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# Option B Scram Times For Clinton Power Station

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## SUMMARY

An evaluation has been completed for Clinton Power Station (CPS) to derive Option B scram times that can be used in pressurization event transient analysis to improve MCPR operating limits (OLMCPR). The CPS specific Option B scram times result in approximately 0.1 improvement in the OLMCPR for [ ] events. This report provides statistical adders that will be used to derive the cycle specific Option B OLMCPRs. This report also provides a COLR compliance procedure that is used to demonstrate that the plant is within the Option B basis.

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# 1.0 INTRODUCTION

BWR/6 type plants have control rod drives that provide scram speeds that are faster than possible in BWR/2-5 type plants. With a faster scram speeds comes lower MCPR operating limits for pressurization events. Prior to the introduction of GE14 fuel, the BWR/6 Tech Spec scram speed (Option A) limited the severity of the operating limits for pressurization events such that [ ] were limiting. With the introduction of 9x9 and 10x10 fuel types, the [ ] have become limiting. Typically the GE14 [ ] OLMCPR is 0.1 higher than the slow transients.

BWR/2-5 type plants have historically been limited by [ ] events. As a method to improve operating limits, the plants have credited the application of a mean scram speed based operating limits (Option B). The Option B basis does not require any additional scram speed data beyond what is required in the plant Tech Specs. The measured scram time data is averaged at about the 20% inserted point and compared to a reference mean scram that is used in the transient analysis. If the mean scram time is below the analytical mean value, the Option B OLMCPR may be applied. If the mean scram time is exceeded, the OLMCPR may be linearly interpolated between the reference mean scram and the slower Tech Spec scram. The definition of this process is not contained in the Tech Spec but is provided in the Core Operating Limits Report (COLR).

It is expected that BWR/6 plants can see a significant benefit in OLMCPR by using a similar process. The implementation of this process requires development of a BWR/6 specific mean scram speed and a scram speed uncertainty. Plant scram time data can be used to develop this mean scram. The uncertainty in the scram speed is not based on the uncertainty in [ ] rods but it is the uncertainty on the mean scram speeds of [ ] rods.

# 2.0 METHODS AND ASSUMPTIONS

## 2.1 Option B Basis

The application of improved scram times is NRC approved by Reference 1 (ODYN LTR) and 2 (GESTAR II Section S.5.1.5).

The approved process requires evaluating scram data to:

(a) derive a statistical mean and standard deviation of measured scram times,

(b) [ ],

(c) [ ],

(d) [ ],

(e) determine the statistical adders from the $\Delta CPR/ICPR_{95/95}$ results,

(f) develop the plant surveillance requirements so that they can demonstrate that they are within the statistical scram times, and

(g) develop the COLR process for applying the Option B and Option A limits.

## 2.2 Scram Speed Determination

The CPS scram data for Cycle 5 through 8 is provided in Reference 3. The data is used to derive the mean and the sigma of the data at a representative pressure. The mean and sigma are not calculated based on [ ] rods but rather on [ ] of rods. A [ ] is a surveillance test done over a few days. The mean is, therefore, [ ].

The data is used to derive the slope of scram time vs. reactor dome pressure so that the results at a representative pressure can be converted to 1050 psig reactor dome pressure. The

1050 psig scram times are then converted to an analytical scram time (call BOPT) to evaluate MCPR pressurization transients.

The pressure conversion is required since the scram times slow down as the CRD (with it's pressurized accumulator) acts against reactor pressure. The correction is similar to the correction applied between the Tech Spec times and the AOPT times in the OPL-3 (Reference 4). The scram performances of CRDs, with various postulated abnormal conditions that affect scram performance, were modeled with the reactor pressure at 1050 psig. The following abnormal conditions were considered:

[

]

The scram performances of the postulated "Option B" CRDs during the AOO pressure history were then determined for each of the abnormal conditions listed above. Utilizing the maximum predicted scram times, the BOPT scram performance was determined.

The surveillance requirements for BOPT are derived based on the pressure correction to 1050 psig and then linear interpolation to 20% control fraction.

### 2.3 ODYN Statistical Analysis

ODYN transient analyses are performed using the BOPT scram times and sigma variation shown below. Nine cases are analyzed.

**Power** **Scram Speed**

[

]

| **Power** | **Scram Speed** |
|---|---|

[

]

The analyses are performed with the ODYNV09 version of ODYN. The Clinton Cycle 9 reference core and OPL-3 (Reference 5) are utilized as the basis for the transient analyses, however, the adders derived are applicable to all future CPS reloads loading GE14 fuel.

