FINAL SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

TOPICAL REPORT PWROG-17011-NP, REVISION 2

UPDATE FOR SUBSEQUENT LICENSE RENEWAL: WCAP-14535A, "TOPICAL REPORT ON REACTOR COOLANT PUMP FLYWHEEL INSPECTION ELIMINATION" AND WCAP-15666-A, "EXTENSION OF REACTOR COOLANT PUMP MOTOR FLYWHEEL EXAMINATION"

PRESSURIZED WATER REACTOR OWNERS GROUP

WESTINGHOUSE ELECTRIC COMPANY

1.0 INTRODUCTION AND BACKGROUND

On May 15, 2018, the Pressurized Water Reactor Owners Group (PWROG), formerly Westinghouse Owners Group or WOG, submitted Topical Report (TR) PWROG-17011-NP, Revision 1, "Update for Subsequent License Renewal: WCAP-14535A, 'Topical Report on Reactor Coolant Pump Flywheel Inspection Elimination' and WCAP-15666-A, 'Extension of Reactor Coolant Pump Motor Flywheel Examination'" (Ref. 1), dated May 2018 (referred to as the TR, Revision 1 in the remainder of this document) for the U.S. Nuclear Regulatory Commission (NRC) staff review. Further clarifying information related to this TR, Revision 1 was submitted on August 31 and December 21, 2018 (Refs. 2 and 3), by Florida Power & Light Company (FPL) in response to a request for additional information (RAI) for its subsequent license renewal (SLR) application for Turkey Point, Unit 3 and 4. By letter dated January 28, 2019, the PWROG submitted PWROG-17011-NP, Revision 2 (Ref. 4), to supplement TR, Revision 1 (referred to as the TR in the remainder of this document). The purpose of this TR is to extend the applicability of WCAP-14535A (Ref. 5) and WCAP-15666-A (Ref. 6) to the subsequent period of extended operation (SPEO), i.e., from 60 years of operation to 80 years of operation. The original inspection frequency for reactor coolant pump (RCP) flywheels was specified in Regulatory Guide (RG) 1.14, Revision 1, "Reactor Coolant Pump Flywheel Integrity," dated August 1975 (Ref. 7).

Prior to 1996, plants gathered more than 20 years of operating experience and inspection results, and there were no service-induced flaws identified which would affect RCP flywheel integrity. Therefore, considering the inspection history, the savings in inspection cost, and the reduction in personnel radiation exposure, the WOG submitted a deterministic and probabilistic fracture mechanics methodology in WCAP-14535A to the NRC in January 1996 for elimination of the RCP flywheel inspection. As indicated in the NRC staff's safety evaluation (SE) of WCAP-14535A, the NRC staff only evaluated the stress and deterministic fracture mechanics part of the methodology and approved the extension of the RCP flywheel inspection interval from 40 months as specified in RG 1.14, Revision 1 to 10 years.

Subsequently in 2001, the WOG submitted and the NRC staff approved an extension of the RCP flywheel inspection interval from 10 years to 20 years for the PEO based on a probabilistic fracture mechanics (PFM) and risk-informed methodology (Ref. 6).

2.0 REGULATORY EVALUATION

The function of the RCP in the reactor coolant system (RCS) of a pressurized water reactor (PWR) plant is to maintain an adequate cooling flow rate by circulating a large volume of primary coolant water through the RCS. Following an assumed loss of power to the RCP motor, the flywheel, in conjunction with the impeller and motor assembly, provides sufficient rotational inertia to assure adequate primary coolant flow during a RCP coastdown, thus maintaining adequate core cooling. A concern regarding the overspeed of the RCP and its potential for failure led to the issuance of RG 1.14. This RG describes a method acceptable to the NRC staff for implementing the requirements of General Design Criterion 4, "Environmental and Missile Design Basis," of Appendix A, "General Design Criteria for Nuclear Power Plants," to Title 10 of the *Code of Federal Regulations* Part 50, "Licensing of Production and Utilization Facilities."

As mentioned in the introduction, the original inspection interval was specified in RG 1.14, Revision 1. However, following the NRC staff approval for WCAP-14535A and WCAP-15666-A, inspection of RCP flywheels was performed using the approved inspection interval stated in the SEs for WCAP-14535A and WCAP-15666-A (Refs. 5 and 6).

Once approved, the TR will provide the basis to continue a 20-year inspection interval for the RCP flywheels into the SPEO.

