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Axial Power Peaking Factors for
Point Beach 2

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MASTER

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Introduction

This report discusses a series of NGAH calculations whose purpose is to check the accuracy of Westinghouse predictions of some "load-following" transients. Generally, our calculations check the Westinghouse results quite closely.

In order to meet the LOCA criteria, it is necessary for a manufacturer to demonstrate that the power peak to average does not exceed design values during normal operation. One type of normal operation is load-following during which a reactor will follow a prespecified power transient. For example, from an initial full power state it may reduce to a half power state for a specified number of hours, for example, T(6), after which it is returned to a full power situation. Symbolically, this may be represented by P(100, 50,100). Control of the power level may be by the maneuvering D-Bank, whose rods may be inserted to different fractional depths at each power state. This is represented, for example, by D(20,50,20) or by part-length rod bank which similarly may be represented by, for example, PLR(60,0,0). Thus, a full load following transient may be represented by: P(100,50,100), D(0,20,10), PLR(62.5,0,0),T(6), which is read as: the reactor has been operating at 100% of full power with the D-Bank out and the part-length rods inserted 62.5% (that is centered, since they are 1/4 length rods); the power

is reduced to 50% power, the D-Bank inserted to a depth of 20 percent and the PLR removed; this state lasts six hours at which time the power is raised to 100% of full power, the D-Bank withdrawn to only a 10% insertion, while the PLR remains out. As far as we are concerned, the final state is assumed to continue indefinitely.

Our study has considered two aspects of the problem: first, do we concur with the solutions presented by Westinghouse for particular load following transients, and second, do we agree with the structure of the fly speck graph.

Comparison with Westinghouse

The Westinghouse analysis is done using the code PANDA. The code uses a quasi-steady-state, two-group model containing a simplified power feedback model to account for Doppler effects (only the fast absorption cross section is affected) and a more complex but still approximate (they use the outdated Bowring model and assume unit slip) voiding model; because the model assumes unit slip the void fractions will tend to be too large (hence, too stabilizing). The time steps used are one hour in length.

The Brookhaven analysis uses NØAH which is an "equivalent one-group" model and contains more realistic feedback models for both fuel and coolant effects. The time step used was 1/3 hour.

The solutions presented by Westinghouse are contained in Attachment 3 (Proprietary) to the Point Beach 2 Fuel Densification Report. We feel that there is no good reason to repeat all of the BOL cases but have chosen one case with and one without part-length rod insertion. Fig. 1 shows a comparison with case 4 of the document cited above. The results are sufficiently close both in axial offset and power peak/average to make further discussion unnecessary. Similar conclusions can be drawn for a case with PLR (63,0,0) where Fig. 2 shows the axial power distribution at 8 hours into a transient and Fig. 3 shows the BNL prediction of the power peak/average for the first 12 hours. These calculations (as well as others not reported) show (at least to our satisfaction) that for all the differences in the calculational techniques the predicted load-following transients are essentially the same as those obtained by Westinghouse.

Some interesting phenomena occur when the PLR bank is used. Fig. 4 shows the effect at low power of a nearly centrally located PLR; as expected the maximum F_Z is reduced by insertion of the PLR bank. At full power, however, different effects occur. Fig. 5 shows F_Z for three different cases, all at full power. The first has no xenon and no PLR and the curve is nearly sine shaped. Case 2 has the PLR inserted, again with no xenon effect, and the maximum F_Z decreases as expected; but, as xenon builds into its equilibrium value, the maximum F_Z actually increases. The folklore that xenon buildup flattens the power distribution is disproved by this result. The effect is caused by the decrease of boron concentration as xenon poisoning takes over. This increases the negativity of the moderator coefficient and shifts the power peak sufficiently towards the inlet to actually increase the maximum F_Z .

Adequacy of the Fly Speck Chart

The LOCA accident analysis starts with the assumption of the maximum allowed power peak/average. This limiting value is set so as to preclude violation of the Final Acceptance Criteria (F.A.C.)^{*} We address ourselves to a single question: is the envelope (the straight lines in the fly speck chart) located to include all reasonably probable cases.

