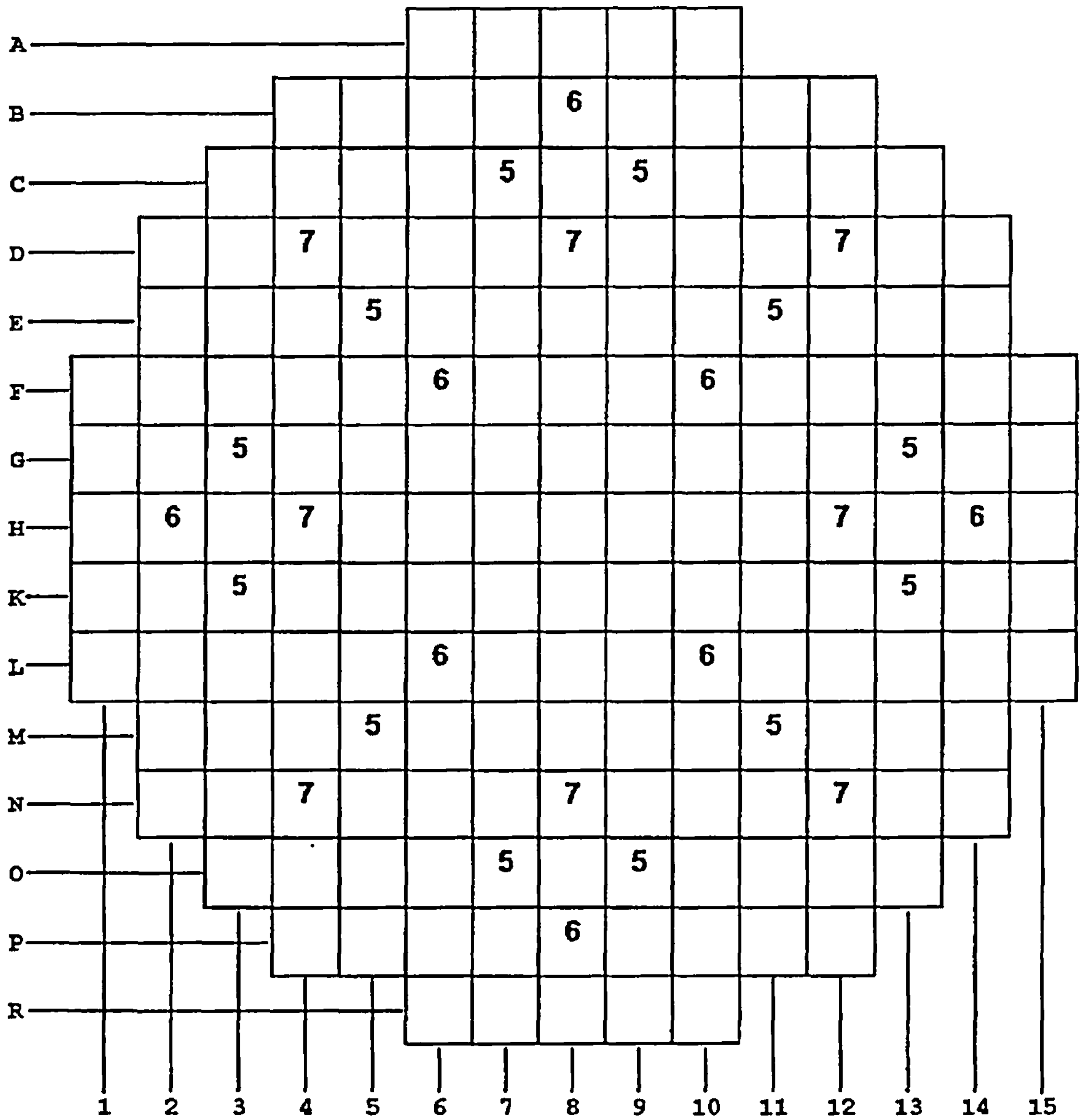
Plant	Cycle	Group 7 (60 to 100)		
		Predicted	Measured	% Dev
Crystal River 3	10	244	355.6	-45.7
	11	261	362.0	-38.7
	12	274	382.3	-39.5
	13	295	291.0	1.3
Davis Besse	10	290	319.9	-10.3
	11	277	283.7	-2.4
	12	288	323.0	-12.2
	13	285	303.8	-6.6
ANO-1	15	316	339.0	-7.3
	16	326	341.3	-4.7
	17	329	366.7	-11.5
TMI-1	10	265	302.4	-14.1
	11	314	382.1	-21.7
	12	310	311.4	-0.4
	13	359	387.0	-7.8
	14	345	368.7	-6.9
Oconee 1	17	290	258.8	10.7
	18	277	288.0	-4.0
	19	265	287.6	-8.5
	20	279	271.7	2.6
Oconee 2	16	299	290.1	3.0
	17	275	247.7	9.9
	18	277	282.8	-2.1
	19	269	258.4	3.9
Oconee 3	16	257	225.2	12.4
	17	281	256.6	8.7
	18	253	244.2	3.5
	19	307	273.1	11.0