3.0 TECHNICAL EVALUATION

3.1 The Stress and Deterministic Fracture Mechanics Methodology Evaluation

The primary regulatory position of RG 1.14, Revision 1, regarding flywheel design concerns three critical speeds: (a) the critical speed for ductile failure, (b) the critical speed for non-ductile failure, and (c) the critical speed for excessive deformation of the flywheel. This regulatory position specifies, as a design criterion, that the normal speed of the flywheel should be less than one-half of the lowest of the critical speeds, and the loss-of-coolant accident (LOCA) overspeed should be less than the lowest of these three critical speeds.

Section 2.3 of this TR documents the stress and fracture mechanics analyses that were performed for two bounding RCP flywheel groups to address these RG issues. They are identical to those in WCAP-14535A (WCAP-14535A contains analysis results for the complete RCP flywheel groups) and WCAP-15666-A. Since fatigue crack growth (FCG) is the only time-limited aging mechanism and the total cycle assumption of 6000 in WCAP-14535A is very conservative, this cycle assumption was used in WCAP-15666-A and again in this TR, considering operating experience. Consequently, the NRC staff's acceptance of the WOG's evaluation in Reference 5 regarding the following to meet the RG 1.14, Revision 1, requirements remains applicable to this TR:

- Material Information
- Analysis for Critical Speed Based on Ductile Fracture
- Analysis for Critical Speed Based on Non-ductile Failure
- Compliance with the Excessive Deformation Failure Criterion
- Compliance with LOCA Overspeed Criterion

3.2 The PFM Methodology Evaluation

Important results from the deterministic fracture mechanics analysis show that the critical crack length is 3.1 inches for Group 1 RCP flywheels under the lowest fracture toughness assumption, and the crack growth after 80 years is 0.08 inch. The relatively small crack growth could be used to qualitatively justify the continued adoption of the 20-year inspection interval in the SPEO. However, Westinghouse supplements the deterministic evaluation with a qualitative and quantitative risk assessment using a methodology consistent with RG 1.174, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Current Licensing Basis" (Ref. 8).

Analytically, the failure of the flywheel is determined by the presence of a crack large enough that, if subjected to the stresses caused by a given speed, will cause the flywheel to fail. The length of a flaw that will cause failure is defined as the critical flaw size, which depends on the rotating speed of the flywheel and the fracture toughness of the flywheel material. Given an event with a specific flywheel speed, if a crack grows from an assumed initial flaw size to the critical size during the evaluation time, then the flywheel is assumed to fail. Since all parameters mentioned above have some uncertainty, this TR treats them as random variables with distributions and uses a PFM methodology to estimate the conditional probability of failure (PoF) of the flywheel for the event. These conditional PoFs for RCP flywheels are essential inputs to the risk assessment.

The PFM methodology provided in this TR employed the core Monte-Carlo simulation modules with importance sampling that have been adopted and validated in the Structural Reliability and Risk Assessment (SRRA) model, supporting WCAP-14572, Revision 1-NP-A, “Westinghouse Owners Group Application of Risk-Informed Methods to Piping Inservice Inspection Topical Report” (Ref. 9). Due to the simplicity of the RCP flywheel geometry and loading, only six flywheel-specific equations needed to be incorporated into the standard subroutines of the computer code to support PFM analyses in this TR. The limited number of equations needing modification also made identification and correction of any errors in coding easier. Therefore, evaluation of the PFM methodology for RCP flywheels is reduced to evaluation of the input constants and random variables (with mean and standard deviation (σ) for a normal distribution or a median and factor for a log-normal distribution).

3.2.1 The Driving Force for an Assumed Crack

Regarding the driving force for an assumed crack, the loading in the PFM methodology is reflected in two normally distributed random variables: (1) speed change per transient and (2) speed for design limiting events. The first random variable corresponds to the normal speed with a mean of 1200 rpm and a σ of 120 rpm for FCG calculations. The NRC staff found this acceptable because using the steady state condition parameter (in this case, the normal speed) as a mean value in the FCG calculation is a standard approach by the industry and the NRC. Further, the assumption that σ is 10 percent of the mean is commonly used when actual data are not available for a statistical analysis. The second random variable corresponds to the design limiting speed with a mean of 1500 rpm and a σ of 150 rpm for the first three events identified in Table 3-7 of the TR and a mean of 3321 rpm for the fourth event identified in the table. The NRC staff approved 1500 rpm as the design speed and 3321 rpm as the peak speed for the double ended guillotine break (DEGB) LOCA event in WCAP-15666-A (Ref.6). This acceptance remains valid during the SPEO because these speeds are not time dependent. Likewise, using 10 percent of the mean value as the σ value for the limiting event speed is acceptable as stated above. The corresponding speeds for Calvert Cliffs are 1125 rpm and

1368 rpm. Since the TR is not responsible for the accuracy of its reported plant-specific data, these speeds should be confirmed in the future Calvert Cliffs SLR application. This is further discussed in Section 4.0.

