OG-02-051
November 15, 2002

WCAP-15666, Rev. 0
Project Number 694

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Attention: Chief, Information Management Branch, Division of Inspection and Support Programs

Subject: Westinghouse Owners Group
Transmittal of Revised Pages of WCAP-15666-NP, Rev. 0, "Extension of Reactor Coolant Pump Motor Flywheel Examination" and Clarification to RAI Response Number 3.a (MUHP-3043)

Ref.:

1) Westinghouse Owners Group Letter, R. Bryan to Document Control Desk, "Transmittal of WCAP-15666, 'Extension of Reactor Coolant Pump Motor Flywheel Examination' Non-Proprietary Class 3," OG-01-051, August 24, 2001.

2) NRC Letter, D. Holland to G. Bischoff, "Westinghouse Owners Group - WCAP-15666, Rev. 0, 'Extension of Reactor Coolant Pump Motor Flywheel Examination'," February 11, 2002.

3) Westinghouse Owners Group Letter, R. Bryan to Document Control Desk, "Transmittal of Response to Request for Additional Information Regarding WCAP-15666-NP, Rev. 0, 'Extension of Reactor Coolant Pump Motor Flywheel Examination'," OG-02-014, April 23, 2002.

In August 2001, the Westinghouse Owners Group (WOG) submitted WCAP-15666, Rev. 0, "Extension of Reactor Coolant Pump Motor Flywheel Examination," for review and approval (Ref. 1). In February 2002, the NRC issued a Request for Additional Information (RAI) concerning WCAP-15666, Rev. 0 (Ref. 2). In April 2002, the WOG provided written responses to the individual RAI questions (Ref. 3). Based on discussions with Messrs. G. Shulka and S. Dinsmore the WOG has agreed to make a number of changes to WCAP-15666, Rev. 0 and to provide additional information to clarify response to RAI 3.a. Please find enclosed the revised pages of WCAP-15666, Rev. 0, with the changes clearly identified, that will be incorporated into the approved version of the topical report. Attachment 1 provides the additional information to clarify the response to RAI 3.a.

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If you require further information, feel free to contact Mr. Ken Vavrek, Westinghouse Owners Group Project Office at 412-374-4302.

Very truly yours,

Robert H. Bryan, Chairman
Westinghouse Owners Group

attachment

cc: WOG Steering Committee
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Responses to NRC Request for Additional Information on WCAP-15666, Rev. 0, "Extension of Reactor Coolant Pump Motor Flywheel Examination"

RAI Number 3.a:

Section 3.3 states that the nominal rotation per minute (rpm) for a flywheel is 1200 rpm and discusses "peak speed[s]" of 1500 rpm or 3321 rpm that are "used in the evaluation" of failure frequency. The entries in Table 3-8 identify the failure frequencies by these peak speeds. Table 3-5 includes input parameters as "Number of Transients per Operating Cycle" and "Speed Change per Transient (rpm)".

a. What is the relationship between the "peak speed" and the probability of failure at 40 and 60 years? For example, does the calculation in Table 3-8 for 1500 rpm assume that the flywheel runs continuously at 1500 rpm during the life of the plant? Does the calculation for 3321 rpm assume that the flywheel runs continuously at 3321 rpm during the life of the plant?

Response to RAI Number 3.a:

The failure probability with time is calculated as shown in Figure 3-5 in Section 3.3 of WCAP-15666, by calculating the distribution in time to failure, truncated at 40 or 60 years of operation. This is the same method that is used for piping risk-informed ISI (see Section 3.5 of Reference 4). An initial flaw (crack), undetected during preservice inspection, is first assumed to exist with a certain probability (e.g., 10% per Table 3-6 of WCAP-15666). The size of this crack increases with time by fatigue crack growth due to RCP startup and shutdown (e.g., a fatigue stress range corresponding to a median change in speed between 0 and 1200 rpm applied at a median value of 100 times a year per Table 3-6 of WCAP-15666). After the crack growth for each year, the crack size is compared to its critical size, which is based on the RCP overspeed during the design-limiting LOCA condition, to determine if failure would occur during the LOCA event. This fatigue crack growth and critical size check for a LOCA is repeated each year, until either failure is predicted to occur, or the end of operating life is reached (40 years or 60 years).