Avg	-6.2
Std Dev	14.3

Figure 1

Typical Control Rod Group Location in 177-FA Core

Full Core Layout – CRGs 5 & 6 & 7



Key:

X x – Control Rod Group Number

Figure 2

Typical Control Rod Group Location in 177-FA Core

Full Core Layout – CRGs 6 & 7

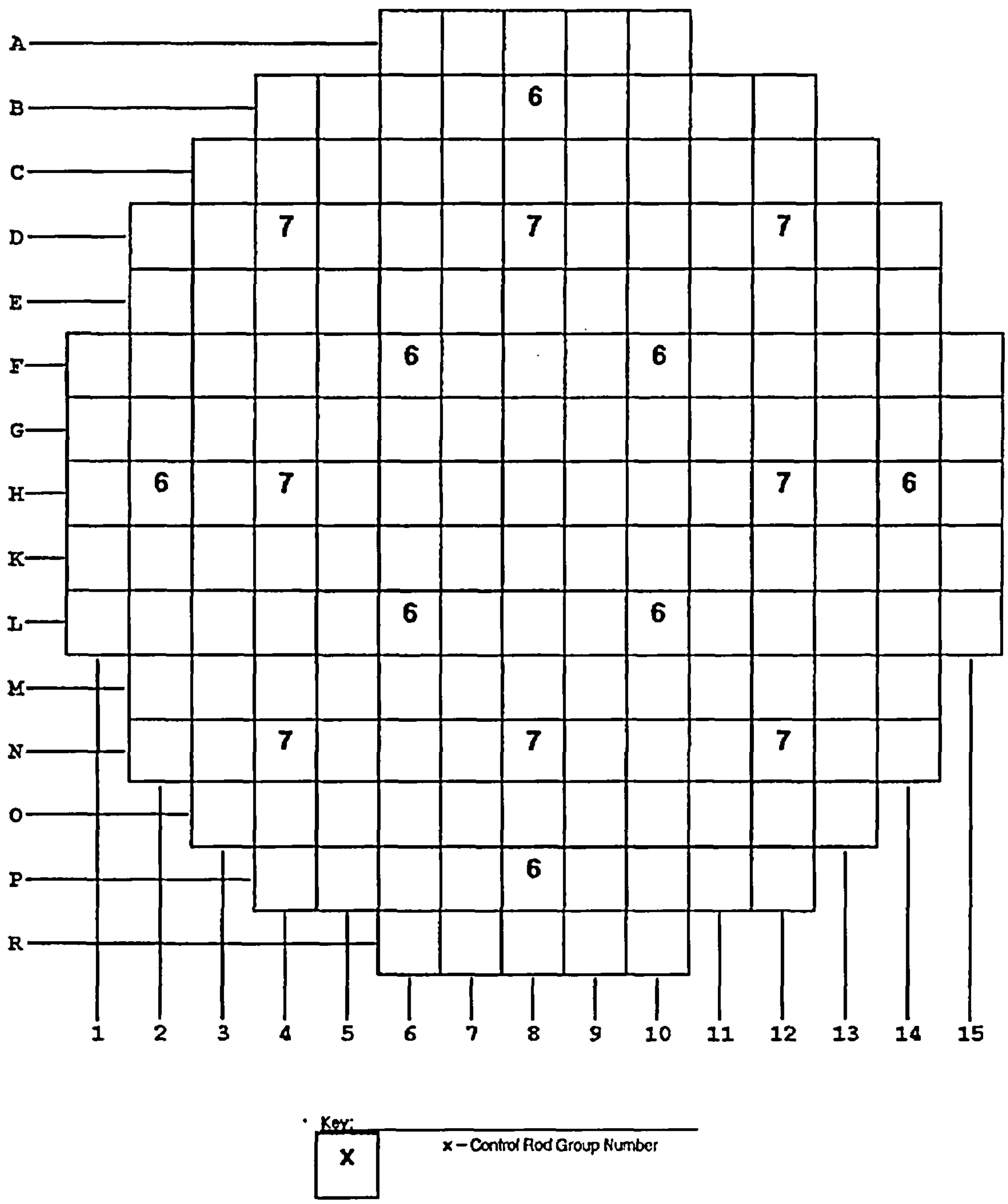


Table 4
NEMO vs SIMULATE Predicted Rod Worths

Plant	Cycle	Group 7 Worth (pcm)			Group 6 Worth (pcm)			Group 5 Worth (pcm)			Total		
		SIMULATE	NEMO	% Dev	SIMULATE	NEMO	% Dev	SIMULATE	NEMO	% Dev	SIMULATE	NEMO	% Dev
ANO-1	15	828	851	-2.8	860	894	-4.0	1584	1625	-2.6	3272	3370	-3.0
	16	835	861	-3.1	850	881	-3.6	1327	1364	-2.8	3012	3106	-3.1
	17	886	913	-3.0	795	825	-3.8	1358	1409	-3.8	3039	3147	-3.6
TMI-1	9	833	856	-2.8	889	822	7.5	1051	1117	-6.3	2773	2795	-0.8
	10	913	952	-4.3	708	735	-3.8	1318	1377	-4.5	2939	3064	-4.3
	11	996	1023	-2.7	791	812	-2.7	1155	1188	-2.9	2942	3023	-2.8
D-B	11	881	860	2.4	754	768	-1.9	1315	1258	4.3	2950	2886	2.2
	12	838	830	1.0	806	807	-0.1	1344	1314	2.2	2988	2951	1.2
	13	817	795	2.7	930	913	1.8	1194	1173	1.8	2941	2881	2.0
Oconee-1	20	808	823	-1.9	846	873	-3.2	1094	1083	1.0	2748	2779	-1.1
Oconee- 3	16	800	837	-4.6	873	905	-3.7	1255	1268	-1.0	2928	3010	-2.8

B. Critical Boron Concentration

The all rods out critical boron concentration (AROCBC) measures overall core reactivity. At a given rod configuration (near the all-regulating rods out condition), the boron concentration is measured and small corrections are made to correct to the ARO condition. The resulting measured ARO critical boron concentration is compared to a predicted value.

The primary correction made to correct to the ARO condition is the inserted rod worth of the lead control rod group (CRG). B&W plant owners have historically measured the inserted worth of CRG 7 to 100 %WD. Since the measurement is limited by the startup rate allowed and due to the uncertainty of obtaining critical conditions for a new core, there have been many instances where a boron adjustment was required to position CRG 7 closer to the ARO condition. The additional accuracy achieved by obtaining the critical configuration that would allow pulling CRG 7 to ARO is small and an inefficient use of time. To document this assertion, measured AROCBC values were determined for startups that had critical, equilibrium conditions present with a deeper CRG 7 position than desired.