The randomly selected speed, when combined with a randomly selected initial flaw length, adjusted for crack growth based on a randomly selected crack growth rate (CGR), would determine the change of stress intensity factor (ΔK) per transient for the fatigue crack growth evaluation and the applied K for the critical flaw evaluation. This TR used a log-normally distributed initial flaw length with a median of 0.1 inch and an uncertainty factor of 2.153. These are acceptable to the NRC staff because they are more conservative than the values used in the SRRA program, supporting WCAP-14572, Revision 1-NP-A.

For FCG calculations, the following CGR equation is used,

$$da/dN = C_0(\Delta K)^n,$$

where C_0 is treated as a log-normally distributed random variable with a median of 9.95×10^{-11} and an uncertainty factor of 1.414. The exponent “n” is treated as a constant with a value of 3.07, consistent with the ASME Code FCG equation for ferritic steels in an air environment. The ASME Code FCG equation represents best-estimate values. However, the TR used one half of the C_0 in the ASME Code FCG equation as the median for this random variable and, thus, underestimated the CGR by 50 percent (correct CGR = 2 x TR CGR). The NRC staff evaluated and found that this non-conservatism is completely compensated for by considering the shrink-fit stresses, which were neglected in the TR CGR calculations. The response to an RAI documented in WCAP-14535A (Ref. 5) indicated that, if the shrink-fit stresses were considered, the ΔK and the CGR would be significantly reduced due to decreased stresses at high speed caused by reduced shrink-fit and increased stresses at zero speed caused by full shrink-fit. Therefore, using the TR CGR would overestimate the CGR by 150 percent (correct CGR = 0.4 x TR CGR). The NRC staff found that the TR CGR is acceptable because the net effect of underestimating C_0 and overestimating ΔK will result in an overestimation of the CGR by 25 percent (correct CGR = 2 x 0.4 TR CGR). Consequently, the NRC staff determined that the FCG methodology that was used to generate the conditional PoF values presented in Table 3-3 and Tables 3-6 to 3-9 of the TR is acceptable.

Another random variable related to FCG is the number of transients per operating cycle. The TR used a mean of 100 transients and a σ of 10 transients for this random variable. This is very conservative and acceptable because a plant is unlikely to experience 100 transients in an operating cycle which would require frequent RCP starts and stops.

3.2.2 Fracture Resistance for an Assumed Crack

Regarding the fracture resistance of the flywheel to a crack after 80 years of growth, the PFM methodology determines the K_{IC} value using two normally distributed random variables: (1) operating temperature of the flywheels and (2) nil-ductility transition reference temperature (RT_{NDT}) value of the flywheel material. The K_{IC} value can then be determined by these two variables using the ASME Code Appendix A K_{IC} equation. The TR used a mean of 95 °F for Westinghouse plants (70 °F for Calvert Cliffs) and a σ of 12.5 °F for the flywheel operating temperature. The TR states that the containment building temperature is typically 100 °F to 120 °F. Therefore, using the above mean and σ for the flywheel ambient temperature would be conservative and acceptable because (1) 95 percent of the time, the randomly selected ambient temperature would be between 70°F (mean - 2σ) and 120°F (mean + 2σ) for Westinghouse plants, giving lower K_{IC} values for the biased lower temperatures; and (2) the corresponding 95 percent ambient temperature range is between 45 °F and 95°F for Calvert Cliffs, giving an even lower K_{IC} values. The TR used a mean of 30 °F and a σ of 17 °F for the RT_{NDT} value. Using these values are conservative, considering that the first flywheel specification dated 1969 requires the RT_{NDT} values from both longitudinal and transverse Charpy specimens be less than 10 °F. To supplement this determination, the NRC staff examined the initial RT_{NDT} values for SA-533 Grade B material for reactor pressure vessels (RPVs) fabricated before 1975 (approximately the same vintage) and found the highest initial RT_{NDT} value for this RPV material is 60 °F, supporting the TR's selection of mean and σ for the RT_{NDT} value.