The RCP has a synchronous speed of 1200 rpm, and a design speed of 1500 rpm. The peak speed for a LOCA considering no loss of electrical power to the RCP, or for a LOCA considering an instantaneous loss of electrical power and up to a 3 ft^2 break area, is 1200 rpm. A peak speed of 1500 rpm was conservatively used in WCAP-15666 for these cases. For the double-ended guillotine break of the main coolant loop piping *coincident with a loss of electrical power*, a speed of 3321 rpm was used. The calculations assume that the flywheel normally operates at a median value of 1200 rpm, and at the peak speeds (*median values of* 1500 rpm or 3321 rpm) *only* for the LOCA design-limiting events. *The probability of exceeding the critical size obviously increases with time (60 years versus 40 years) due to the fatigue crack growth each year, or with peak LOCA speed due to a smaller critical crack size for brittle fracture*.

EXECUTIVE SUMMARY

A previous Westinghouse Owners Group (WOG) program MUHP-5042 established the technical basis that allowed for relaxation of reactor coolant pump (RCP) motor flywheel examinations for all domestic WOG plants and several Babcock and Wilcox plants. This was summarized in Westinghouse report WCAP-14535, which concluded that flywheels are well-designed, are manufactured from excellent materials, have an excellent inspection history, and are structurally sound based on deterministic stress and fracture analyses. An assessment concluded that flywheel inspections beyond 10 years of plant life have no significant benefit on reducing the likelihood of flywheel failure.

WCAP-14535 was submitted for review by the United States Nuclear Regulatory Commission (NRC) in January 1996, with Beaver Valley as the lead plant. Following two requests for additional information (RAI), the NRC issued a Safety Evaluation Report (SER) in September 1996, wherein they accepted the technical arguments, but did not allow for total elimination of examinations. The SER did provide for partial relief from the examination requirements of NRC Regulatory Guide 1.14, by allowing for an extension of the examination frequency from 40 months to 10 years, and a reduction in the required examination volume. The NRC stated in the SER that they had not reviewed the risk assessment in WCAP-14535, but had relied solely on the deterministic methodology to review the submittal. The final NRC-approved version of the report, which includes the RAIs and SER, is WCAP-14535A, which was issued in November 1996.

The currently approved 10-year inspection interval does not coincide with actual RCP refurbishment schedule at many WOG plants. Refurbishment currently occurs at 10 to 15 year intervals at all domestic WOG plants, but could be extended to 20 years, at most. The current WOG program, MUHP-5043, which is summarized in this report, provides the technical basis for the extension of the RCP motor flywheel examination frequency for all domestic WOG plants from the currently approved 10-years to a maximum of 20 years. The current WOG program builds on the MUHP-5042 arguments, which assumed Leak-Before-Break (LBB) limits the RCP overspeed to 1500 rpm. It also provides additional rationale, including a risk assessment of all credible flywheel speeds, following the guidance of Regulatory Guide 1.174, to justify the interval extension to 20 years to allow for inspection coincident with RCP refurbishment. The change in risk for extending the ISI interval is ~~3 to 4 orders of magnitude~~ below the Regulatory Guide 1.174 core damage frequency (CDF) and large early release frequency (LERF) acceptance guidelines. The extension of the inservice inspection frequency for the RCP motor flywheel from 10 years to 20 years satisfies Regulatory Guide 1.174 risk criteria as an acceptable change. Proposed changes to Specification 5.5.7, "Reactor Coolant Pump Flywheel Inspection Program," of NUREG-1431, Revision 2, Improved Standard Technical Specifications, are provided in Section 4 of this report.

Table 3-10: Estimated RCP Motor Flywheel Failure Probabilities

Flywheel Group and Condition*	Cumulative Probability of Flywheel Failure over 60 Years*	
	With ISI at 4-Year Intervals	With ISI at 4-Year Intervals Prior to 10 Years, and without ISI after 10 Years
Group 1 – Normal/Accident	2.45E-07	2.57E-07
Group 1 – LOCA/LOOP	1E-02/year**	1E-02/year**
Group 2 – Normal/Accident	1.43E-07	1.47E-07
Group 2 – LOCA/LOOP	1E-02/year**	1E-02/year**

*For the failure probability calculations the mMean flywheel speed for normal/accident conditions is 1500 rpm; for LOCA/LOOP it is 3321 rpm.