The statistical adders are determined for two events at two exposures, Turbine Trip No ByPass (TTNBP) at EOC and MOC and FeedWater Controller Failure (FWCF) at EOC and MOC. TTNBP results are applicable to the Load Rejection NBP transient. The final statistical adder is determined by the most limiting result from either the TTNBP or the FWCF event.

The ΔCPR/ICPR results are [ ] and then evaluated to derive the $\Delta CPR/ICPR_{95/95}$. The statistical adder (Adder-B) is defined as:

$$\text{Adder-B} = \Delta CPR/ICPR_{95/95} - \Delta CPR/ICPR_{mean\ scram}$$

The Option-A adder (Adder-A) is defined as the difference between the Option A and Option B OLMCPR. A case is analyzed at the AOPT scram speed (for the four events) to determine the Option A OLMCPR. In future Option A / Option B reload analyses only the BOPT scram speed will be used in the analysis of fast pressurization events. Once the OLMCPR-B is determined, the OLMCPR-A is determined by adding Adder-A (OLMCPR-A = OLMCPR-B + Adder-A). Note that Adder-B is applied to the ΔCPR/ICPR while Adder-A is applied to the OLMCPR.

# 3.0 ANALYSIS

## 3.1 Scram Speed Determination

The Reference 3 data is provided as pickup times at three notch positions: 43, 29, and 13. The majority of the Reference 3 data (76%) is taken at reactor pressures between 950 and 959 psig (the 0 pressure data is not used). There are 6 sets of scram times in this pressure interval between August 1994 and May 2001. The mean and sigma of these sets is shown in Table 3.1.

**Table 3.1 Scram Time Data at 950 psig**

[

| | CRD time (sec) 43 pickup | CRD time (sec) 29 pickup | CRD time (sec) 13 pickup |
|---|---|---|---|
| | | | |
| | | | |

]

[ ] is added to the mean to increase the probability that the plant will meet the Option B surveillance. The 950 psig times are shown in Table 3.2.

**Table 3.2 Analytical Scram Times at 950 psig**

[

| | CRD time (sec) 43 pickup | CRD time (sec) 29 pickup | CRD time (sec) 13 pickup |
|---|---|---|---|
| | | | |
| | | | |

]

The sigma for the other Reference 3 data (976-995 psig) is bounded by the [ ].

Utilizing Reference 3 scram performance data for fuel cycles 5 through 8, a linear correlation between the mean scram performance and the reactor vessel dome pressure was determined.

The correlation was then used to determine the expected scram performance at a reactor vessel dome pressure of 1050 psig. The 1050 psig CRD times were determined by adding the [

]. The results are shown in Table 3.3.

**Table 3.3 Analytical Scram Times at 1050 psig**

[

| | CRD time (sec) 43 pickup | CRD time (sec) 29 pickup | CRD time (sec) 13 pickup |
|---|---|---|---|
| | | | |
| | | | |

]

The analytical times in Table 3.2 and 3.3 form the basis of the Option B scram time surveillance in Section 4.

The 1050 psig CRD times were then evaluated as described in Section 2.2. The assumed pressure vs. scram time trajectory for pressurization transients are shown in Table 3.4. This pressure is the pressure above the core support plate (pressure the CRD is acting against). The ODYN calculated pressure vs. scram time for CPS bounds the transient pressure in Table 3.4.

**Table 3.4 AOPT / BOPT Pressure vs. Time After Start TCV/TSV Motion**

| Time (sec) | AOPT / BOPT Basis Pressure (psig) |
|---|---|
| 0 | 1086 |
| 0.2 | 1088 |
| 0.4 | 1108 |
| 0.6 | 1132 |
| 0.8 | 1158 |
| 1.0 | 1186 |
| 1.2 | 1208 |
| 1.4 | 1228 |
| 1.6 | 1236 |
| 1.8 | 1238 |
| 2.0 | 1238 |
| 2.4 | 1236 |
| 2.8 | 1230 |
| 3.0 | 1229 |
| 3.75 | 1212 |

The resulting BOPT scram times are shown in Table 3.5.

**Table 3.5 BOPT CRD Speed-Control Fraction vs. Time***

[

| | 0% | 1% | 10% | 20% | 40% | 75% | 100% |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |

]

### 3.2 ODYN Statistical Analysis

ODYN statistical analyses have been performed as described in Section 2.3. The results of the statistical analysis are provided in Tables 3.6 and 3.7. The results are reasonable and consistent with Option B analyses preformed for [ ]. Additional [ ] was added to the Adder-B because the CPS Cycle 9 results were [ ].