The TR provides no description for the crack initiation toughness factor (F-KIC), which is another random variable with a mean value of 1.0 and a σ of 0.1. In the PFM analysis, the fracture toughness K_{IC} can be determined by the randomly selected RT_{NDT} value and the operating temperature of the flywheel. Therefore, F-KIC must be related to the use of the ASME Code K_{IC} curve. Since the ASME Code K_{IC} curve is a 95 percent lower bound curve, applying F-KIC to it, or a mean curve based on the ASME Code K_{IC} curve, is acceptable. Reference 3 confirmed that the TR used the mean K_{IC} curve.

3.2.3 Constant Variables Related to Inspections

Except for the flywheel inner radius, outer radius, and the FCG exponent, all other constant variables are related to inspections. The TR used 0.1 for the probability of a flaw existing after the preservice inspection. This is conservative because the preservice inspection was performed to detect and to repair all relevant indications and it is unlikely to miss a flaw emanating from the keyway which is 0.1 inch radially and 6.5 inches through-thickness.

The TR used 3 for the operating cycles for the first ISI and 4 for the operating cycles between ISIs. Since Table 3-3 of the TR used "ISI at 4-year intervals" to characterize the PFM results, it is clear that the operating cycle is conservatively set to one year in the PFM analyses. Using these ISI parameters for the first 10 years of operation is consistent with RG 1.14, Revision 1. The risk increase based on the PFM results between the base case having ISIs at the entire 80 years (20 ISIs) and the proposed case having ISIs for only the first 10 years (about 3 ISIs) is evaluated in the risk assessment in Section 3.3 of the TR. This assumption is very conservative because it maximized the difference in the number of ISIs between the two cases. Based on this, the NRC staff determined that there is additional margin in the conditional PoF difference between these two cases.

In summary, the NRC staff determined that the PFM methodology that was used to generate the conditional PoF values presented in Table 3-3 and Tables 3-6 to 3-9 of the TR is acceptable.

3.3 Risk Assessment

The quantitative risk assessment discussed in the TR provides the justification for applying the WCAP-15666-A 20-year flywheel inspection interval for 80 years of operation. Specifically, the risk analyses confirm that applying the inspection extension to flywheels in operation up to 80 years has a negligible impact on risk (core damage frequency (CDF) and large early release frequency (LERF)), i.e., it is within the risk acceptance criteria of RG 1.174. Section 3 of the TR provides a discussion on the requirements of RG 1.174, and extends the previous flywheel failure probability assessment in WCAP-15666-A to 80 years of operation.

The risk evaluation includes the likelihood that a crack will grow large enough to cause failure at the following conditions or events: (1) normal plant operation resulting in a plant trip, (2) a transient or LOCA event with no loss of electrical power to the RCP, (3) a transient or LOCA event with loss of electric power to the RCP motor, and (4) after the DEGB LOCA with the simultaneous loss of power to the RCP motor.

Section 3.4.3 of the TR provides descriptions and frequencies of the initiating events for the different conditions listed in Table 3-5. The NRC staff noted apparent inconsistencies between TR Tables 3-5, 3-7, and 3-8 and WCAP-15666-A. Tables 3-12 and 3-13 regarding conditions for LOCA events versus non-LOCA events. In the RAI response to a SLR application for Turkey Point Units 3 and 4 (Ref. 2), FPL clarified that the two documents represent the same conditions and employ the same analysis assumptions. Furthermore, it clarified that all entries are bounded by the design limiting transient. The NRC staff finds this clarification acceptable and no changes are needed to further clarify information in the TR.

The risk assessment requires an estimate of the conditional PoF of the flywheel at a given event (speed), an estimate of the event frequency, and the change in CDF and LERF given a flywheel failure.

3.3.1 Flywheel Conditional Failure Probability

The method for calculating flywheel failure probabilities is based on the method described in section 3.3.1 of the TR and evaluated in Section 3.2 of this SE. In the evaluation, the NRC staff also relied on the more detailed information in WCAP-15666-A.

3.3.2 Core Damage Evaluation

The failure of the RCP motor flywheel during normal plant operation would directly result in a reactor trip. However, the potential indirect or spatial effects associated with a postulated flywheel failure present a greater challenge in terms of failure effects or consequences. The flywheel has the potential to catastrophically fail, resulting in flywheel fragments, which are essentially high energy missiles, which could impact other structures, systems, and components (SSCs) important to plant safety. Failure of these other SSCs could potentially impact the overall plant safety in terms of core damage (e.g., as a result of the loss of safety injection) or large early release (as a result of potential impacts on containment structures or systems).