** The failure probability calculations show very little change in the probability from the first through the sixtieth year of operation. 1.0E-02 is assumed to be the failure probability.

What Are the Consequences?

The consequence evaluation is performed to identify the potential consequences from the failure of the RCP motor flywheel from an integrity standpoint. The consequences are discussed in Section 3.2.

The consequence evaluation identifies both direct effects and indirect effects. Direct effects are those effects associated directly with the component being evaluated, such as loss of process fluid flow. Indirect effects are those effects on surrounding equipment that may be impacted by mechanisms such as jet impingement, pipe whip, missiles, and flooding.

The direct consequences are defined as failure of the RCP motor flywheel resulting in a failure of the RCP. With failure of the RCP, a reactor trip would be required.

The potential indirect or spatial effects associated with the postulated flywheel failure are the potential missiles generated from the fragmented portions of the flywheel given a significant flywheel crack.

For this evaluation, the conditional core damage probability given the failure of the flywheel will be assumed to be 1.0 (no credit for safety system actuation to mitigate the consequences of the failure).

Risk Calculation

This methodology is described in detail in the Westinghouse Owners Group Risk-Informed Inservice Inspection Methodology for Piping, WCAP-14572, Revision 1-NP-A (Reference 17). For failures that

Table 3-11: Estimated Frequency of Large LOCA (flow greater than 5000 gpm) by Line Size

Line Size (diameter in inches)	Mean Frequency (per year)
27.5	2.62E-07
29	1.86E-07
31	1.93E-07
32	1.29E-06
34	4.19E-07
36	2.31E-07

A given plant has either 27.5, 29 and 31 inch diameter piping or 32, 34, and 36 inch diameter piping. Summing these line sizes equates to 6.41E-07/year for the 27.5-inch cold leg case and 1.94E-06/year for the 32-inch cold leg plant. This evaluation will use the 2E-06/year as the estimated frequency of a large LOCA greater than 23 inches in diameter.

To estimate the probability of flywheel failure given an initiating event, a conservative approach is taken. The 60 year cumulative failure probability is used without adjusting the value for the specific case.~~the failure probability is calculated for a continuously operating system as follows:~~

~~CFP = FR * T_m — Equation 17~~

~~where:~~

~~CFP — = Conditional Failure probability [unitless]~~

~~FR — = Failure probability from the model divided by years at EOL [per hour]~~

~~T_m — = Total defined mission time [24 hours or 1 day]~~

Tables 3-12 and 3-13 show the calculations to estimate the frequency of the initiating event combined with the probability of the RCP motor flywheel failure. These calculations are also estimates of the core damage frequency given that the assumption of the conditional core damage probability (CCDP) is set to 1.0 (no credit taken for safety systems).

The calculations show that the change in CDF for flywheel Evaluation Group 1 is ~~2E-10~~1.2E-08/year, while the change in the CDF for flywheel Evaluation Group 2 is ~~7E-11~~4.0E-09/year. The RG-1.174 criteria for an acceptable change in risk for CDF ~~are~~ is 1E-06/year and for LERF is 1E-07/year. These calculations show the change in risk from extending the inspection interval for the RCP motor flywheel is significantly below the acceptance criteria.

Even considering the uncertainty in the estimated flywheel failure frequency, the change in risk would still be expected to be well below the acceptance criteria.