The alternative (new method) AROCBC values were calculated using the following equation:

$$AROCBC\ (ppmB) = Boron_{RCS}\ (ppmB) + \left\{ \frac{Group\ 7\ Worth\ (pcm)}{Predicted\ DBW\ (pcm/ppmB)} \right\}$$

where

$Boron_{RCS}$	=	*RCS boron concentration measured by chemistry samples (equilibrium conditions)*
Group 7 Worth	=	*CRG 7 inserted bank worth (predicted value) based on CRG 7 position (%WD) at boron equilibrium*
Predicted DBW	=	*predicted value of DBW*

Alternate critical condition data for determining AROCBC values using the new method were obtained for 13 startups at B&W-designed reactors. The results are tabulated in Table 5 which demonstrates the adequacy of the new method. The difference between new method AROCBC values determined using predicted CRG 7 worth to correct to the ARO condition and the original AROCBC are negligible.

Table 5
Calculated AROCBC Data Using New Method

Plant	Cy	RCS Boron (ppmB)	Group 7 Position (%WD)	Group 7 Worth (pcm)	DBW (pcm /ppmB)	New Method AROCBC (ppmB)	Original Measured AROCBC (ppmB)	Delta (New Method -Measured) (ppmB)	Predicted AROCBC (ppmB)
TMI	6	1397	45	467.5	9.31	1447	1449	-2	1394
	7	1614	35	605.5	8.74	1683	1691*	-8	1636
	8	1806	56	351.2	7.93	1850	1846	4	1829
	10	2398	81	91	6.62	2412	2406	6	2449
	11	2249	61	304.6	6.54	2296	2295	1	2295
	12	2147	76	163	6.51	2172	2167	5	2195
	13	2134	72	230.6	6.41	2170	2176	-6	2164
CR-3	12	2269	70	179.5	6.43	2297	2299	-2	2297
Oco-1	20	1746	73	151	8.02	1765	1760	5	1760
Oco-2	15	1935	82	114	7.61	1950	1954	-4	1942
Oco-2	16	1984	62	276.4	7.42	2021	2015	6	2003
Oco-3	19	2026	65.6	243.7	7.08	2060	2064	-4	2108
ANO-1	17	2078	75	177.5	7.09	2103	2101	2	2129
						Average		0.58	
						Standard Deviation		4.89	

* A strong case can be made that measured AROCBC was actually 1687 ppmB. The "official" value is used here, but using 1687 would lower the delta to –4 ppmB.

