Evaluation of Babcock and Wilcox Licensing
Topical Report BAW-10122, "Normal Operating
Controls"

Report No.: BAW-10122
Report Title: Normal Operating Controls
Report Date: July 1978
Originating Organization: Babcock & Wilcox
Reviewed By: Core Performance Branch/W. Brooks

The Power Generation Group of Babcock and Wildox has submitted licensing topical report BAW-10122 entitled, "Normal Operating Controls" for our review. This report describes the techniques and procedures used to establish core related limiting conditions of operation (LCOs). It is one of a series of topical reports which have been submitted by Babcock and Wilcox in order to provide the staff with generic information on the nuclear design of B&W reactors and to facilitate the review of such designs.

1. Summary of Report

Topical Report BAW-10122 describes the criteria and methods used by Babcock and Wilcox to establish the limits for normal reactor core operation - the limiting conditions for operation (LCOs). Core operating limits are established which assure that transients or accidents which are initiated from the limiting conditions do not violate appropriate acceptable limits. As a practical matter, the most restrictive operating limits on power distributions are currently imposed by the requirements of the loss of coolant accident as expressed in Appendix K of 10 CFR 50. Limits on control rod positions are imposed by the necessity of having an adequate shutdown margin and of limiting the reactivity worth of a potential ejected rod in addition to the power distribution restriction.

The calculational methods employed in the analysis are briefly described. They have been fully described in other topical reports in the series. Most of the calculations are three-dimensional and are performed with the PDQ07 and/or FLAME3 codes. Total rod worths and detailed radial power distributions are performed with the PDQ07 code in two dimensions.

The control philosophy of the bleed-and-feed reactor system is described and differences between bleed-and-feed and rodded plants pointed out. The core parameters which are investigated in the analysis of operating limits are listed and the analyses performed are described. In general, the parameter is varied over a range larger than is expected and the effect on the core operating condition determined.

For the LOCA limited heat generation rates the effects of five operating parameters are considered - axial offset, quadrant power tilt, control rod position, transient xenon, and fuel depletion. The manner in which each of these parameters affects the core peaking is described. The uncertainties applied to the calculated results are listed and typical values given. The manner in which the various limits are combined to obtain final operating limits is also described.

The procedures followed in determining the rod insertion limits relative to the shutdown margin requirements are described. Briefly, the reactivity increase in going from the operating power to zero power is calculated and one percent reactivity change is added to achieve the required shutdown margin. This is the amount of reactivity which must be held in control rods at the operating power. The fraction of rods which must be withdrawn to obtain this amount of reactivity then determines the insertion limit.

Another restraint on the amount of reactivity that may be held in control rods is the worth of a rod that could possibly be ejected from the core. In general this worth is larger for more inserted rod worth. Acceptable ejected rod worths are determined from the analysis of the ejected rod event and are currently one percent reactivity change at zero power and 0.65 percent reactivity change at full power, varying linearly at intermediate powers.

In summary there are three restraints on the amount of inserted rod worth; LOCA-limited power peaking, shutdown margin requirements, and ejected rod worths. The final insertion limits are obtained by combining the most limiting portions of the three insertion limit curves. In general at low power ejected rod worth considerations will be limiting and at high power the limit will be established by the LOCA.

The uncertainties to be applied to the operating limits are described - both calculational and measurement uncertainties are considered. Measurements of quadrant tilt and axial offset are performed with the incore monitoring system. The measurement uncertainties are described and typical values are presented.

The final step in the process of establishing operating limits is the conversion of the computed limits to alarm settings. The power dependence of the limits is represented by a series of straight line segments and entered into the alarm unit of the plant computer system. Audible and visual alarms are provided as well as an alarm message at the computer console. The

algorithms used to calculate the various limited parameters are given. The calculated values are compared to the error-corrected limits and appropriate alarms sounded.

Finally, an example of the normal operating limits for the standard B&W plant, Babcock-205 cycle 1 is presented. An appendix to the report describes the differences between the current techniques and those used for current generation plants with 177 fuel assemblies. The chief difference is in the use of axial imbalance rather than offset to characterize the axial power distribution where imbalance is the product of offset and the fraction of full power in the core.

2. Summary of Evaluation

We have reviewed the description of methods and techniques used for obtaining normal operating limits given in topical report BAW-10122. The following comments summarize our evaluation.

The calculational methods and procedures employed for obtaining the information on power distributions, control rod worths, and core reactivity balances have been described in other topical report supplied by Babcock and Wilcox. These reports have been reviewed and approved and their use for establishing limiting conditions of operation is acceptable.

The choice of parameters to be considered for establishing LOCA power distribution limits is state-of-the-art and is acceptable. The use of axial offset to characterize the axial power distribution is an industry-wide practice

and is acceptable. Allowance is made in the power distribution limits for a quadrant tilt of the order of five percent. This is conservative since normally the core will have negligible tilt. A further conservatism in the analysis is the fact that when the limit for a particular parmeter is derived all other parameters are assumed to be at their respective limits. The uncertainties applied to the determination of power peaking are state-of-the-art and the values for these uncertainties have been shown to be bounding. On the basis of the stated conservatisms and the use of appropriate uncertainties we conclude that the procedure and techniques are used to establish LOCA related limiting operating parameters are acceptable.

Calculations of the number of control rods that must be withdrawn in order to assure that the shutdown margin is adequate have been reviewed. The available rod worth is first corrected for the assumed stuck rod and for loss of reactivity due to burnout and the corrected value is reduced by ten percent to account for calculational uncertainty. Comparisons to measured values have shown that this is a conservative value of the uncertainty. The reactivity defect is calculated and a flux redistribution correction added. The corrected available rod worth and the corrected reactivity defect are then compared to obtain the rod withdrawal limits. This is an acceptable procedure.

The power dependent values of the ejected rod worth limiting values are reduced by fifteen percent to account for calculational uncertainty in the rod worth. Comparisons between calculated and measured ejected rod worths have shown that this is a conservative uncertainty value. The

comparison of calculated ejected rod worth to the error-corrected limit establishes the withdrawal limit. This is an acceptable procedure.

The use of the most limiting of the withdrawal curves at each power level is an acceptable procedure which is industrywide practice.

Measurement uncertainties are applied in addition to the calculated ones described above. The incore monitoring system and rod position indication system measurement uncertainties are described in sufficient detail to permit the conclusion that proper techniques and methods are used in their evaluation. Algorithms are presented for certain portions of the errors and typical values given for other portions. We conclude that an acceptable discussion of measurement errors has been given.

The calculational and measurement errors are combined and the limiting conditions of operation (Technical Specification limits) are adjusted by the amount of the combined error. It is these error-adjusted limits to which core parameters are compared in order to give alarms. This is an acceptable procedure.

3. Evaluation Procedure

The review of topical report BAW-10122 has been conducted within the guidelines provided by the Standard Review Plan, Section 4.3. Sufficient information is included to permit a knowledgeable person to conclude

that the methods and techniques employed are state-of-the-art and are acceptable. The parameters chosen to characterize the core power distribution are those widely used in the industry and are acceptable. The calculational and measurement uncertainties have been shown to be conservative and are appropriately applied.

4. Regulatory Position

Based on our review of licensing topical report BAW-10122 we conclude that it is acceptable for referencing in licensing actions by Babcock and Wilcox with respect to the establishment of limiting conditions of operation for the parameters discussed above.