Supplemental Safety Evaluation

For The

General Electric Topical Report

Qualification Of The One-Dimensional

Core Transient Model For

Boiling Water Reactors

NEDO-24154 and NEDE-24154P

Volumes I, II and III

Prepared By

Reactor Systems Branch, DSI

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The Safety Evaluation Report on the ODYN code (Reference 2) is primarily an evaluation of the calculational model with little discussion of implementation requirements. Reference 3 provides the information required to bridge the gap between evaluation and implementation. Specifically, there are eight items covered in Reference 3; these are:

1. ODYN Option B statistical adjustment factors,
2. Control rod drive scram insertion time conformance procedure for plants licensed under ODYN Option B,
3. Uncertainty in ODYN pressure calculations,
4. ODYN model temperature limits,
5. Uncertainty in subcooled boiling model,
6. Description of electronic hydraulic control model,
7. Listing of ODYN input variables,
8. Comparison of minimum critical power ratio operating limits established by REDY and ODYN.

Each of these items is discussed below.

Item 1. Statistical Adjustment Factors

Page III-6 of Reference 2 allows two statistical approaches; one is a plant-specific statistical analysis and the other is a generic analysis for plant groups (e.g. BWR/2, 3, 4, 5, 6) and transients. The second approach involves the establishment of generic ΔCPR/ICPR adjustment factors for groupings of similar-type plants which can be applied to plant-specific ΔCPR/ICPR calculation from the ODYN licensing topical report (LTR) deterministic approach. Reference 3 provides the statistical adjustment factors for the three transients which are normally limiting transients (load rejection or turbine trip without bypass, feedwater controller failure to maximum demand and pressure regulator downscale failure). These generic statistical adjustment factorsare shown in Table 1; we find them to be acceptable.

Item 2. CRD Scram Insertion Time Conformance Procedure

Page III-3 of Reference 2 states "In order to take credit for conservatism in the scram speed performance for reloads, it must be demonstrated that there is insufficient reason to reject the plant-specific scram speed as being within the distribution assumed in the statistical analysis. For CP and OL, the scram speed distribution for the specific plant must be demonstrated consistent with those used in the statistical approach."

General Electric presents the following procedure as one which satisfies the Staff's objectives for scram conformance. It should be noted that some utilities using ODYN Option B may desire to establish their own conformance procedures.

The procedure consists of testing, at the 5% significance level, the scram surveillance data at the 20% insertion position which is generated several times each cycle as required in the Reactivity Control System Technical Specification (20% insertion is representative of that portion of the scram most affecting the pressurization transient). The unique rod notch position closest to 20% (and the appropriately adjusted time of insertion) is expected to be utilized in actual plant application of this generic concept. For most plants, the surveillance requirements are as follows:

(1) all control rods are measured at beginning of cycle (BOC), and

(2) X% of control rods are measured every 120 days during cycle (X is plant-dependent and ranges from 10 to 50).

At the completion of each surveillance test performed in compliance with the technical specification surveillance requirements, the average value of all surveillance data at the 20% insertion position generated in the cycle to date is to be tested at the 5% significance level against the distribution assumed in the ODYN analyses. The surveillance information which each plant using this procedure will have to retain throughout the fuel cycle is the number of active control rods measured for each surveillance test (the first test is at the BOC and is denoted N_1; the ith test is denoted N_i) and the average scram time to the 20% insertion position for the active rods measured in test i (τ_i). The equation used to calculate the overall average of all the scram data generated to date in the cycle is:

$$\tau_{ave} = \frac{\sum_{i=1}^{n} N_i \tau_i}{\sum_{i=1}^{n} N_i} \qquad (2\text{-}1)$$

where

n = number of surveillance tests performed to date in the cycle;

$\sum_{i=1}^{n} N_i$ = total number of active rods measured to date in the cycle; and

$\sum_{i=i}^{n} N_i \tau_i$ = sum of the scram times to the 20% insertion position of all active rods measured to date in the cycle to comply with the Technical Specification surveilllance requirements.