Table 3-12: RCP Motor Flywheel Evaluation Group 1

Condition	Initiating Event Frequency	Likelihood of RCP Motor Flywheel Failure (@60 years)	Event with RCP Motor Flywheel Failure (and Core Damage Frequency Given CCDP = 1.0)
1. Normal Operating Condition	N/A	With ISI after 10 years = 2.45E-07 Without ISI after 10 years = 2.57E-07	With ISI after 10 years: ~~(~~2.45E-07/60 years~~)~~ = 4.08E-09/year Without ISI after 10 years: ~~(~~2.57E-07/60 years~~)~~ = 4.28E-09/year
2. Failure of the RCP motor flywheel given a plant transient or LOCA event with NO loss of electrical power to the RCP (1200 rpm peak speed)**	1.0/year	With ISI after 10 years = 2.45E-07 Without ISI after 10 years = 2.57E-07	With ISI after 10 years: ~~1.0/year (2.45E-07/60 years * 1 year/365 days * 1 day) = 1.12E-11/year~~1.0/year * 2.45E-07 = 2.45E-07/year Without ISI after 10 years: ~~1.0/year (2.57E-07/60 years * 1 year/365 days * 1 day) = 1.17E-11/year~~1.0/year * 2.57E-07 = 2.57E-07/year
3. Failure of the RCP motor flywheel given a plant transient or LOCA event (up to a 3 ft^2 break in the RCS loop piping) with loss of electrical power to the RCP (1200 rpm peak speed)**	1.0/year * (1.4E-02) = 1.4E-02/year	With ISI after 10 years = 2.45E-07 Without ISI after 10 years = 2.57E-07	With ISI after 10 years: ~~1.4E-02/year (2.45E-07/60years * 1 year/365 days * 1 day) = 1.57E-13/year~~1.4E-02/year * 2.45E-07 = 3.43E-09/year Without ISI after 10 years: ~~1.4E-02/year (2.57E-07/60 years * 1 year/365 days * 1 day) = 1.64E-13/year~~1.4E-02/year * 2.57E-07 = 3.60E-09/year

Condition	Initiating Event Frequency	Likelihood of RCP Motor Flywheel Failure (@60 years)	Event with RCP Motor Flywheel Failure (and Core Damage Frequency Given CCDP = 1.0)
4. Failure of the RCP motor flywheel given a large LOCA (from a greater than 3 ft^2 break up to a DEGB of the RCS loop piping) coincident with an instantaneous power loss (e.g., loss of offsite power (LOOP) or loss of electrical power to the RCP) and therefore no electrical braking effects (3321 rpm peak speed)	2E-06/year * (1.4E-02) = 2.8E-08/year	With ISI after 10 years = 1E-02/year Without ISI after 10 years = 1E-02/year	With ISI after 10 years: 2.80E-08/year (1.0E-02/year * 1 year/365 days * 1 day) = 7.67E-13/year2.8E-08/year * 1.0E-02 = 2.8E-10/year Without ISI after 10 year: 2.80E-08/year (1.E-02/year * 1 year/365 days * 1 day) = 7.67E-13/year2.8E-08/year * 1.0E-02 = 2.8E-10/year
TOTALS			With ISI after 10 years: 4.08E-09 + 1.12E-11+1.57E-13 + 7.67E-13 = 4.09E-09 / year4.08E-09 + 2.45E-07+ 3.43E-09 + 2.8E-10 = 2.53E-07/year Without ISI after 10 years: 4.28E-09 + 1.17E-11 + 1.64E-13 + 7.67E-13 = 4.29E-09 / year4.28E-09 + 2.57E-07 + 3.60E-09 + 2.8E-10 = 2.65E-07/year Change in CDF = 4.29E-09 – 4.09E-09 = 2.0E-10/year2.65E-07 – 2.53E-07 = 1.2E-08/year. For a plant with 4 RCPs, the change in CDF is 4 times 1.2E-08/year = 4.8E-08/year.

** The peak speed is 1200 rpm, however, 1500 rpm is used for the failure probability calculations.

Table 3-13: RCP Motor Flywheel Evaluation Group 2

Condition	Initiating Event Frequency	Likelihood of RCP Motor Flywheel Failure (@60 years)	Event with RCP Motor Flywheel Failure (and Core Damage Frequency Given CCDP = 1.0)
1. Normal Operating Condition	N/A	With ISI after 10 years = 1.43E-07 Without ISI after 10 years = 1.47E-07	With ISI after 10 years: (1.43E-07/60 years) = 2.38E-09/year Without ISI after 10 years: (1.47E-07/60 years) =2.45E-09/year
2. Failure of the RCP motor flywheel given a plant transient or LOCA event with NO loss of electrical power to the RCP (1200 rpm peak speed)**	1.0/year	With ISI after 10 years = 1.43E-07 Without ISI after 10 years = 1.47E-07	With ISI after 10 years: ~~1.0/year (1.43E-07/60years * 1 year/365 days * 1 day) = 6.53E-12/year~~1.0/year * 1.43E-07 = 1.43E-07/year Without ISI after 10 years: ~~1.0/year (1.47E-07/60 years * 1 year/365 days * 1 day) = 6.71E-12/year~~1.0/year * 1.47E-07 = 1.47E-07/year
3. Failure of the RCP motor flywheel given a plant transient or LOCA event (up to a 3 ft^2 break in the RCS loop piping) with loss of electrical power to the RCP (1200 rpm peak speed)**	1.0/year * (1.4E-02) = 1.4E-02/year	With ISI after 10 years = 1.43E-07 Without ISI after 10 years = 1.47E-07	With ISI after 10 years: ~~1.4E-02/year (1.43E-07/60years * 1year/365 days * 1 day) = 9.14E-14/year~~1.4E-02/year * 1.43E-07 = 2.00E-09/year Without ISI after 10 years: ~~1.4E-02/year (1.47E-07/60 years * 1 year/365 days * 1 day) = 9.40E-14/year~~1.4E-02/year * 1.47E-07 = 2.06E-09/year