In order to address plant specific design differences on a generic basis, the risk assessment in the TR conservatively assumed that failure of the RCP motor flywheel results in core damage and a large early release, i.e., the flywheel failure frequency is equal to CDF and LERF. Section 3.3 of the TR discusses the process for estimating the likelihood of the primary failure mode of the RCP motor flywheel. Section 3.4 of the TR then combines this failure probability estimation with the likelihood of various plant events and consequences to estimate the change in risk for continuing the 20-year examination interval for RCP flywheels in the SPEO.

To investigate the consequences of RCP overspeed, the TR analyzed a spectrum of LOCA events resulting in a range of flywheel transients. Results of this analysis indicated that the limiting event was the DEGB with an instantaneous loss of power, this led to a peak flywheel speed of 3321 rpm. It was also noted that the 3 ft^2 break area case showed a decrease in speed such that the normal operating speed is not exceeded. Based on the WCAP-15666-A assessments, the following scenarios are associated with the primary mode of potential failure in the Westinghouse RCP motor flywheel that are related to operating speed and potential overspeed during various conditions:

- Failure during normal plant operation resulting in a plant trip (1200 rpm peak speed)
- Failure of the RCP motor flywheel associated with a plant transient or LOCA event with no loss of electrical power to the RCP (1200 rpm peak speed)
- Failure of the RCP motor flywheel associated with a plant transient or LOCA event up to 3 ft^2 with an instantaneous loss of electrical power to the RCP (1200 rpm peak speed)
- Failure of the RCP motor flywheel associated with a DEGB coincident with an instantaneous loss of electrical power, such as loss offsite power (3321 rpm peak speed). This case bounds and is conservatively applied to all flywheel transients for LOCA break areas.

The TR states that the normal operating speed of the flywheel is 1189 rpm with a synchronous speed of 1200 rpm. If there is a pipe rupture in the RCP's outlet piping, the high reactor coolant pressure will force reactor coolant out through the RCP into the low pressure containment structure and hydraulic torque would be applied to the shaft in the direction of increasing shaft speed. If electrical power is maintained to the RCP motor, the motor will function as a dynamic brake and limit the increase in speed of the shaft to less than 1500 rpm. If, however, electric power is lost to the RCP, the flywheel will accelerate. The maximum estimated flywheel speed is 3321 rpm for a DEGB, the largest possible break in the RCP outlet piping with simultaneous loss of electric power to the RCP motor.

The TR evaluated the likelihood of a flywheel developing a critical crack for the overspeed of 3321 rpm and the overspeed of 1500 rpm. The speed of 3321 rpm is used for the DEGB with loss of electric power to the RCP motor (Event 4). The speed of 1500 rpm is used for all other scenarios (Events 1 to 3). The probability of cracks reaching the critical sizes given different inservice inspection (ISI) programs was estimated using the PFM methodology discussed in Section 3.2. In order to develop estimates applicable to the current fleet of reactors, the TR conservatively estimated the impact of the requested 20-year inspection interval by assuming that, aside from the initial inspections during the first 10 years of plant life, there will be no more inspections over the operating life of the units. The base case for comparison assumed ISIs for the entire 80 years. As discussed in Section 3.2.3, this conservative evaluation is acceptable. Given these four events, the conditional PoFs of the flywheel from the PFM results are presented in Table 3-3 of the TR.