The average scram time, τ_{ave}, is tested against the analysis mean using the following equation:

$$\tau_{ave} \leq \tau_B \tag{2-2}$$

where

$$\tau_B = \mu + 1.65 \left(\frac{N_1}{\sum_{i=1}^{n} N_i} \right)^{1/2} \sigma \tag{2-3}$$

The parameters μ and σ are the mean and standard deviation of the distribution for average scram insertion time to the 20% position used in the ODYN Option B analysis.

If the cycle average scram time satisfies the Equation 2-2 criterion, continued plant operation under the ODYN Option B operating limit minimum critical power ratio (OLMCPR) for pressurization events is permitted. If not, the OLMCPR for pressurization events must be re-established, based on a linear interpolation between the Option B and Option A OLMCPRs. The equation to establish the new operating limit for pressurization events is given below:

$$OLMCPR_{New} = OLMCPR_{Option\ B} + \frac{\tau_{ave} - \tau_B}{\tau_A - \tau_B} \Delta OLMCPR \tag{2-4}$$

where

τ_{ave} and τ_B are defined in Equations 2-1 and 2-3, respectively;

τ_A = the present technical specification limit on core average scram time to the 20% insertion position; and

ΔOLMCPR = the difference between the OLMCPR calculated using Option A and that using Option B for pressurization events.

Note that Equation 2-3, which establishes the maximum allowable scram insertion time for operation under Option B, may also be expressed in the following manner:

$$\tau_B = \mu + A\sigma \tag{2-5}$$

where

$$A = 1.65 \left(\frac{N_1}{\sum_{i=1}^{n} N_i} \right)^{1/2} \tag{2-6}$$

The relationship between the coefficient, A, and the amount of surveillance data generated during the cycle is illustrated in Figure 2-1. As more data become available through the performance of in-cycle surveillance tests, the coefficient decreases, as does the acceptance criterion, τ_B. Thus, the scram speed criterion is being tightened as the cycle progresses, based on the assumption that, as more scram data become available during the cycle, the uncertainty in the mean value calculation should decrease.

We find the scram insertion time conformance procedure to be acceptable.

Item 3. Uncertainty in ODYN Pressure Calculations

Page III-7 of Reference 2 states that if GE can demonstrate that the uncertainty in calculated pressure is small (e.g. by a factor of 10 or more) relative to the bias in determining ASME vessel overpressure limit, no addition of uncertainty to the calculation's of pressure is needed. A sensitivity study varying ODYN input parameters over the range of Table 1 of Reference 2 shows the RMS uncertainty in the peak vessel pressure to be 11 psi. GE estimates the bias in the ASME code to account for the material uncertainty to be approximately 310 psi. Therefore, there is no need to account for pressure uncertainty in the ODYN calculations.

Item 4. ODYN Model Temperature Limit

An early draft of the ODYN SER limited the code calculation to fuel temperatures less than $1500^{o}K$ (approximately $2240^{o}F$). This was because Figure 8-2 of Reference 1 limited the thermal conductivity of UO_2 to $1500^{o}K$. The actual equation used in ODYN,

$$K = \frac{38.24}{402.4+T} + 6.07123 \times 10^{-13} \quad (T+273)^3$$

where T = fuel temperature (^{o}C) and

K = thermal conductivity (watts/Cm^{o}C)

is based on data which extended to the UO_2 melting temperature ($3080^{o}K$). Therefore, the fuel temperature limit for ODYN analyses is the UO_2 melting temperature ($3080^{o}K$ or $5100^{o}F$).