* all time in seconds

**Table 3.6 ODYN Option B Statistical Adder Data**

| Transient | Cycle Exposure | Mean scram ΔCPR/ICPR | 95/95 ΔCPR/ICPR | 95/95 – Mean | Adder-B |
|---|---|---|---|---|---|
| [ | | | | | |
| | | | | | |
| | | | | | |
| | | | | | ] |

* The pressurization portion of the MOC FWCF ΔCPR/ICPRs are < 0.01, therefore the [ ].

**Table 3.7 ODYN Option A Statistical Adder Data**

| Transient | Cycle Exposure | OLMCPR-B * | OLMCPR-A * | A – B | Adder-A |
|---|---|---|---|---|---|
| [ | | | | | |
| | | | | | |
| | | | | | |
| | | | | | ] |

* Based on a MCPR Safety Limit of 1.09 (the adder is [ ] to this value)

## 4.0 OPTION B SCRAM TIME COMPLIANCE PROCEDURE

The procedure consists of testing, at the 5 percent significance level, the scram surveillance data at the 20 percent insertion position which is generated several times each cycle as required in the Reactivity Control System Technical Specification (20 percent insertion is representative of that portion of the scram most affecting the pressurization transient. The CPS Tech Spec surveillance requirements is as follows:

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

(2) 10% of control rods are measured every 120 days during cycle.

At the completion of each surveillance test performed in compliance with the technical specifications surveillance requirements, the average value of all surveillance data at the 20 percent insertion position generated in the cycle to date is to be tested at the 5 percent 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 the total number of rods tested is denoted $N_1$. The ith test is denoted $N_i$ and the average scram time to the 20 percent insertion position for the active rods measured in test i is denoted $\tau_i$. The value of $\tau_i$ is converted to a dome pressure of 1050 psig and then interpolated to 20% as follows:

$$\tau_i^{1050(20\%)} = \left[\tau_i^{P(43\,pickup)} + (0.00054)(1050 - P_{dome})\right][0.66] + \left[\tau_i^{P(29\,pickup)} + (0.00064)(1050 - P_{dome})\right][0.34]$$

where 0.00054 and 0.00064 are the slopes of scram speed vs. pressure for 43 pickup and 29 pickup respectively.

The equation used to calculate the overall average of all the scram data generated to date in the cycle is:

$$\tau_{ave} = \frac{\sum_{i=1}^{n} N_i \tau_i^{1050(20\%)}}{\sum_{i=1}^{n} N_i} \tag{1}$$

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

$\sum_{i=1}^{n} N_i \tau_i =$ sum of the scram time to the 20 percent insertion position of all active rods measured to date in the cycle to comply with the Technical Specification surveillance requirements.

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

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

where:

$$\tau_B = \mu + 1.65\sqrt{\left(\frac{N_1}{\sum_{i=1}^{n} N_i}\right)}\sigma \quad \text{or} \quad \tau_B = 0.40 + 1.65\sqrt{\left(\frac{N_1}{\sum_{i=1}^{n} N_i}\right)}0.02 \tag{3}$$

The parameters $\mu$ and $\sigma$ are the mean and standard deviation of the distribution for average scram insertion time to the 20 percent position used in the ODYN Option B analysis. For CPS $\mu$ is 0.40 and $\sigma$ is 0.02.

If the cycle average scram time satisfies the Equation 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:

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

where $\tau_{ave}$ and $\tau_B$ are defined in Equations 1 and 3, respectively;

$\tau_A$ = the technical specification limit on core average scram time to the 20 percent insertion position or 0.503 seconds.

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

## 5.0 REFERENCES


1. "Qualification of the One-Dimensional Core Transient Model for BWRs", NEDO-24154-A, Vols. 1 – 3, February 1, 1986.

2. "GE Standard Application for Reactor Fuel (GESTAR II)", NEDE-24011-P-A, as amended through Amendment 26.

3. "Nuclear Fuel Management Transmittal of Design Information, NFM ID# NFM0100136, Rev. 0, Clinton Power Station Unit 1, Subject: Transmittal of CPS Scram Time Data for Option-B Analyses", D. A. Phegley, November 29, 2001.

4. "OPL-3 Design Guide", TDP-0087, February 1998.

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