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SUBJECT: Forwards description of B-10 depletion effects on shutdown margin that may be of interest to operators of PWRs. Attachment describes boron depletion phenomena & recommendations made to plant to correct problem.

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October 8, 1986
AEP:NRC: 1011

Donald C. Cook Nuclear Plant Units No. 1&2
Docket No. 50-315 and 50-316
License No. DPR-58 and DPR-74
B-10 Depletion Effects on Shutdown Margin

Mr. Harold R. Denton, Director
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Denton:

This letter has been prepared to describe a condition which may be of interest to the operators of Pressurized Water Reactors. During the operation of Donald C. Cook Nuclear Plant Unit 1, Cycle 9, it was noticed that the measured critical boron concentration in the Reactor Coolant System was gradually deviating from the predicted boron concentration curve. A step change in the boron concentration was also noticed after a reactor shutdown for maintenance.

An investigation of the behavior of the Cycle 9 boron letdown curve showed that the reason for this was the depletion of the ^{10}B isotope in the Reactor Coolant System boric acid. Also, the investigation showed that the shutdown margin calculations were affected. Attachment 1 to this letter describes the boron depletion phenomena and recommendations made to the Plant to correct the problem.

This document has been prepared following Corporate procedures which incorporate a reasonable set of controls to insure its accuracy and completeness prior to signature by the undersigned.

Very truly yours,

M. P. Alexich 10/8/86
M. P. Alexich
Vice President

MPA/clf

Attachment

cc: John E. Dolan
W. G. Smith, Jr. - Bridgman
R. C. Callen
G. Bruchmann
G. Charnoff
NRC Resident Inspector - Bridgman

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ATTACHMENT 1 TO AEP:NRC:1011

Attachment 1

During the operation of Donald C. Cook Nuclear Plant Unit 1, Cycle 9 it was noticed that the measured critical boron concentration in the Reactor Coolant System (RCS) gradually deviated from the predicted boron concentration curve. A step change in the measured boron concentrations was observed after a reactor shutdown at a cycle burnup of ~ 5500 MWD/T as shown in attachment 2. Calculations to estimate the critical rod position for subsequent reactor startup were also found to be less accurate than expected in view of the fact that the reactor was down for a long time resulting in the decay of xenon. Some error in the estimated critical rod position is usually expected if xenon is present.

An investigation was undertaken to find the reason for the discontinuity in the measured boron points at approximately 5500 MWD/T. The investigation showed that the reason for this drop of approximately 50 ppm could be attributed to the depletion of Boron-10 (^{10}B) isotope in RCS boric acid.

Boric acid is mixed with the reactor coolant in order to control the core excess reactivity of pressurized water reactors. ^{10}B isotope which is a strong neutron absorber and has an abundance of 19.8 atom % in natural boron depletes by neutron absorption during reactor operation.[1] In addition to this effect, the ^{10}B isotopic ratio varies due to boration and dilution during plant operation since boric acid depleted in ^{10}B is replaced.

The gradually increasing deviation between the measured boron concentration from predicted boron concentration observed up to 5500 MWD/T was consistent with a calculation of the depletion of isotope ^{10}B in the RCS boric acid. After reactor trip and cooldown, the RCS water level was drained to the "half-loop" or maintenance level for repairs. During this process most of the primary water with boric acid depleted in ^{10}B was replaced. We believe that partial turnover of reactor coolant during the filling and venting evolution contributed to the drop in measured critical boron concentration of ~50 ppm owing to the higher ^{10}B content in the replaced coolant. Since estimated critical positions are calculated relative to a previous critical state point, the turnover also contributed to the misprediction in Estimated Critical Rod Position. Calculations show that the error in the estimated critical position was consistent with boron depletion and turnover of RCS coolant.

Further investigation of this matter showed that the shutdown margin calculations for operating modes 3, 4, 5, and 6 were affected. Due to the depletion of isotope ^{10}B in the boric acid, the shutdown boron concentration curve calculated by the fuel vendor which is used by the operator to calculate shutdown margin may not include the margin originally anticipated. Two effects were identified that could reduce the shutdown margin (SDM).

(a) ^{10}B Depletion in RCS During Normal Operation:

The measured RCS critical boron concentration may be higher than the calculated critical boron concentration due to ^{10}B depletion as shown in the boron letdown curve for Unit 1, Cycle 9. This increase was calculated to be 66 ppm at a cycle burnup of 5500 MWD/T. Calculations also indicate that the maximum error could have been as high as 99 ppm for Unit 2, Cycle 3 if the unit had operated at full power without trips. After reactor shutdown, the RCS boron concentration is increased to the shutdown boron concentration calculated by the fuel vendor. Since the Shutdown Margin (SDM) procedure does not have any provisions for changing shutdown boron concentration based on observed differences in calculated and measured critical boron concentration, the SDM could be reduced as illustrated in attachment 3.