Item 5. Uncertainty in Subcooled Boiling Model

Page II-19 of Reference 2 states "We estimate the corresponding minimum and maximum values of 'n' to be 0.5 and 2.0 respectively. General Electric is required to make sensitivity studies to verify that these values correspond to $\pm$ 0.023 uncertainty in ΔCPR/ICPR." GE analyzed the turbine trip without bypass transient for n = 2.0, as requested for a 251 BWR/4. The peak core average heat flux (% rated) increased from 121.6% (for n = 1.0) to 124.0 (for n = 2.0). This leads to a ΔCPR/ICPR sensitivity of about 0.024. It is concluded that the Staff's estimate of $\pm$0.023 for n values between 0.5 and 2.0 is valid.

Item 6. Description of Electronic Hydraulic Control Model

An early draft of Reference 2 stated "Wherein electronic hydraulic controls are used in the design, the model used in selection of initial control setting shall be submitted for staff review." This statement was made because Reference 1 provided information only for the mechanical hydraulic control. GE claims that there is no functional difference between the two types of control. However, they provided a description of the model in Reference 3. We agree with the GE claim that there is no functional difference between the two types of control.

Item 7. Listing of ODYN Input Variables

Page III-10 of Reference 2 states "Listing of important input variables such as listed in Table IV and initial plant parameters including but not limited to control system characteristics as depicted in Figures 4-13 through 4-16 of NEDO-24154, vol. 1, but with numerical values provided should be provided with each submittal. The initial control system characteristics, including the model used in the selection of initial settings, shall be defined and substantiated in terms of the design basis for each control system of the plant." Item 7 of Reference 3 lists typical values of these initial parameters which may be included by reference into individual plant submittals provided the values are appropriate to the individual submittals.

Item 8. Comparison of MCPR Operating Limits Established by REDY and ODYN

The Staff requested GE to provide a comparison of CPR operating limits based on REDY and ODYN prediction. The purpose of such a comparison was to evaluate the appropriateness of continued plant operation under the current REDY-based operating limits during the transition period in which ODYN is implemented for rapid pressurization events.

In addition, the Staff indicated that the initial ODYN analysis for each BWR operating plant must include all the pressurization events identified in Table 2-1, Volume 3 of Reference 1, unless justification could be provided that fewer events (such as the limiting events presently analyzed for reload submittals) would be sufficient.

Table 2 shows ODYN and REDY-based CPR operating limits for the limiting pressurization events (load rejection without bypass and feedwater controller failure-maximum demand) for plants in which both ODYN and REDY calculations are available. Two sets of ODYN numbers are provided: ODYN deterministic calculations per the GE letter (Reference 1), labelled "ODYN-GE LTR" in Table 2; and ODYN Option B statistical calculations, labelled "ODYN Option B" in Table 2. Also included in the table are the plant minimum operating limits, based on all the abnormal events, when using REDY, ODYN GE LTR, and ODYN Option B to calculate the rapid pressurization events.

Because the overall plant operating limits are, in all cases, either uneffected or improved, GE concludes that implementation of ODYN will not represent a significant change to the operating limits for BWR plants. For those plants which use ODYN Option B, it is generally expected to either produce no change to the limit or else to improve it slightly. We agree with this conclusion.

The events for which ODYN has been qualified and approved are listed in Reference 1, Volume 3, and include the following: (1) feedwater controller failure-maximum demand; (2) pressure regulator failure-closed direction; (3) generator load rejection with and without bypass operation; (4) main steamline isolation valve closure (trip scram and flux scram); (5) loss of condenser vacuum; (6) turbine trip with and without bypass; and (7) loss of auxiliary power - all grid connections. GE proposes that only the following three events be reported for reload submittals or safety analysis report revisions: generator load rejection/turbine trip without bypass (whichever is limiting), feedwater controller failure-maximum demand, and main steamline isolation valve closure-flux scram (to satisfy ASME code pressure requirements). These are the same pressurization events presently included in reload submittals, and reflect the consistency in the ODYN and REDY results. The events not included in the submittal are much less severe, for the reasons discussed below.