The staff noted that the PoF values in Table 3-3 of the TR, Revision 1 for the Groups 1 and 2 flywheels are nearly identical to those from WCAP-15666-A for 60 years of operation, but slightly lower. This could be reasonable because the PFM analyses used 100 fatigue cycles per year. When ISI was performed every 4 years for 60 and 80 years, the total number of ISIs is 15 and 20, respectively. The slightly lower PoF for 80 years reflects the benefit from 5 additional ISIs. However, the NRC staff also found that the TR, Revision 1 needs to explain why the PoFs for the case with ISI performed every 4 years for only the first 10 years in 80 years of operation are lower than the corresponding PoFs in WCAP-15666-A for 60 years. Reference 3 indicated that through a verification and validation process, Westinghouse found that changes were made to the core PFM executable program that produced PoF results in the TR. These changes were not managed through configuration control and resulted in calculations that should be discarded. The Westinghouse effort also discovered a mistake in the mean K_{IC} equation in the PFM calculation. Therefore, Westinghouse provided revised PoF values to replace the values in Table 3-3 of the TR, Revision 1. The NRC staff reviewed Reference 3 and considers the explanation of the loss of configuration control and the discovery of a mistake in the core PFM program credible and the corrective actions appropriate. Therefore, the revised PoF values can be used in the subsequent risk evaluation. The PWROG later issued Revision 2 of the TR in January 2019 based on the new information and the updated PoF values in Reference 3. These updated PoF values are reported in Table 3-3 of Revision 2 of the TR. As stated in Section 1.0 of this SE, Revision 2 of the TR is referred to simply as "the TR."

The peak speed of the flywheel during normal operation (Event 1) is about 1200 rpm. Because the PFM results shown in Figures 3-6 to 3-8 of Reference 5 indicated that the failure probability of the RCP flywheels is not changing much with time, the PoF under normal operation during any given year can be reasonably approximated by the cumulative probability at the end of 80 divided by 80 years.

The failure of a flywheel is an irreversible change of state, i.e., the flywheel cannot be repaired and returned to service and there is no likelihood that more than one flywheel failure may occur during the operating lifetime. Without the possibility of multiple failures during the operating lifetime, the assumption – that the probability that a critical flaw exists prior to each transient is equal to the probability that a critical flaw will develop by the end of the 80 year operating life – is conservative and acceptable.

Rather than attempt to develop a full spectrum of break sizes, overspeeds, and associated critical sizes, Table 3-5 in the TR stated that LOCAs up to a three square foot break in the primary loop with a loss of electric power to the RCPs would not cause the flywheel to exceed 1500 RPM. Therefore, the frequency of LOCAs up to this size are grouped together with the transient frequency.

The TR estimated the frequency of large break LOCA (LBLOCA) events with break areas in excess of three square foot break using NUREG-1829 and, therefore, the NRC staff finds that the LOCA frequency is appropriate for use in support of this submittal.

A DEGB must be accompanied by a simultaneous loss of power to the RCP motor in order for the flywheel speed to exceed 1200 rpm. Loss of power to the RCP motor is most likely caused by a loss of station power caused by transfer from the offsite electrical grid to the onsite emergency electrical grid, and failure of the emergency grid to properly load and operate. The probability of the loss of station power is dependent on the LOCA because the changing electrical configuration and loads induced by the LOCA may cause the loss of power. Evaluation of the potential for loss of station power indicates that a reasonable estimate for the probability of loss of station power following a LOCA is about 1.4E-2 (Ref. 10). The TR uses this conditional probability.

The above discussion regarding Westinghouse RCP motor flywheels applies to Calvert Cliffs flywheels also, but with the reduced overspeeds specific to Calvert Cliffs (i.e., 1125 RPM and 1368 RPM).

The NRC staff noted, however, that Tables 3-7 to 3-9 of the TR show that the event frequency for the fourth condition is 1.4E-8/year. In WCAP-15666-A, Table 3-12, the corresponding event frequency is 2.8E-8/year based on a maximum LOCA frequency (LOCAs with greater than

5000 gpm blowdown) of 2E-6/year and the probability of loss of station power following a LOCA of 1.4E-2/year. In the RAI response to the SLR application for Turkey Point, Units 3 and 4 (Ref. 2), FPL indicated that the frequencies of LBLOCA events with break areas in excess of 3 ft^2 (fourth condition) reported in WCAP-15666-A were based on Westinghouse fracture mechanics calculations performed prior to NRC issuance in 2008 of NUREG-1829 (Ref. 11). The frequencies of LBLOCA events with break areas in excess of 3 ft^2 estimated in the TR were updated based on NUREG-1829 and the mean failure rates associated with the larger LOCA break sizes presented in Table 7.19 of NUREG-1829. NUREG-1829 states that, "The results in Table 7.19 are appropriate to use for PRA [probabilistic risk assessment] applications that separately consider SGTRs [steam generator tube ruptures]." Specifically, in establishing the large break frequency, the 14 inch and 31 inch diameter breaks were extrapolated to 80 years and interpolated to determine a cumulative frequency for a 3 ft^2 break. The NRC staff finds the use of NUREG-1829 acceptable because it is consistent with current probabilistic risk assessment practices and provides LOCA frequencies as a function of break size.