(b) Overall ^{10}B Depletion in Boric Acid Storage Tanks (BAST):

Due to reuse of boric acid recovered from the Reactor Coolant System water, the ^{10}B content in the BAST could be less than the value assumed in the vendor analyses. Therefore, the effective shutdown boron concentration could be less than the shutdown boron concentration calculated by the fuel vendor and used by the operator to maintain SDM. Again the net effect could be reduced SDM as illustrated in attachment 4. This effect will increase in significance as the losses due to leakage during refueling outages are curtailed.

The maximum error due to these two effects was calculated to be 110 ppm for Unit 1, Cycle 9. We believe this is the highest potential error in all past cycles for both units.

The calculated shutdown boron concentration curve assumes that the most reactive RCCA is stuck out of the core which is worth approximately 90 ppm plus the provision of an additional allowance of 100 ppm. Therefore a 190 ppm margin was available for Unit 1, Cycle 9 in modes 3-6. Since no stuck rods have been observed, we can conclude that there was adequate SDM. We are also monitoring critical boron concentration closely for both units in order to facilitate changes to shutdown boron concentration. Attempts are also being made to find a testing laboratory to determine the ^{10}B content.

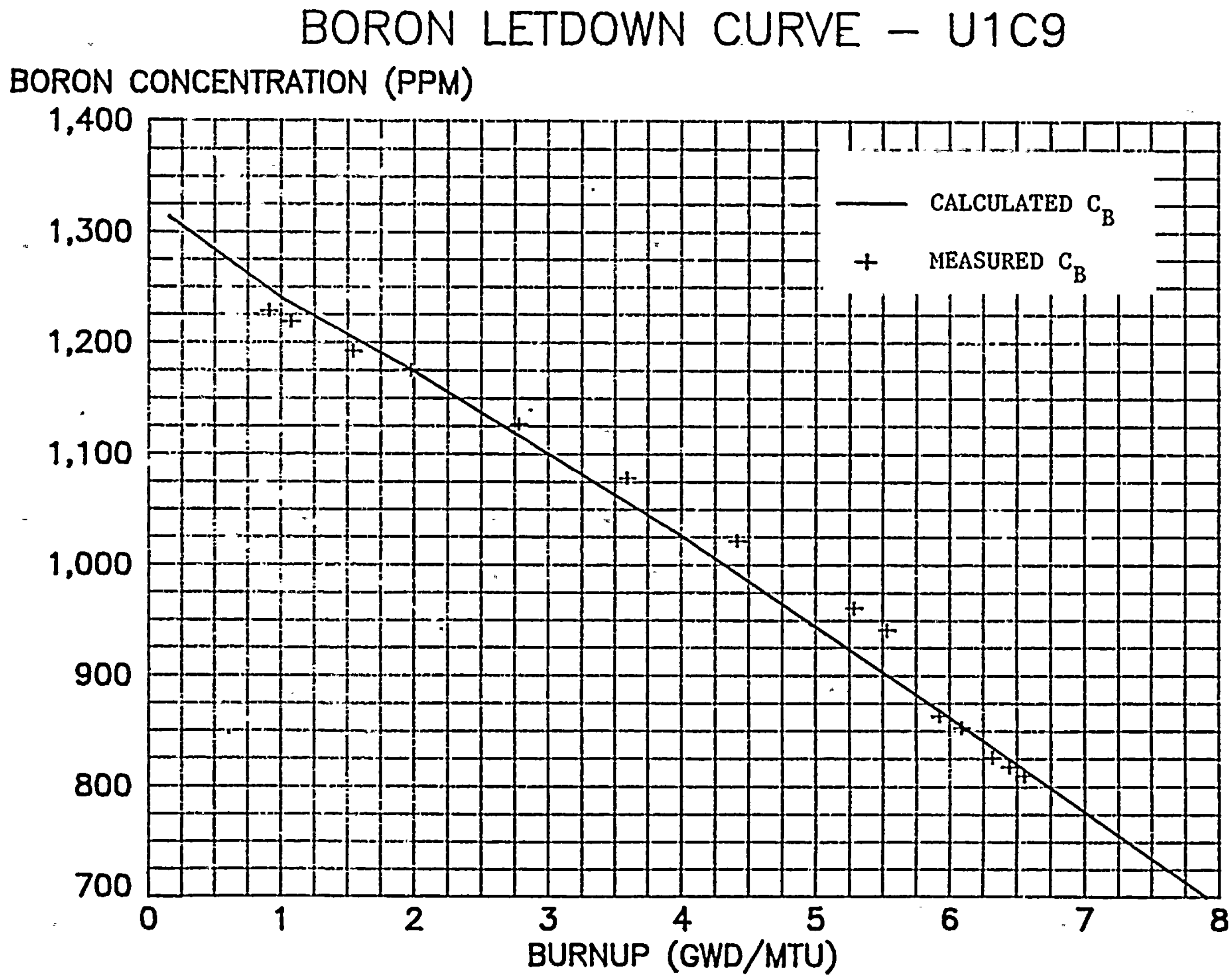
In order to overcome problems associated with SDM, the following recommendations for operation will be implemented:

(a) The shutdown boron concentration may be increased by the same amount the measured critical boron concentration is above the predicted critical boron concentration or the shutdown boron curve may be increased by 100 ppm at the beginning of the cycle.