1) Turbine/Generator Trips With Bypass

These events are considerably less severe than the transients in which the bypass system is assumed to fail. Typical turbine bypass capacities range from 25-40% of rated steamflow. This bypass capacity results in a considerably milder thermal and overpressurization event.

2) Pressure Regulator Failure - Closed Direction

The standard event evaluated in SAR analysis is one in which the controlling pressure regulator is assumed to fail in the closed direction. Under these failure conditions, the backup regulator takes over control of the turbine admission valves, preventing any serious transient. The disturbance is mild and similar to a pressure set point change with no significant reductions of fuel thermal margins occurring. As shown in the SARs, this event is considerably less severe than the generator and turbine trips without bypass.

3) Loss of Condenser Vacuum

Various system malfunctions can cause a loss of condenser vacuum due to some single equipment failure. The reduction or loss of vacuum in the main turbine condenser will sequentially trip the main and feedwater turbines and bypass system and, for some plants, close the main steamline isolation valves. While these are the major events occurring, other resultant actions will include scram (from stop valve closure) and bypass opening with the main turbine trip. Because the protective actions are actuated at various levels of condenser vacuum, the severity of the resulting transient is directly dependent upon the rate at which the vacuum pressure is lost. Normal loss of vacuum due to loss of cooling water pumps or steam jet air ejector problem produces a very slow rate of loss of vacuum (minutes, not seconds). If corrective actions by the reactor operators are not successful, then simultaneous trips of the main and feedwater turbines, and ultimately complete isolation by closing the bypass valves (opened with the main turbine trip) and the MSIVs, will occur. This event is bounded by the turbine trip without bypass event.

4) Loss of Auxiliary Power - All Grid Connections

This event is initiated by a generator load rejection. Since the turbine bypass system is assumed to operate during the initial portion of this event, it is comparable to the load rejection with bypass and is considerably less severe than the without bypass events.

5) MSIV Closure - Trip Scram

This event has a slower shutoff of steam flow than the turbine trip without bypass event. Therefore, the transient is not as severe. This has been confirmed by ODYN calculations.

The staff agrees with the GE assessment of the relative severity of the transients listed. Therefore, the following events should be reanalyzed with ODYN for plants which have analyses of record using REDY:

1) generator load rejection/turbine trip without bypass
2) feedwater controller failure maximum demand
3) main steam line isolation valve closure-flux scram.

If for a particular plant another event should be more limiting than those just listed, then the other event should also be reanalyzed with ODYN. For the new plants with transient analyses supplied by GE, all of the events listed in Table 3 of Reference 1 should be analyzed with ODYN.

References

1. NEDO-24154 and DEDE-24154P, Volumes I, II and III, "Qualification of the One-Dimensional Core Transient Model for Boiling Water Reactors," October, 1978.

2. Memorandum for T. Novak and R. Tedesco from P. S. Check, "Safety Evaluation for Qualification of the One-Dimensional Core Transient Model for Boiling Water Reactors," DEDO-24154 and NEDE-24154P, Volumes I,II and III," October 22, 1980.

3. Letter to P. S. Check (NRC) from R. H. Buchholz (GE), MFN-155-80, "Response to NRC Request for Information on ODYN Computer Model," September 5, 1980.

Table 1

SUMMARY OF GENERIC STATISTICAL ADJUSTMENT FACTORS ($\Delta CPR/ICPR$)

Plant Groupings	LR/TTWOBP*	FWCF	PRDF
BWR 2/3 - EOC	+0.006	-0.016	—
BWR 4/5 w/o RPT - EOC	-0.039	-0.009	—
BWR 4/5 w/o RPT - MOC	-0.111	-0.009	—
BWR 4/5 w/RPT - EOC	-0.024	+0.016	—
BWR 4/5 w/RPT - MOC	-0.001	+0.026	—
BWR 6 - EOC	-0.021	+0.003	+0.017

*With the exception of FWCF or PRDF events, this set of adjustment factors will be applied to all pressurization events analyzed with the ODYN code to establish the CPR operating limit, since they typically involve generator or turbine trips.