Below are additional justifications for this change:

1) Industry experts (the current membership of ANS 19.6.1) have already endorsed this method and have incorporated this approach at several U.S. Utilities.

2) The approach adopted by B&W plants will typically involve using less than 100 pcm predicted worth, depending on where exact critical conditions are obtained. Table 5 supports corrections using predicted rod worth of greater than 200 pcm in several cases. Hence, the amount of rod worth correction using predicted data will be less for smaller values of CRG worth.

3) The primary contribution of measurement uncertainty for this parameter is the measurement uncertainty of the boron concentration. For most AROCBC measurements performed when the CRG 7 endpoint was measured, more than 99% of the measured AROCBC is determined from the chemistry sample. Similarly, for the revised technique, the percentage of the measured AROCBC that is still chemistry sample is 98 percent.

4) Predicted versus measured comparisons of the upper part of CRG 7 worth are depicted in Table 3. The average percent deviation for this dataset is –6.2 percent

(with a standard deviation of 14.3 percent). The data for CR-3 Cycles 10-12 and for TMI-1 Cycle 11 merit additional discussion. These measurements were taken for reload cycles that observed significant measured versus predicted imbalance differences in the previous fuel cycle. Computer simulations have shown that differences between measured and predicted offset at EOC explain the observed deviation.

To address any potential error with using predicted CRG 7 worth for the AROCBC determination, FANP will recommend that the original method for establishing critical, equilibrium conditions at a CRG 7 position such that the CRG 7 endpoint can be measured by pulling to 100 %WD (usually < 100 pcm) <u>if</u> the $\pm$ 50 ppm acceptance criterion for the test is being approached. This recommendation will take the following form:

<u>IF</u> predicted rod worth data is used to determine the measured AROCBC, <u>and</u> the difference between measured and predicted AROCBC is greater than $\pm$ 45 ppm, <u>then</u> a boron addition is initiated (if required) such that the endpoint correction consists entirely of measured CRG 7 data.

5) The endpoint correction for the AROCBC has always involved the use of predicted data. The use of the predicted DBW has always been the standard practice for this correction since the measured DBW was not available at the time of the AROCBC test. This approach is already being employed by several U.S. utilities.

C. Temperature Coefficient (α_T)

The test for determining the all rods out temperature coefficient (α_T) has been revised to perform two RCS temperature changes (decrease followed by increase, or increase followed by decrease) of 3-5 °F rather than the original +5/-10/+5 °F approach.

Section III. B. results in the possibility of performing the all rods out α_T test at a deeper CRG 7 position than before. The effects of performing this test with possibly deeper insertion of CRG 7 have been evaluated and determined to be negligible for CRG 7 positions greater than 55 percent withdrawn.

Below are additional justifications for this change:

1) ANS-19.6.1 for ZPPT (Reference 1) endorses the 3-5 °F decrease/increase method. Hence this method is widely employed in the industry by many utilities.

2) 3-5 °F decrease/increase method will provide two α_T values, which are averaged. No additional criterion is applied to the two measured values. For the previous approach measured α_T values were compared to the measured α_T value, and occasionally, the check criterion would not be satisfied. A re-test or lengthy evaluation process would

be required. Neither of these methods would significantly change the measured versus predicted result.

3) Heating up the RCS by 5 °F is inefficient.

D. Differential Boron Worth

The measured differential boron worth (DBW) value for B&W-designed reactors has been obtained during rod worth testing by dividing the measured rod worth (by dilution) by the difference between equilibrium boron samples before and after the rod worth measurements. The DBW test has been modified in the following manner:

Boron equilibrium (between the RCS and pressurizer and between the RCS and the makeup tank) is no longer required following the completion of rod worth measurements.

A measured DBW will be obtained by taking the ratio of the reactivity rate of change (from the reactivity computer) to the boron rate of change from measured boron samples at specific time intervals.

The measured DBW results will be considered information only. This change is consistent with previously approved exceptions to Reference 1 at other U.S. PWRs (Reference 4).

To justify this new approach, the database of DBW measurements at B&W-designed reactors was examined. The results in Table 6 based on using the revised method are comparable to the results from the original method and are more consistent with predicted values than the original method.