To fully answer this question would require the reproduction of most of the cases done by Westinghouse. We do not believe this is actually necessary and we substitute the independent analysis of a number (not especially large) of BOL cases both with and without PLR insertion. The result of these calculations may be found in Fig. 6. The limit lines are those for Point Beach 2. The calculations comprise steady-state results with and without xenon, specific transients using various D-Bank insertion limits. PLR only before the shutdown to part power (i.e., PLR (X,0,0)). The only cases of interest are those on the line which crosses the Point Beach 2 limit line. This line of cases represents BOL steady-state without xenon or PLR and for the D-Bank partly inserted 10% to 60%. Between 27% and 32% insertion we find results

^{*} A number of other damage limits (and criteria for their avoidance) exist; it happens that the first of these occurs for the FAC.

which exceed those allowed by Westinghouse. The maximum error $(100(2.66-2.62)/2.62)$ is about 1.5% in peaking factor and quite likely is an indication of differing calculational methods. The error differences in Fig. 1 and Fig. 2 are generally about $\pm 1-2\%$ in power peak/average.

In the newer 17 x 17 assembly cores the expected mode of operation during the early part of life will be to leave the PLR bank out of the core, and attempt to maintain the D-Bank at a fixed position (generally 10% inserted). During a load following transient the D-Bank might be inserted to bring the core to part power, but then boron would be substituted as rapidly as is reasonable to allow replacement of the D-Bank at its original position. When returning to full power boron dilution would be used. The 3411 MW, 12 foot long core and the 3800/4100 MW, 164 inch long cores have less spatial stability and we were concerned that the non-interference procedure could lead to overshooting of the power peak/average. Indeed, this has not been found to be true and the transients' decay is essentially complete in 40-50 hours. The technical specifications state that the axial offset will be maintained between -5% and -15% (Fig. 16-3-10,11 RESAR 41 vol. viii) our analysis shows that this would be true for the 3411 MW core at BOL but not for the 3800/4100 series core. For the RESAR 41 core operating in the 3800 MW configuration we find that the axial offset reaches -17% 18 hours into a transient described by $P(100,50,100)$, $T(6)$, $PLR(0,0,0)$, $D(10,10,10)$, and for the 4100 MW configuration we reach -18% when 15 hours

into the same transient. In both cases the initial axial offset is approximately -10.7%.

The only way we know to bring the axial offset back within the target band would be to withdraw the D-Bank and reborate; however, it is not clear that the full withdrawal of the D-Bank (it is only 10% inserted) is either allowed by the technical specifications or would in fact return the offset to its desired location. If no action at all is taken, the offset will return within eight hours.

Conclusions

We find that the Westinghouse calculations for Point Beach 2 are accurate within calculational error; that is, our methods compare with theirs within $\pm 2\%$ in peaking factor. This degree of accuracy is, however, sufficient to find cases which just cross the fly speck lines, thus indicating that the lines are very closely drawn and leave little leeway.

We find that the proposed operational scheme for load following for the 3800/4100 RESAR-41 cores allows the flux difference to exceed the technical specifications.

A COMPARISON BETWEEN WESTINGHOUSE AND BNL IN PREDICTING THE LIMITING TRANSIENT
REFERRED TO AS CASE 4, TABLE 2 OF ATTACHMENT 3 TO THE POINT BEACH DESIFICATION REPORT

A COMPARISON OF POWER SHAPES 8 HOURS INTO A LOAD FOLLOWING TRANSIENT
WITH INITIALLY (NEARLY) CENTRALLY LOCATED
PART LENGTH RODBANK

WESTINGHOUSE--DASHED LINE
B.N.L. — SOLID LINE

FIGURE 2

A LOAD FOLLOWING TRANSIENT WITH INITIALLY (NEARLY) CENTRALLY LOCATED
 PART LENGTH ROBBANK. (63.0,0.0), (20.50,20), (100,50,100)

FIGURE 3

A COMPARISON OF THE LOW POWER AXIAL POWER DISTRIBUTION WITH
AND WITHOUT (NEARLY) CENTRALLY LOCATED
PART-LENGTH RODBANK

SOME EFFECTS OF PART LENGTH RODS AND XENON BUILD-UP ON AXIAL PEAKING FACTORS

- 1: FULL POWER, NO XENON, NO PLR
- 2: FULL POWER, NO XENON, PLR
- 3: FULL POWER, XENON, PLR

LOCATION OF SOME NAAH PREDICTIONS OF F_Q VERSUS POWER AXIAL OFFSET WITH RESPECT
TO THE WESTINGHOUSE FLYSPECK CHART LIMIT LINES FOR POINT BEACH 2

FIGURE 6