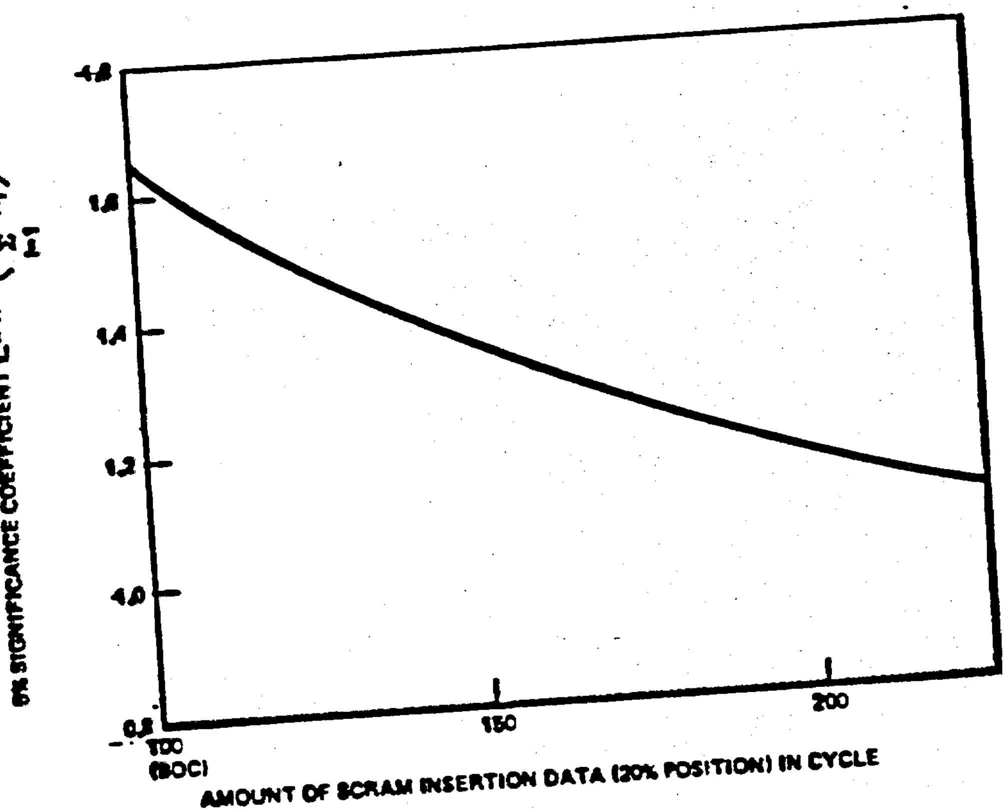

Figure 2-1. 5% Significance Coefficient (A) vs. Surveillance Data in Cycle

Table 2

COMPARISON OF REDY/ODYN RESULTS

Operating CPR Limits

Plant	LR w/o BP			FWCF			Plant Minimum		
	REDY	ODYN (GE Ltr)	ODYN (Option B)	REDY	ODYN (GE Ltr)	ODYN (Option B)	REDY	ODYN (GE Ltr)	ODYN (Option B)
BWR/3-205 EOC6	1.46	1.36	1.37	1.41	1.36	1.33	1.46	1.36	1.38
BWR/4-183 EOC5	1.42	1.33	1.27	1.31	1.25	1.23	1.42	1.33	1.27
BWR/4-218(3) EOC4	1.18	1.20	1.17	1.13	1.12	1.14	1.21(2)	1.21	1.21(2)
BWR/6-238 EOEC	1.16	1.10	1.08	1.14	1.11	1.12	1.20(1)	1.20(1)	1.20(1)

Notes: (1) Limited by Rod Withdrawal Error

(2) Limited by Loss of 100°F Feedwater Heating

(3) Plant with RPT