Table 6
Comparison of Measured DBW Values for Various Reactor Cycles

Plant	Cycle	Predicted DBW (pcm/ppmB)	Original Method		Revised Method	
			Meas. DBW (pcm/ppmB)	% Deviation	Meas. DBW (pcm/ppmB)	% Deviation
Davis-Besse	11	6.472	6.928	-7.05	6.590	-1.83
	12	6.572	7.015	-6.74	6.399	2.64
	13	6.373	6.683	-4.86	6.283	1.42
Arkansas Nuclear One – Unit 1	16	7.206	7.508	-4.19	7.425	-3.04
	17	7.088	7.461	-5.26	7.082	0.08
Crystal River Unit 3	10	6.774	7.441	-9.85	6.811	-0.54
	11	6.439	6.950	-7.94	6.403	0.55
	12	6.433	7.054	-9.65	6.506	-1.13
	13	6.497	6.923	-6.56	6.157	5.23
Three Mile Island Unit 1	11	6.543	6.927	-5.87	6.212	5.06
	12	6.510	6.754	-3.75	6.105	6.22
	13	6.414	6.449	-0.55	6.088	5.08
	14	6.342	6.431	-1.40	5.631	11.20
			Average	-5.67	Average	2.38
			Std. Dev.	2.79	Std. Dev.	4.01

IV. ADDITIONAL CONSIDERATIONS

Cases Where CRG 5 Worth Will Be Measured

FANP recommends that B&W-designed plants measure CRG 5 worth during reload physics testing for the first fuel cycle following the introduction of new control rod assemblies for CRG 5.

FANP recommends that B&W-designed plants measure CRG 5 worth during reload startup physics testing if any of the rod worth acceptance criteria are failed.

Startup Testing

The entire FANP recommended reload startup physics testing program is presented in this section to demonstrate the continued commitment that licensees of B&W-designed reactors have in verifying that their reload cores are operating as designed.

The purpose of the design analyses of the reload cycle is to ensure that the reference safety analyses remain applicable. The nuclear design analyses are based on modeling the core characteristics using the approved methods, procedures, and computer calculations described in Reference 5. The results of the design analyses show that bounding peaking distributions and bounding nuclear parameters are within the criteria required by the safety analyses. However, there remains an uncertainty related to the accuracy of the design calculations and modeling of the reload cycle characteristics relative to actual measurements. Reload startup physics testing is performed following refueling outages to verify that the core is operating as designed.

The previous cycle design predictions are benchmarked to startup test measurements, and core-follow calculations of the power distributions are also benchmarked to measured data. The previous cycle is the reference cycle for the reload core design. If there are no design changes or changes to the manufacturing specifications, then the conclusion could be reached that the design calculations are completely satisfactory to ensure that the safety parameters have been accurately analyzed. This conclusion is further supported by the topical reports on the computer codes, methods and procedures, and uncertainties, which have shown that the design analyses are sufficiently accurate.

However, prudence suggests that some amount of startup physics testing is important to ensure that the safety evaluations are valid. A small probability exists that the calculations will have larger-than-expected deviations simply because the calculational accuracy was established statistically. Also, a small probability exists that loading or manufacturing deviations may occur. Thus, a startup testing program is part of the reload evaluation process for the nuclear analysis.

Acceptance Criteria

The previous subsections in this nuclear design section have discussed the methodology for performing design analyses to ensure that the characteristics of a reload cycle are bounded by the reference safety analyses. The methodology referenced the calculational codes, models, and procedures that are used to determine the nuclear parameters. The same calculational codes, models, and procedures must be revalidated during the startup of each reload cycle by performing a minimum amount of startup physics tests which compare the resulting measured values to calculational predictions. Design calculations, using the calculational codes, models, and procedures that were used to verify that the nuclear parameters are bounded by the reference safety analyses, shall model startup conditions to produce predictions that can be compared to measurements.

Startup testing requirements should meet the requirements of ANS 19.6.1 (Reference 1). The standard startup physics testing scope for B&W-designed plants complies with ANS 19.6.1 (Reference 1) with the following exceptions:

1) Reference 1 specifies that if the boron dilution method for determining HZP measured rod worth is employed, then measurement of all control rod groups, or at least 3000 pcm is required. Reference 1 also specifies measurement of the entire CRG worth (over the entire range of travel). FANP has justified a ZPPT program that includes measurement of only CRG 7 (partial – at least 80% of the worth of CRG 7 is measured) and CRG 6. This is typically at least 1500 pcm.

2) Reference 1 suggests (the appropriate specification is contained in the Appendix, which is technically not part of the Standard) that the endpoint worth for CRG 7 is measured for the boron equivalent correction to the measured all rods out critical boron concentration (AROCBC). FANP has justified that up to 200 pcm predicted worth can be used for this correction.

3) Reference 1 requires a measured differential boron worth and application of a test criterion to a comparison of measured to predicted values. FANP has developed a modified differential boron worth measurement technique not included in the Appendix of Reference 1. Rather than eliminate the measurement of differential boron worth entirely, this new technique is employed with the results as information only (no test criterion is applied).

The current minimum scope of reload startup physics testing for B&W-designed plants is contained in Table 7.