<u>Consequence Estimate</u>

The flywheel has the potential to catastrophically fail, resulting in flywheel fragments which are essentially high energy missiles that could impact other SSCs important to plant safety. The TR states that the initial investigations indicate that there is not much uniformity with respect to the layout of critical targets that potential flywheel fragments could impact given its failure and, therefore, a generic damage scenario is difficult to develop. The TR assumes that a flywheel failure would lead directly to core damage and large early release. Therefore, the adequacy of a generic scenario and the quality of the probabilistic risk assessment analysis used to support the TR methodology are not issues and the consequence evaluation is acceptable.

<u>Risk Estimates</u>

The detailed results for all the scenarios for each of the three flywheel types are provided in Tables 3-7 to 3-9 of the TR. The NRC staff performed independent calculations to verify the accuracy of these updated risk values and listed the staff's calculated values in the following Table along with the TR values for comparison. The Table shows that the discrepancy between the NRC staff's and the licensee's risk value is within 0.2 %, representing a very good match. However, for a very small risk value such as the current case, an insignificant discrepancy of 0.2 % between the NRC staff's and the licensee's risk value could cause a discrepancy as large as 13 % between the NRC staff's and the licensee's increase in risk value (i.e., Δ risk).

	Group 1		Group 2	
	NRC	TR	NRC	TR
CDF and LERF with ISI after 10 years	2.125E-08	2.12E-08	1.317E-08	1.31E-08

CDF and LERF without ISI after 10 years	2.156E-08	2.16E-08	1.430E-08	1.43E-8
Increase in CDF and LERF for one flywheel	3.10E-10	3.57E-10	1.13E-09	1.19E-9
Increase in CDF and LERF for four flywheels	1.24E-09	1.43E-09	4.52E-09	4.75E-9

* CDF values for Groups 1 and 2 are based on PoF values from Reference 3, which are identical to those in the TR.

As can be seen in the table, the bounding estimated increase in risk is 4.52E-09/year for Group 2 flywheels. This estimate is well below the very small change in LERF guideline of 1E-7/year in RG 1.174. The NRC staff noted that the revised CDF values for Groups 1 and 2 based on PoF values from Reference 3 are less than the corresponding values in Reference 1. This indicated that if the revised PFM program in Reference 3 is used to generate the CDF values for Calvert Cliffs, the CDF values will also be less than those in Reference 1, establishing that the estimate for Calvert Cliffs is also well below the very small change in LERF guideline of 1E-7/year in RG 1.174. The updated risk increase for Calvert Cliffs in the TR supports the above qualitative justification.

4.0 LIMITATIONS AND CONDITIONS

There is no limitation or condition for the Westinghouse RCP flywheels, considering that the flywheel operating and material data used in the generic analyses have already been examined twice and accepted during plant-specific applications using WCAP-14535A and WCAP-15666-A. However, the flywheel operating and material data used in the generic analyses for Calvert Cliffs in this TR are new and need to be confirmed by the licensee:

- the normal operating speed for the RCP flywheels is 900 rpm
- the design limiting speed for the RCP flywheels is 1125 rpm
- the maximum overspeed following a design basis LOCA is 1368 rpm
- it is appropriate to use 70 °F as the medium temperature for design limiting event (Table 3-2) in the PFM analysis

The TR requires applicants of this TR to confirm that 6000 cycles for 80 years of operation is applicable on a plant-specific basis. This confirmation shall be made in all SLR applications to fulfill the TR requirement. Please note that TR requirements are not considered as SE limitations and conditions.

5.0 CONCLUSIONS

The change in risk estimate includes numerous conservative assumptions including:

- The use of the 1500 rpm for 1189 and 1200 rpm scenarios for Westinghouse RCP flywheels and 1125 rpm for 900 rpm scenarios for Calvert Cliffs.
- The use of the probability that a critical crack exists at the end of the 80 year life as the probability that the crack would exist during each operating year.
- The use of 100 start-ups and shutdowns per calendar year when simulating the FCG.
- Maximizing the difference in number of ISIs between the base case and the proposed case.
- Characterizing the DEGB flow rate as 5000 gpm or higher.
- The failure of the flywheel will cause core damage and a large early release event with a probability of 1.