(b) If the boric acid recovered from the RCS is reused, methods will be developed to assure the content of ^{10}B isotope in the boric acid storage tank is adequate. The shutdown boron curve will be adjusted as required.

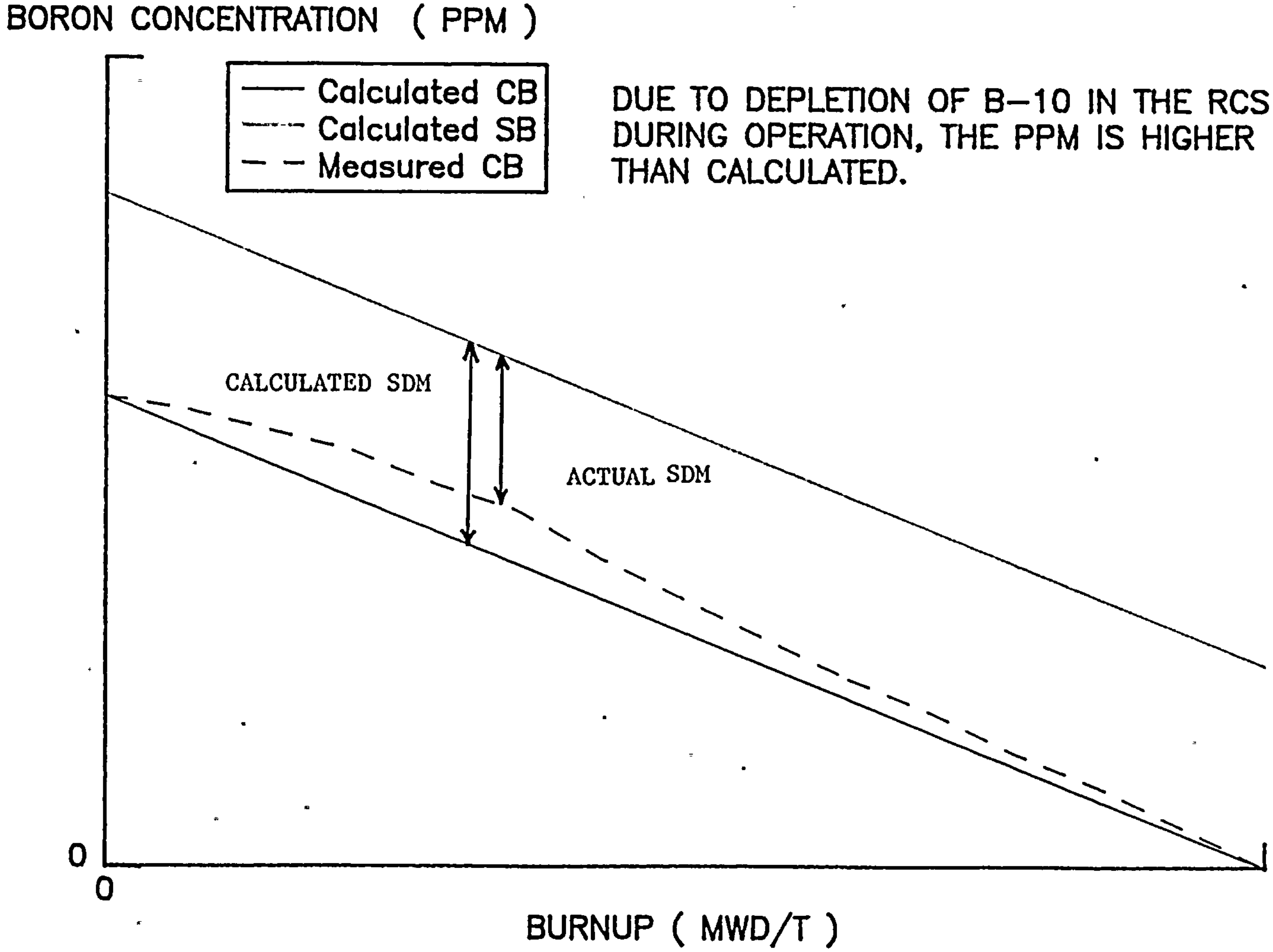
Reference

1. Nobuo Asai, et. al., "Evaluation of B-10 Depletion During PWR Operation", ANS Topical Meeting on Reactor Operating Experience, August 3, 1983.



Attachment 2

Calculated Critical Boron and Shutdown Boron Curve



Attachment 3
AEP:NRC:1011

Calculated Critical Boron and Shutdown Boron Curve