Table 7
Reload Startup Physics Testing for B&W-Designed Plants

Test	Test Criterion	Notes
All Rods Out Critical Boron Concentration	± 50 ppm – Acceptance (Predicted – Measured) ± 45 ppm – Review*	Up to 200 pcm predicted worth of CRG 7 allowed for endpoint correction. * - Only applied if predicted worth is used.
Isothermal Temperature Coefficient	± 2 pcm/°F (Predicted – Measured)	
Moderator Temperature Coefficient	< Tech Spec Limit	Measured MTC inferred from measured ITC by application of predicted Doppler coefficient.
Individual CRG Worths	± 15 % % dev = {(P–M) / P}x 100%	At least 80 % of CRG 7 and all of CRG 6.
Total CRG Worth	± X % % dev = {(P–M) / P}x 100%	X = Shutdown margin related uncertainty on rod worth – always between 5-10%, depending on fuel cycle.
Differential Boron Worth	No criterion applied	Ratio of measured rod worth to measured boron differences during CRG worth measurements.
Flux Symmetry Test	| Tilt | < full power limit. Symmetric incore detector readings within ± 10 %	Both of these criteria are considered "review criteria". Evaluation should be accomplished before physics testing is performed at a higher power level.
Intermediate Power Level Core Power Distribution	Several specific acceptance criteria apply, including the criteria in Reference 1	Between 40-80 %FP
HFP AROCBC	± 50 ppm	Difference between the HZP AROCBC P – M delta and the HFP AROCBC P – M delta.
HFP Core Power Distribution	Several specific acceptance criteria apply, including the criteria in Ref. 1	Between 90-100 %FP

V. CONCLUSIONS

This report documents the technical evaluations performed to justify a revised ZPPT program for B&W-designed reactors. The resulting revised ZPPT program will significantly reduce ZPPT time for future reload fuel cycles at B&W-designed reactors while obtaining equivalent information as the previous ZPPT program.

VI. REFERENCES

1. "Reload Startup Physics Tests for Pressurized Water Reactors", ANS-19.6.1-1997, American Nuclear Society.

2. NRC Letter Robert Jones to J.H. Taylor, "Acceptance of Revised Measurement Uncertainty for Control Rod Worth Calculations", January 26, 1996.

3. BAW-10180-A Rev. 1, "NEMO Nodal Expansion Method Optimized", B&W Fuel Company, Lynchburg, Virginia, March, 1993.

4. USNRC Letter L Raghavan to Harold B. Ray, "San Onofre....Low Power Physics Testing Methodology", October 10, 2000.

5. BAW-10179P Rev. 4, "Safety Criteria And Methodology For Acceptable Cycle Reload Analyses, Framatome-ANP, Lynchburg, Virginia, August, 2001.

Appendix A to BAW-10242(NP)

Response to NRC Request for Additional Information

FRAMATOME ANP

An AREVA and Siemens company

FRAMATOME ANP, Inc.

September 23, 2003
NRC:03:064

Document Control Desk
ATTN: Chief, Planning, Program and Management Support Branch
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Response to Request for Additional Information – BAW-10242(NP), "Zero Power Physics Testing for B&W Reactors" (TAC No. MB9977)

Ref.: 1. Letter, Drew Holland (NRC) to James Mallay (Framatome ANP), "Request for Additional Information – BAW-10242(NP), 'Zero Power Physics Testing for B&W Reactors' (TAC No. MB9977)," August 25, 2003.

In the above referenced letter, the NRC requested additional information to facilitate the completion of its review of the Framatome ANP, Inc. topical report BAW-10242(NP), "Zero Power Physics Testing for B&W Reactors." The response to this request is contained in the attachment to this letter.

The timely completion of the review of this topical report is important because TMI Unit 1 has an opportunity to utilize the results of this topical report in the preparation and planning of the zero power physics test program for startup from the upcoming refueling outage T1R15 (Fall 2003).

Very truly yours,

Jerald S Holm for

James F. Mallay, Director
Regulatory Affairs

Enclosure

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Attachment A
Request for Additional Information on Topical Report
BAW-10242(NP), "Zero Power Physics Testing for B&W Reactors"

Regarding the request to eliminate CRG5 from the boron dilution measurement, the NRC staff notes that there are no formal regulatory requirements for the performance of the startup physics tests. In the past, the staff adopted the relevant ANS standards (in this case ANS 19.6.1) or Regulatory Guides (such as RG 1.68) in lieu of regulations.

The staff notes that both versions of ANS-19.6.1 (the current and the proposed revision) clearly state that: "The Standard specifies the minimum acceptable startup reactor physics program (underline added) and acceptable test methods..." to which FANP and the NRC staff have concurred.

The staff also notes that BAW-10242(NP) states, "...present-day-physics codes for predicted CRG worth have demonstrated the ability to calculate individual CRG worth." However, the purpose of the physics tests is not to test the computer codes, rather it is to assure that human or other types of errors did not distort the computer predictions.