Considering all the conservative assumptions listed above, the NRC staff determined that the increase in CDF and LERF values for three groups of flywheels provide a bounding estimate of the change in risk associated with the continued adoption of the 20-year inspection interval from the PEO to the SPEO. The bounding estimate is below the very small change in LERF guidelines in RG 1.174, and the NRC staff finds that the increase in risk is small and is consistent with the Commission's Safety Goal Policy Statement.

The TR also addresses the other key principles of risk-informed licensing actions described in RG 1.174. There are no changes to the evaluation of design basis accidents and the margin of safety is being maintained. Nondestructive examinations and inspections will continue to be conducted every 20 years. Therefore, the NRC staff finds the requested change to be well-defined, consistent with defense-in-depth philosophy, contains adequate margin of safety, and incorporates a performance measurement strategy to monitor the change. The NRC staff also finds that the risk evaluation is consistent with the risk-informed methodology and guidelines described in RG 1.174 and that the potential change in risk caused by the continued adoption of the 20-year inspection interval from the PEO to the SPEO is small and acceptable.

The request is a change from the current RG 1.14, Revision 1 guidance. The NRC staff finds that the regulatory positions in RG 1.14, Revision 1 concerning the three critical speeds are satisfied, and that the TR evaluation indicating that critical crack sizes are not expected to be attained during the 20-year inspection interval in the SPEO is reasonable and acceptable. The potential for failure of the RCP flywheel is, and will continue to be, negligible during normal and accident conditions.

6.0 REFERENCES

1. Letter from Ken Schrader, Pressurized Water Reactor Owners Group, to USNRC, May 15, 2018, enclosing Westinghouse Electric Company Report PWROG-17011-NP, Rev. 1, "Update for Subsequent License Renewal: WCAP-14535A, 'Topical Report on Reactor Coolant Pump Flywheel Inspection Elimination,' and WCAP-15666-A, 'Extension of Reactor Coolant Pump Motor Flywheel Examination'" Non-Proprietary Class 3, dated May 2018 (Agencywide Documents Access and Management System (ADAMS) Package Accession No. ML18143B465).

2. Letter from William Maher, Florida Power & Light Company, to USNRC, August 31, 2018, enclosing Florida Power & Light Company response to NRC request for additional information Set 1 regarding Turkey Point Units 3 and 4 subsequent license renewal application (ADAMS Accession No. ML18248A257).

3. Letter from William Maher, Florida Power & Light Company, to USNRC, December 21, 2018, enclosing Florida Power & Light Company response to NRC request for additional information Set 5 Response 4.3.5-2 Revision regarding Turkey Point Units 3 and 4 subsequent license renewal application (ADAMS Accession No. ML18362A146).

4. Letter from Ken Schrader, Pressurized Water Reactor Owners Group, to USNRC, January 28, 2019 enclosing Westinghouse Electric Company Report PWROG-17011-NP, Rev. 2, "Update for Subsequent License Renewal: WCAP-14535A, 'Topical Report on Reactor Coolant Pump Flywheel Inspection Elimination,' and WCAP-15666-A, 'Extension of Reactor Coolant Pump Motor Flywheel Examination'" Non-Proprietary Class 3, dated May 2018 (ADAMS Package Accession No. ML19036A684).

5. WCAP-14535A, "Topical Report on Reactor Coolant Pump Flywheel Inspection Elimination," November 1996 (ADAMS Accession No. ML18312A151).

6. WCAP-15666-A, "Extension of Reactor Coolant Pump Motor Flywheel Examination," October 2003 (ADAMS Accession No. ML18303A413).

7. U.S. Nuclear Regulatory Commission, "Reactor Coolant Pump Flywheel Integrity," Regulatory Guide 1.14, Revision 1, August 1975 (ADAMS Accession No. ML003739936).

8. U.S. Nuclear Regulatory Commission, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis," Regulatory Guide 1.174, Revision 3, January 2018 (ADAMS Accession No. ML17317A256).

9. WCAP-14572, Revision 1-NP-A, *"Westinghouse Owners Group Application of Risk-Informed Methods to Piping Inservice Inspection Topical Report,"* February 1999 (ADAMS Accession No. ML042610469).

10. NUREG/CR-6538, "*Evaluation of LOCA with Delayed LOOP and LOOP with Delayed LOCA Accident Scenarios*," July 1997 (ADAMS Accession No. ML071630062).

11. NUREG-1829, "Estimating LOCA Frequencies Through the Elicitation Process," April 2008 (ADAMS Accession Nos. ML081060300 and ML082250436).

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Date: July 25, 2019