Condition	Initiating Event Frequency	Likelihood of RCP Motor Flywheel Failure (@60 years)	Event with RCP Motor Flywheel Failure (and Core Damage Frequency Given CCDP = 1.0)
4. Failure of the RCP motor flywheel given a large LOCA (from a greater than 3 ft^2 break up to a DEGB of the RCS loop piping) coincident with an instantaneous power loss (e.g., loss of offsite power (LOOP) or loss of electrical power to the RCP) and therefore no electrical braking effects (3321 rpm peak speed)	2E-06/year * (1.4E-02) = 2.80E-08 /year	With ISI after 10 years = 1E-02~~/year~~ Without ISI after 10 years = 1E-02~~/year~~	With ISI after 10 years: ~~2.80E-08/year (1.0E-02/year * 1 year/365 days * 1 day) = 7.67E-13/year~~2.8E-08/year * 1.0E-02 = 2.8E-10/year Without ISI after 10 years: ~~2.80E-08/year (1.0E-02/year * 1 year/365 days * 1 day) = 7.67E-13/year~~2.8E-08/year * 1.0E-02 = 2.8E-10/year
TOTALS			With ISI after 10 years: ~~2.38E-09 + 6.53E-12+9.14E-14 + 7.67E-13 = 2.39E-09/year~~2.38E-09 + 1.43E-07 + 2.00E-09 + 2.80E-10 = 1.48E-07/year Without ISI after 10 years: ~~2.45E-09 + 6.71E-12 + 9.40E-14 + 7.67E-13 = 2.46E-09/year~~2.45E-09 + 1.47E-07 + 2.06E-09 + 2.80E-10 = 1.52E-07/year Change in CDF = ~~2.46E-09 – 2.39E-09 = 7.0E-11/year~~1.52E-07 – 1.48E-07 = 4.0E-9/year. For a plant with 4 RCPs, the change in CDF is 4 times 4.0E-09/year = 1.6E-08/year.

** The peak speed is 1200 rpm, however, 1500 rpm is used for the failure probability calculations.

5 CONCLUSIONS

Results from previous WOG program MUHP-5042, as summarized in WCAP-14535A (Reference 2), remain valid and are reiterated below:

1. Flywheels are carefully designed and manufactured from excellent quality steel, which has high fracture toughness.

2. Flywheel overspeed is the critical loading, but LBB has limited the maximum speed to 1500 rpm. *(Note however that the LBB exclusion for LBLOCA does not pertain to the risk assessment contained in the current WCAP-15666 report, which does consider the overspeed due to LBLOCA).*

3. Flywheel inspections have been performed for over 20 years, with no service-induced flaws.

4. Flywheel integrity evaluations show a very high flaw tolerance for the flywheels.

5. Crack extension during service is negligible.

6. Structural reliability studies show that eliminating inspections will not change the probability of failure.

7. Inspections result in man-rem exposure and the potential for flywheel damage during assembly and reassembly.

Results from the current WOG program MUHP-5043, summarized in this report, are as follows:

1. The failure probabilities for RCP motor flywheels are small.

2. The change in risk is ~~3 to 4 orders of magnitude~~ below the Regulatory Guide 1.174 CDF and LERF acceptable guidelines.

3. The extension of the RCP motor flywheel ISI frequency from 10 to 20 years satisfies Regulatory Guide 1.174 criteria as an acceptable change.

Proposed changes to Specification 5.5.7, "Reactor Coolant Pump Flywheel Inspection Program," of NUREG-1431, Revision 2, Improved Standard Technical Specifications, are provided in Section 4 of this report.