Your submittal makes the additional argument that CRG5 is rarely used as a CRG. This essentially delegates CRG5 to the shutdown group of rod clusters. However, the distribution of the CRG5 rods into the core is clearly the same as 6 and 7, i.e., has the characteristics of the CRG.

The staff understands that the reason for the request is to cut down on the time required to perform the CRG boron dilution measurement.

In view of the above, please respond to the following questions.

Question 1: *What is the basis for requesting the change?*

Response 1: Framatome ANP is requesting the change based on the collective study by the B&W-designed plant owners and our staff regarding the appropriate balance between collecting sufficient data during post-refueling zero power physics testing to determine if the core is operating as designed and collecting this data efficiently. Based on several factors (contained in BAW-10242), we have concluded that the measurement of CRG5 by boron dilution provides little added information to the overall purpose of the test program versus the time spent gathering the measured data.

The measurement of rod worth has long been viewed as an important check on what the computer code results are for predicted rod worth, since predicted rod worth is an important component of shutdown margin.

The NRC makes the following statement in the introductory remarks to the questions on BAW-10242(NP):

> "However, the purpose of the physics tests is not to test the computer codes rather it is to assure that human or other types of errors did not distort the computer predictions."

The first paragraph of the ANSI-19.6.1 Standard states:

> "In conjunction with each refueling shutdown or other significant reactor core alteration, nuclear design calculations are performed to ensure that the reactor physics characteristics of the new core will be consistent with the safety limits. Prior to return to normal operation, successful execution of a physics test program is required to determine if the operating characteristics of the core are consistent with the design predictions and to ensure that the core can be **operated as designed**." (Emphasis added.)

Since reload cores are designed using computer codes, the purpose of physics testing is larger than looking for as-loaded core errors. The identification of core loading errors could be accomplished exclusively with power escalation testing (since power escalation testing, particularly core power distribution verification, is the best method of detecting these errors).

The Framatome ANP recommendations for post-refueling power escalation testing for B&W-designed reactors take advantage of the fixed incore detector system and associated core monitoring software that exist at each of these plants. An outline of the typical B&W-plant post-refueling power escalation test sequence is as follows:

- 10-15% Full Power (FP) – Incore detector checkout, preliminary core power distribution comparisons, begin core symmetry evaluations
- 15-40% FP – Continued power distribution comparisons, core symmetry evaluations
- 40-80% FP – Official core power distribution test
- 80-100% FP – Continued power distribution monitoring
- 100% FP – Official, full power core power distribution test

The core power distribution testing performed at B&W-designed plants during the post-refueling startup sequence is very thorough, going far beyond the minimum requirements set forth in ANSI-19.6.1. Some examples of additional criteria and/or conditions (beyond those imposed by ANSI-19.6.1) imposed by the power escalation testing for B&W-designed plants are:

- Core symmetry requirements revaluated at 10-15% FP
- Preliminary core power distribution evaluations begin at 10-15% FP
- Absolute values of quadrant power tilts are compared to the full power tilt limit
- Measured linear heat rate values are compared to the appropriate LOCA initial-condition based limits
- 95/95 tolerance-based acceptance limits for allowed peaking deviation are applied for EACH fresh fuel location for official core power distribution testing
- Segment peaking factors are examined in addition to radial (assembly) peaking factors

The final, conclusive evidence on determining if a core loading error based on human error or other mechanical problem is present will always be provided by the core power distribution results.

Therefore, a very important component for the request to measure less rod worth by dilution for B&W-designed reactors is that the results obtained from the very thorough power distribution testing that is performed at these units are more reliable, more valid, and more conclusive in revealing as-loaded core anomalies.

Another point not specifically mentioned in the topical report is that one example of a core anomaly that has occurred in the past involving control rods is having an "uncoupled" control rod assembly (CRA). The likelihood of this occurring again at a B&W-designed reactor is extremely remote. Procedural changes were put in place following the last episode of a B&W-plant starting up with an uncoupled rod to prevent the occurrence. Additionally, reviewing the rod drop time test results are a final check to assure that all the rods are coupled. Reference is made to "unlatched" rods in BAW-10242, and it is more correct to refer to this situation as "uncoupled" rather than "unlatched." A reference is also made in BAW-10242 to a situation where an uncoupled rod was not detected by measuring CRG5 worth. One of the episodes of starting up with an uncoupled CRA was with an uncoupled CRA in CRG5. Therefore, to repeat the point emphasized in BAW-10242, the zero power physics testing program did not reveal an uncoupled rod in CRG5 – even measuring CRG5 worth. The fact that the CRA was uncoupled was not revealed until the power escalation sequence.

The primary purpose of the rod worth test is to validate the assumptions on shutdown margin in the reload analysis. Therefore, the basis of the request for measuring CRGs 6 and 7 rather than CRGs 5, 6, and 7 is that this validation can be accomplished with just as much reliability.

Finally, ANSI-19.6.1 allows exceptions to be taken. Section 6.1.5 "Alternate Test Methods" states that new methods and/or new criteria can be considered under certain conditions (consideration of the overall test program, benchmarking, etc.). Framatome ANP attempted to accomplish the relaxation of the 3000 pcm/all control banks proviso within the workings of this committee. Since the ANSI Standard is for all PWRs, the committee decided retain the 3000 pcm/all control banks requirement with the understanding that an exception can be taken.

Questions 2: *What is the data base of the incidents where CRG5 was used as a CRG?*

Response 2: The topical report contains the following: "The ANS 19.6.1 Standard distinguishes between 'control rod groups' and 'safety groups' based on normal practice. While CRG5 is still considered a control rod group, CRG5 is very rarely inserted during normal power operations, such that it is essentially a safety group." Normally, in MODES 1 and 2, B&W plants consist of the three regulating control rod groups (CRGs 5-7) operating in overlap, and the safety groups (CRGs 1-4) are fully withdrawn. The overlap for the regulating CRGs is typically at 25% withdrawn (one unit uses 20% withdrawn for defining group overlap), such that once CRG5 reaches 75% withdrawn, CRG6 begins to lift. When CRG5 is at 100% withdrawn, CRG6 is at 25% withdrawn.

Therefore, the question becomes how often is CRG6 more deeply inserted than 25% withdrawn (because with the control rods in overlap, with CRG6 less than 25% withdrawn, CRG5 is only slightly inserted)?

Current cycle rod insertion limits in the Core Operating Limit Reports restrict plant operation with CRG6 less than 25% withdrawn (a "Rod Index" of 125% withdrawn) below ~40% FP for all times in core life. The percentage of time spent below this power level is very low – typically much less than 0.1% of core life.

A different way to look at this question is where do B&W-designed plants target their estimated critical position (for a "normal" mid-cycle startup)? All B&W-designed plants have a target ECP on CRG6 or higher (greater than 125% withdrawn rod index) and at least two units target criticality on CRG7 (a rod index of greater than 225% withdrawn).

So, in essence, the reactor was over-designed in that it does not need as many regulating rod groups as exist. Therefore, CRG5 simply operates fully withdrawn like the safety groups.

Question 3: *Could you propose an alternate (faster) method to measure CRG5 in place of Boron dilution?*

Response 3: There is not an alternate method to measure the worth of CRG5 in place of the boron dilution approach that would result in a similar time reduction.

When Framatome ANP (then B&W) submitted the Rod Exchange Topical Report (BAW-10175 in 1989), applicability was extended from just the Catawba and McGuire units to include all PWRs. Applying this technique to B&W-designed plants was considered and quickly dismissed on the basis of time. If this technique were to be employed, all control groups would be measured. The dilution of the Reference Bank would be approximately half of the ~3000 pcm measured by CRGs 5-7. However, the swapping of the other six banks would take at least that much time, giving no clear advantage to using that technique.

Framatome ANP (and formerly B&W) has always provided Ag-In-Cd control rods for the B&W-designed plants, and there has never been a wear or loss of absorber material concern that would require the measurement of every bank.

Question 4: *How did you choose the cycles shown in Table 1? What would be the statistics if all available cycle data were used?*

Response 4: The approach was to go at least three cycles back for each unit and to use startups where the same physics code was used as the "official" predictions. Framatome ANP acknowledges that the database for ANO-1 looks "stands out" in that only three cycles of data appear (versus at least four for the other units).

The data for Table 2, Individual Group Worth Comparisons, for ANO-1 Cycle 14 is as follows:

ANO-1 Cycle 14 Control Rod Group Worths at HZP

Control Rod Group	Predicted (pcm)	Measured (pcm)	% Deviation
CRG5	1151	1136	1.30%
CRG6	884	879	0.57%
CRG7	780	783	-0.38%
Sum (5+6+7)	2815	2798	0.60%

Using the additional rod worth data that is available would have little impact on the statistics presented in BAW-10242.

Question 5: *Regarding Section IIIB (4th paragraph) verify that you refer to Table 5 (and not Table 1) and explain how the entries shown in Table 5 were chosen. How would the average and standard deviation change if all of the cycles were represented?*

Response 5: This was a typographical error. The reference should indeed be to Table 5.

The data chosen in Section IIIB were selected based on available data. Any startup for which critical, equilibrium conditions were established with a deeper CRG7 position than "standard" (data where circumstances allowed) was used in Table 5. No such data were selectively excluded.

Question 6: *Respond to the same question for the remaining Tables, i.e. how were the entries shown chosen and are the average and mean values supportive of your argument?*

Response 6: For the differential boron worth (DBW) data in Table 6, insufficient measured boron concentration data existed for many startups. Again, all available data was used.

bcc: NRC:03:064
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